The relationship of lateralization and phenomenology to neural circuits

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In “Cerebral lateralization and religion: a phenomenological approach,” Iain McGilchrist argues that religious experience is mediated by the differences within the brain of the functional specializations of the right and left hemispheres. This contribution is thought-provoking. However, McGilchrist’s “Master and his emissary” metaphor of the role of lateralized function may be an overextension in the case of religious phenomenology. In this commentary, we discuss current views of brain lateralization from the neurosciences in comparison to putative RH and LH function, and phenomenology. We then propose an alternative model for relating brain anatomy, function and phenomenology. Critically, we infer that McGilchrist’s use of studies based on “low-resolution” methods may have been susceptible to biases to inferring a greater role for lateralization in phenomenology than is the case. Newer studies using high-resolution data reveal that a neural circuit basis of brain organization can correlate to phenomenology with high predictive and explanatory power. The chance for multivalent interactions between neural circuits moreover suggests a vast space of brain states and correlated phenomenology. We conclude with how this approach may be well suited to discussions of phenomenology, in general and of religion, while supporting a pluralistic view.

Introduction

In “Cerebral lateralization and religion: a phenomenological approach”, Iain McGilchrist argues that religious experience is mediated by the differences within the brain of the functional specializations of the right and left hemispheres. The thesis of “Cerebral lateralization” is shared with McGilchrist’s book, The Master and his Emissary: The Divided Brain and the Making of the Western World. McGilchrist uses a metaphor where the brain engages the world using the right hemisphere (RH) as master, and left hemisphere (LH) as emissary. Quoting McGilchrist, “Master and emissary each know things the other does not know: the difference is that the Master knows more than the emissary, and knows he needs the emissary, where the emissary does not know he needs the Master.” In “Cerebral lateralization,” it is concluded that the RH “may be more able to mediate religious experience or is more prone to accept it as a reality, depending on one’s point of view.” To make his case, McGilchrist uses mostly clinical reports such as behavioral and cognitive changes following lateralized brain tumors, hemispheric dissection, or suppression of one hemisphere using electroconvulsive therapy. McGilchrist’s contribution to the long-running discussion on the role of brain lateralization is thought-provoking. However, the “Master and his emissary” metaphor of the role of lateralized function may be an overextension in the case of religious phenomenology, in light of up-to-date neuroscientific findings. In this commentary, we discuss current views of brain lateralization from the neurosciences in comparison to putative RH and LH function and phenomenology. We then propose an alternative model for relating brain anatomy, function and phenomenology that may comport as well or better in discourses on the phenomenology of religion.
The bodies of work that make up the basis of this commentary are from systems and cognitive neuroscience. Briefly, systems neuroscience is the study of neural circuits in terms of cellular and molecular constituents and in relation to function. Cognitive neuroscience involves correlating, more explicitly, neural circuits to mental processes, through the use of psychological experiments. Both make use of non-invasive brain imaging of healthy individuals and/or patients using MRI and other modalities. Using the latest hardware and analysis techniques, millimeter-resolution views of brain structure and activity can be attained (Van Essen et al. 2013). Other techniques are used as well, including PET metabolite imaging, and EEG measures of electrical activity. Direct manipulation of brain activity is also possible, by using transcranial magnetic stimulation (TMS) and direct current stimulation (TDCS), which can transiently enhance or inhibit brain activity focally on the scale of centimeters. Given careful experiment and analysis design (Button et al. 2013), which is key to both disciplines, these bodies of work lead to a remarkably detailed map that correlates brain structure and function (Glasser et al. 2016).

Three aspects of the approach in “Cerebral lateralization” will be addressed in this commentary. First is how lateralization differences are characterized. While it is explicitly acknowledged by McGilchrist that neural processing occurs across both hemispheres, the exposition tends to suggest monolithic differences between RH and LH. In contrast, systems neuroscience has for over two decades recognized that neural processing is highly modularized into circuits, each involving “nodes” of gray matter regions on the scale of millimeters to centimeters connected with specific white matter tracts (Bullmore and Sporns 2009). Each circuit has degrees of bilaterality, and only a minority of circuits are highly lateralized (Gotts et al. 2013). A circuit basis for lateralization has shown high explanatory power for behavior and cognition, with implications for phenomenology. Second is how domains of function are defined and addressed. Some of the domains addressed are recognizable to cognitive neuroscience, such as “theory of mind,” which relates to empathy (Stone, Baron-Cohen, and Knight 1998). However, others are more specious, such as a “religion circuit” localized the RH. So are the claims that the LH is “unreasonably optimistic” and RH “tends towards the pessimistic.” Neither reasonability nor optimism are accepted, or clearly testable, domains of brain function. Third is how the localization of functional processing in the brain, which is measurable, is conflated with how experience arises from neural processing, which is metaphysical. This issue is expressed within the statement of purpose: “from the standpoint of the phenomenology of each hemisphere.” While McGilchrist predicts criticism of this and related concepts, from “cognitivists” for example, it is implausible to measure the experience of one cerebral hemisphere independent in time and anatomy. Thus, such a standpoint is untenable from an experimental perspective.

This commentary will focus on neural correlates of cognition, perception, and behavior. These relate closely to phenomenology. However, we do not assert that specific circuits cause phenomenology. Rather, we intend to describe a neural correlate model based on neural circuits. We then describe how a model of interactions between these circuits may be quite informative for considering phenomenology, without fully sacrificing mechanistic inference or testability.

**Lateralization versus circuit models for brain organization**

There has been a paradigm shift in the neurosciences from a model of brain function based on cerebral lateralization to one based on neural circuitry (Bullmore and Sporns 2009). This means, for example, that neural processing in language is related not firstly to LH, but to a specific circuit, which appears in both RH and LH. This circuit includes inferior frontal gyrus and superior temporal sulcus (called Broca’s and Wernicke’s areas in LH), linked by the white matter tract called the arcuate fasciculus, in concert with subcortex and cerebellum. This circuit activates most commonly in language processing in the LH, but occurs in RH as well, based on condition.

New methods of brain imaging such as functional and diffusion MRI show that brain activations in health and disease and in many neuropsychological conditions are bilateral, and that white matter tracts link bilaterally co-activated areas (Gallea et al. 2013). These imaging methods do also
recapitulate classical observations that those functions most associated with lateralized function, such as language, do indeed show greater lateralization in activation (Binder et al. 1996). Critically, however, imaging with follow-up neurosurgical evaluation, such as for epilepsy, show that the degree of lateralization of function varies significantly across individuals. For instance, recent evidence indicates that for those individuals where language activates bilateral homologous circuits, surgical resection of regions near right language circuitry leads to poorer preservation of function post-surgery (Negishhi et al. 2011). Thus, in neurosurgical planning for the treatment of epilepsy, the degree of lateralization of language and memory is assessed for every patient, by anesthetizing a hemisphere to determine the degree to which key domains of function are affected (the Wada test). The clinical reality of high inter-individual variability in lateralized functions runs counter to McGilchrist’s view that lateralization is reliable. It is important to note that hemispheric laterality is an obviously important aspect of the brain, from both functional and evolutionary perspectives. It may confer potentially critical advantages in terms of concurrency of processing or redundancy in the case of injury. What is questioned is to what extent it is informative to consider lateralization before circuit organization, and if it is then sensible to see each hemisphere to have “different goals, values, opinions and emotional timbre,” and other RH or LH phenomenology as proposed in “Cerebral lateralization.”

The case for separable RH and LH phenomenology that is made in “Cerebral lateralization” depends on attributing many domains of function to RH or LH. McGilchrist notes that these attributions should be read as “a subject relying on cognitive faculties of the” RH or LH, not that the hemispheres themselves can “believe”, “intend,” etc. Nonetheless, some links that are put forth in plain language by McGilchrist are not mainstream, including those relevant to religious experience. One is that “theory of mind,” central to empathy and compassion, depends essentially on RH. This domain has overwhelmingly bilateral functional localization, however, as per consensus of at least 140 studies (Yarkoni et al. 2011; Fox et al. 1994). Figure 1 shows a meta-analytic brain map of the localization of activity related to TOM from these studies. This map is derived by Bayesian analysis of a database of concepts and brain activation locations from over 10,000 studies. Other problematic claims relate to “embodiment,” including that “RH contains the body image … a multimodal schema of the body as a whole,” and “the LH has no such image.” Body mappings appear in both hemispheres, with sensory and motor regions having separate maps—sensory being stable, while motor being more adaptive to injury (Giraux et al. 2001). Depending on an individual’s handedness, sensorimotor activity can arise more or less bilaterally in the cortex, with regions such as thalamus (in the subcortex) and cerebellum acting in gating and tuning of fine motor control for unilateral movements and sensations. Alternatively, if body image is interpreted in terms of interoception or somesthesis, this also leads to bilateral activation in sensorimotor and insular cortex of both hemispheres (Critchley et al. 2004). Meditation and mindfulness are also associated by McGilchrist to lateralized function. Despite many types of meditation that incorporate varying degrees of compassion, interoception, and other bilateral functions, it is claimed that “compassion meditation

Figure 1. Meta-analysis map of theory of mind based on 140 studies, generated by NeuroSynth. The map shows clear bilateral localization of theory of mind functional localization.
requires engagement of the right frontal cortex.” Other issues are found in statements such as “achievement of blissful states would be accompanied by increased activation of left frontal pole, which has a strong association with positive emotional states.” Here, meditative bliss is linked to “positive emotions,” which is debatable, and is also functional localized—a major metaphysical claim this likely untestable.

**Imposed versus emergent domains of function**

McGilchrist lists 17 categories of cognition, behavior, or experience with opposing modes that each link explicitly to RH or LH, to support the hemispheric phenomenology. These include “certainty” in LH vs. openness to “possibility” in RH, “fragmentary” in LH vs “interconnected” in RH, etc. The categories arise by his construction, with references to philosophic and scientific literature but without adherence to the domains of function that have standardized by consensus in neuropsychology (Insel et al. 2010). It has, however, become possible in the last decade or so to use a data-driven categorization of domains of functions and their associations to regional brain activity. This is done by applying advanced statistical techniques such as exploratory factor analysis to meta-analytic databases of activation localizations such as the ones mentioned earlier. This approach leads to the emergence from analysis of between 10 and 20 self-consistent domains of function along with reproducible neural circuit maps (Smith et al. 2009). These domains differ from McGilchrist’s categorization, despite similarity in count. Data-driven domains are labeled “action-executive”, “cognition-space”, “emotion”, “perception-somesthesis,” as well as primary and secondary motor and visual domains. Around 80% of the domains relate to neural circuits that are functionally bilateral.

A major inspiration in “Cerebral lateralization” seems to relate to attention, and attentional changes after lateralized injuries, such as spatial neglect after right parietal stroke. From recent experiments and meta-analytic studies based on healthy individuals, two distinct circuits emerge that are specific to attention. One is bilateral, the other is RH lateralized. Both involve co-activations across frontal, parietal, and temporal cortices (Fan et al. 2005). The bilateral circuit is associated with sustained attention, and the RH lateralized circuit to novel stimuli. A widely accepted phenomenological description links the bilateral circuit to orienting of attention, and the RH circuit to novelty and alerting. McGilchrist expresses special interest in the role of novelty, but builds a model for activity based on Sherrington’s’ (1906), where RH and LH inhibit each other, and frontal cortex inhibits parietal cortex. The overwhelming evidence for bilateral or fronto-parietal co-activation, particularly for attentional functions, raises serious concerns for any model derived from Sherrington’s. Quoting the ‘Cerebral lateralization,’ there are ‘diametrically opposed types of attention … one, narrow-beam, sharply focused, …; the other, open, broad, … the LH tends to yield the first type of attention, and the RH the second.’ It is apparent that such diametric opposition is not supported.

**Neural circuity interactions and phenomenology**

Evidence for widespread co-occurrence of lateralized and bilateral circuit activations has only been achieved given large datasets from many studies using high-resolution methods. Thus, the evidence for making strong inferences on lateralization is quite recent. The evidence used in “Cerebral lateralization” is mostly from studies with small patient samples, of changes in behavior or self-report after major brain lesions or electroconvulsive suppression of entire hemispheres (Deglin and Kinsbourne 1996). For a measurement standpoint, that evidence cannot support strong conclusions about full lateralization of function, in that it is too biased to finding whole hemisphere differences. Derivative theories of phenomenology are thus inherently speculative. Clinical interpretations related to laterality deserve extra caution, as expressed in the statement “People with autism, who in many respects approximate a RH deficit state, are known to be more included to atheism,” from the Conclusion of “Cerebral lateralization.”
One type oversight that may occur when not seriously factoring neural circuit organization is that of interactions between neural circuits. That oversight may underlie the bias in “Cerebral lateralization” towards full lateralization, such as for the experiences of “beauty” or “truth”. More accessible, more testable, and yet more numerous hypotheses for such complex brain functions may arise when one considers the interaction of neural circuits. As there on the order of 20 or more basic domains of function with neural circuits that may interact in specific areas (called hubs; Achard et al. 2006). Such a model shows the possibility for a vast space of complex brain functions. So far as such functions include perception, interoception, attention, TOM, etc., this space of functions is highly relevant to phenomenology.

**A dimensional model for neural circuitry and phenomenology**

A space of “complex” brain states that may arise from the synaptic interaction of neural circuits can be represented in a coordinate diagram (Figure 2). The 2-dimensional version of this is the familiar Cartesian plane. The 3-dimensional version corresponds to familiar physical space. Each dimension, labeled as $x,y,z$ or $x_1,x_2,x_3$ et cetera, corresponds to a domain of function, with a neural circuit as its correlate. Each position in the space is then demarcated with a coordinate $<x_1,x_2,x_3,x_4 \ldots>$. Any position in any space relates back to the positions on the component dimensions. Each position in this functional space is a combination of levels of activation of functionally-related neural circuits. The co-occurrence of functional activity across neural circuits gives rise to a brain state, represented in a coordinate. That state associates to as much of a phenomenological state as the component dimensions do. An interesting feature of this space is that movement between states occurs by modulating activity on component circuits. Also, every position involves all dimensions, so it may also be possible for states of very many or few active dimensions, with more or fewer dimensional positions near 0. This model is actually supported by data. Recent literature including meta-analyses as well as more direct measurements show that a powerful statistical decomposition called independent components analysis (ICA) applied to various types of brain data show highly comparable circuit component representations across modalities. These correspond well to activation patterns that are evoked by neuropsychological tasks.

![Image](attachment:image.png)

**Figure 2.** Dimensional model for brain states comprised of domain-specific neural circuits. Here, domains are meta-analytic terms (in quotes). Colored points are different brain states, and dashed lines represented transitions. Here, 4 states arising from three domains.
associated to established domains of function. ICA represents data in terms of linear dimensions (Beckmann and Smith 2004), just as in the illustration. By labeling the space dimensions with functional domains and their correlated circuit representations, novel states can be hypothesized and tested.

The state space model may subsume McGilchrist’s laterized functions as interactions of one or more functional domains of varying laterality. Several of the 17 functions he defines relate to either novelty, associated with the RH-weighted alerting network, or language or syntax, associated with the LH-weighted language network. For instance, the state space model suggests that arcuate circuits of RH and LH should co-activate in the experience of a novel narrative. McGilchrist’s model attributes both to RH. Based on a recent study, the former prediction bears true, in both reading and listening of English and Chinese stories (Wang et al. 2015). Such evidence argues against a majority attribution of narrative-related activity to RH. A more conventional experimental condition, the “auditory oddball” task, which involves responding to an unusual sound among familiar sounds, predictably evokes a state of co-activated bilateral auditory cortex and the alerting network. Speculating beyond what is currently testable, interactions of the aforementioned circuits with sensorimotor, TOM, or interoceptive functions may relate to states of music and dance—which are vital in the phenomenology of religion. Alternatively, co-activating the bilateral orienting circuit and the RH-weighted alerting circuit may relate to the experience of soft focus or “open presence.” In fact, attending to heartbeat during compassion mediation has been shown to activate insular cortex bilaterally (interoception) and anterior cingulate cortex (TOM), with a reduction in right insula activity (novelty) with greater exposure to mediation. Thus, unlike the model in “Cerebral lateralization” that relates mindfulness to the RH monolithically, the dimensional model supports a pluralistic view via the interaction of domains. Despite its explanatory power for correlating brain activity to phenomenological states, there are some limitations of the dimensional model. One is that there are known inhibitory relationships between circuits (Fox et al. 2005), so some interactions of dimensions are more possible than others, and it is unlikely that the full space is accessible. Another is that while there is remarkable linearity of interactions at the macroscopic circuit level, neural interaction at the synaptic level is highly nonlinear, based more on temporal firing patterns than response amplitudes. Nonetheless, at the systems level, the linear dimensionality model of brain function based on activity of neural circuits has a striking level of explanatory power.

**Conclusion**

In “Cerebral lateralization,” Iain McGilchrist makes a notable contribution to the important conversation on relating brain science to religious phenomenology. However, his use of findings from studies using low-resolution methods may have led to a bias to inferring a greater role for lateralization in phenomenology than there is support for. Newer studies using high-resolution data show that a neural circuit approach can relate to phenomenology while having high predictive and explanatory power for various brain states. Moreover, the chance for multivalent interactions between neural circuits suggests a vast space of brain states and correlated phenomenology. These may relate naturally to various religious experiences and mystical states. Of note, we have not addressed at length if phenomenology itself can be fragmented, such as for RH and LH, as McGilchrist seems to suggest. Since experimental neuroscience concerns itself with that which is testable, that question may be outside the scope. Nonetheless, many neuroscientists would not claim that phenomenology or “conscious” experience is measurable for anyone but the self as observer. Regardless, phenomenology can be better correlated to neural substrates than before, based on neural circuits, leading to surprising levels of explanatory power for brain activity that pertains to phenomenology. We conclude, then, that the neural circuit approach may be well suited to discussions of phenomenology in general and of religion while supporting a pluralistic view.
Notes

1. That same decomposition when applied to non-brain systems such as pictures of faces shows distinguish features such as eyes, nose, mouth, etc.

2. Arcuate circuits are the most functionally lateralized of the human brain but share mirrored anatomy. This suggests an evolutionary and developmental relationship between the two.

Disclosure statement

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