McGilchrist and hemisphere lateralization: a neuroscientific and metaanalytic assessment

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Iain McGilchrist offers sweeping claims about how the brain supports human understanding and uses these claims to strongly advance an interpretation of Western cultural history involving oppositional hemispheric asymmetries. This paper assesses several of these neuroscientific claims and one of the implications of how global attention might relate to moral formation before turning to novel methods aimed at a more rigorous, comprehensive investigation of McGilchrist’s account. In the end, none of the findings from this study offer support for the broad assertions in the target article or other writings.

Introduction

The target article by Iain McGilchrist provides a link to his more well-known work, The Master and His Emissary: The divided brain and the making of the Western world (McGilchrist, 2009). The article and the book both attempt to draw on neuroscience, especially decisional-valuational social, cognitive, and affective neuroscience (DV-SCAN), to elucidate putative origins and possible futures of the human, including spirituality and religion. Interdisciplinary work undertaken in such an effort generally strives to address critically important questions of broad interest while adhering to standards of scholarship and technical accuracy in the fields on which it depends. Balancing broadly accessible interpretations and language while adhering to scholarly accuracy is difficult and rare. In the case of McGilchrist’s work, the difficulty is enhanced because he introduces the notions of “mode” of understanding, approach, apprehension, attention, and/or being, along with “versions of the world” that he claims identify with philosophical phenomenologies and with evidence from neuroscience, without ever successfully making the link between these fields. The assertions presented in the target article and in the book lack an argument based in either the philosophical phenomenologies or in DV-SCAN and so are not convincing examples of how these two vast areas of understanding might be productively engaged. Further, the many assertions about hemispheric worldviews, seemingly based on sound neuroscience, convey a neuroscientific reductionism about cultural histories, at best, and a set of easily falsified claims at worst. On the one hand, McGilchrist heartily endorses the claim that “both hemispheres are involved in all experience,” he tries to both limit this understanding to cognitive functions or processes or systems (one is never really sure) while advancing a notion of hemispherically isolated or dominant mode or version.

As he stated in a rebuttal to Stephen Kosslyn and Wayne Miller when they critiqued his sweeping claims about hemispheric differences, he already knows and does not need anyone to tell him that “[t]he crude, old ideas that logic and language are in the left, and images and emotions in the right, were exploded long ago. Each hemisphere is involved in absolutely everything we do” (McGilchrist, 2017). However, all of McGilchrist’s attention is focused like a laser beam on the notion that “the hemispheres reliably differ in size, weight, shape, surface structure, cell architecture in some areas, grey to white matter ratio, response to endocrine hormones and in neurotransmitter profile,” so much so that it is “deeply irrational position,” even “a dogmatic response” to “suppose that there are not significant differences between the hemispheres” (McGilchrist, 2017). That there are...
hemispheric differences in some cognitive and neural systems is not usual or controversial. Indeed, tests for hemispheric differences are often sought out by scientists and editors and scientific journals are known to welcome them, so there is hardly a lack of interest in them or a bias against them. The problem is that one or two or three studies, each involving about 20 or so participants, do not provide overwhelming evidence, whatever their outcomes, either for or against. What is more is that even when asymmetries are discovered in structures or in neuroimaging measures, explaining their relevance for and relation to understanding cognitive systems is far from trivial. Rather than dig into the knotty problems of relating neural measures to cognitive modes or systems, McGilchrist’s approach often amounts to hand-waving (McGilchrist, 2009, p. 5839).

Note that McGilchrist’s sweeping claims about entirely mutually exclusive hemispheric phenomenologies and modes or versions of understanding or attention or processing are not controversial, either, though they are unusual. The lack of controversy stems from a combined absence of prevailing neuroscientific evidence in support of these claims, a lack of clarity about what the claims really mean in terms of operational definitions and neural measures, and a failure to engage in any serious way with philosophical phenomenologies and cultural and anthropological studies of religion in asserting that the sweep of Western civilization conforms to the folds of the hemispheres. Prior to reviewing prevailing evidence from DV-SCAN (see Results), it is helpful to note that the differences that McGilchrist postulates are difficult to specify cleanly in attempting a systematic reading of his work. Part of this difficulty stems from the fact that McGilchrist simultaneously highlights claims about hemispheric differences in cognitive functions (“Pragmatics, the ability to understand the overall import of an utterance in context, is a RH function,” target article) while denying at several points that he is doing so because, he claims, he is speaking about versions of the world or modes of being, as in the following:

The contrast between the differing world views of the two hemispheres is brought into focus in a remarkable way by the issue of sameness and difference. Again, seeing their handling of these as just different ‘comparator functions in information processing’ misses the point. They are not ‘functions’ within a world we already know to have a certain (mechanical) structure: they are themselves part of the foundations of the world in which we try to understand them. (McGilchrist, 2009, pp. 1438–1441)

In The Master and his Emissary, analysis of a vast neurological literature over many decades concerning hemisphere differences in birds, animals and humans led to the conclusion that the differences were not in what ‘functions’ the two hemispheres carried out, since both were clearly involved in every brain process, but in the manner in which they each engaged with the world, especially as mediated by clear and reliable differences in the kind of attention they paid to it. (target article)

This paper examines this ambiguity and expands on the absence of clarity in McGilchrist’s concepts of “mode of attention” or “mode of being” or “version of the world,” and how they might be related to aspects of the brain that can at present or may in future be measured. The paper then turns to briefly examine each of the following areas of McGilchrist’s thought: the modal claims about attention in particular, relating these to grounded vs. amodal cognition; the evidence for right hemispheric dominance in empathy and emotion of others; the important area of figurative language and metaphor in relation to religious language and comprehension; and local vs. global, specific vs. holistic processing, especially in relation to seeing others as specific individuals. Finally, the paper presents a method for going beyond the linguistic ambiguities inherent in McGilchrist’s use of modes and versions vs. functions and processing, and relates the results of this method to a series of metaanalyses using the neurosynth in Python (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011).

**Functions vs. modes: the need for bridge laws**

From the perspective of scholarship in neuroscience in general and in DV-SCAN in particular, the primary difficulties presented by McGilchrist’s claims about hemispheric modes or versions is that they do not maintain a relationship to operationalization and expression in terms of neural measures. Much of his writing about hemispheric differences, especially in Chapter 2 of The Master and His Emissary (“What do the hemispheres ‘do?’”) rely on standard citations of neuroscientific
work, mostly falling into experimental behaviour and lesion-deficit mappings, with more occasional use of papers that present neuroimaging measures. This part of McGilchrist’s assertions is not difficult to follow because it adheres to some standard practices. However, though he often refers to cognitive functions, he is ultimately not after those functions. He understands cognitive functions or systems as the “what” of the brain’s doing, and he is really after something he calls the “how” of the brain’s “whats”:

While it is true that we know a lot about what different, in some cases fairly minutely discriminated, areas within each hemisphere ‘do’, in the sense that we can answer the question ‘what’ it is that they appear to help mediate, we have tended to pay less attention to the ‘how’, the way in which they do this – not in the sense of the mechanism by which they do it, of which we have a rapidly increasing understanding, but in the sense of what aspect of a certain ‘function’ is being addressed. As soon as one starts to look in this way at the question – for example, not where language is, but what aspects of language are where – striking differences between the hemispheres emerge. (McGilchrist, 2009, pp. 928–933)

However, the neuroscientific work that he cites to begin supporting accounts of the “hows” of the brain—the hemispherically divergent modes or versions—actually never moves into his language or concepts of “mode” or “version” but remains grounded in cognitive systems and information processing theory. McGilchrist has introduced concepts that do not map onto the scholarship from which he is drawing most of his assertions, and that do not hold up upon close examination of that scholarship.

The central problem is that McGilchrist’s concepts of mode and version have no bridge laws that could potentially link them to operationalizations and neural measures. “Bridge laws” in cognitive neuroscience are not scientific laws but are the methodological approaches that explicitly guide the scholar in linking brain signals to the concepts of interest. Bridge laws perhaps are best understood as the theoretical-philosophical theories, maybe even one’s scholarly commitments, about how measured signals from the brain and the rest of the body (e.g., heart rate, skin conductance, pupil size) convey information about the processes involved in a given cognitive mode or task or experience. Formulating bridge laws begins by affirming that the full depth and breadth of a cognitive system or orientation in the world is, to put it sympathetically, incompletely recreated in the limited mode, task, experience that is most immediately part of the “context of observation” (i.e., the small slice of time, the specific instructions by which, and the specific context in which a contemplative studies participant engages in the research). That is sympathetically phrased, indeed, and is generally the best-case scenario. Worst case is that the mode, task, and experience elicited via a contemplative studies project is orthogonal to or transgresses the basis of the contemplative phenomenon ostensibly at the core of the project’s inquiry. Formulating bridge laws should proceed only after one has several avenues of evidence confirming that one’s study is really studying the process and phenomena of interest, and one of those avenues of evidence ought to be the contemplative community itself.

Another way of understanding the function of bridge laws is to say that they are the laws of interpretation, linking measurements to meaning. They are lawlike in that they both facilitate and constrain cognitive scientists in terms of their explanations of complex cognitive phenomena that are the knotty problems of the field. The most common way to refer to bridge laws in cognitive neuroscience is by the term “neural encoding,” as in, “The activation in ventromedial prefrontal cortex encodes the expected reward probability of choice A.” Neural “codes” are the spatiotemporal patterns of neural processing that correspond to specific cognitive subprocesses, often modeled as computations. These patterns generally take the form of electrical, chemical, or electrochemical events, often coordinated over long distances in the brain.

Bridge laws in human cognitive neuroscience are far from easy to settle upon because their formulation involves four deeply problematic challenges. First, neuroimaging technologies (e.g., intracranial intracellular electrical potential, spikes, and molecular signaling; intracranial extracellular electrical potential, spikes, and molecular signaling; optical imaging for electrical potential and molecular signaling; intracranial and transcranial magnetic stimulation; and extracranial
electroencephalography, magnetoencephalography, magnetic resonance imaging, and optical imaging) are not easily adapted to, and may be inappropriate for, existing ethological and/or ethologically valid investigations of particular cognitive systems in context. For example, in relation to the treatment of mindfulness in the target article, in contemplative contexts, the modes, practices, tasks, and experiences, study design may limit the extent to which a study’s elicited cognitive modes resemble the complete contemplative consciousness that is of interest. For example, to study the neural contributions of each hemisphere within acts of compassion or other-regard, how helpful is it to measure compassion by a one-off scenario in which a participant either helps or does not help a person in need? Would a task that requires ongoing compassionate attention and commitment not be more helpful? Or, to take another example, to study the neural contributions within epochs of mindfulness, how helpful is it to measure mindfulness by calling it the numerical reverse of a self-report measure on distractability? Or, finally, is it helpful to identify compassion with a cognitive skill, a coping mechanism that ensure positive affect despite and perhaps because of encounter with real suffering of real people?

The point is that McGilchrist rarely attends to the experimental contexts that inform the studies he cites to support his concepts of the hemispheres’ modes of being and versions of the world, nor does he devote careful attention to how neural measures-in-context would differentiate between a cognitive function and a hemispheric mode of being or version of the world. At times, it seems that lesion-deficit-mapping analyses serve this kind of role for the sweeping claims about hemispheric modal differences. Here again, the cited scholarship itself does not propose such concepts to explain its findings. Additionally, there is a paucity of caution in McGilchrist’s writings when interpreting the results of lesion-deficit-mappings. Simply because damage to one area of the brain results in radical and sweeping changes to a person’s behavior and perspective does not imply that the brain area was the locus of the previously healthy function. It is critical, for the practicing scientist, for the interdisciplinary scholar, and for the interdisciplinary popularizer to keep foremost in mind the cautions and complexities that apply to our current set of neural measures that attempt to link brain and mind (Spezio, 2011).

Global vs. local modes or versions or attention(s)
The target article’s primary assertions regarding holistic and detailed processing (i.e., global and local forms of attention or apprehension) rest almost entirely on evidence from vision, specifically in the areas of visuospatial and visuoobject (i.e., object-based) attention. The primary argument is that the left (LH) and right hemispheric (RH) circuits of the brain enable two completely different systems of attention or attending (again, variously termed modes, types, kinds, capacities, natures, and versions). The LH The implicit argument, which is not emphasized in the target article but which is critical to it and to the 2009 book, is that the brains humans have today are the result of a long evolution of “the bringing to bear of diametrically opposed types of attention to the world simultaneously: one, narrow-beam, sharply focused, fragmentary, already committed to its object; the other, broad, open, sustained, vigilant and uncommitted as to what it might find.” (target article) Nevertheless, the article’s assertions about hemispheric opposition and religion requires a much more careful unpacking in terms of evolutionary theory and findings, something that is thus far lacking in McGilchrist’s writings.

As seen in general for the concepts of mode and version, the target article redefines “attention” in ways that do not match the scientific literature it cites. Attention as a term of art in the argument of the paper is variously used to mean perception, experience, phenomenology, memory, meaning, and understanding, as in: “The LH fails to understand metaphor, myth, irony, tone of voice, jokes and poetry, and takes meaning literally” because the LH somehow puts these linguistic phenomena “under the spotlight of attention.” Extending far beyond the original term “attention”, the argument hinges on the claim that the LH and RH create completely separate worlds, and that the neural circuits in the RH never use mechanisms on which past research has reliably shown that the RH relies, such as repetition suppression: “If, as in the world made available by the RH, nothing is ever repeated or
precisely the same as anything else, all is unique and fresh.” Yet there is no clarity about the neural measures supporting such a view, a view that goes far beyond specific cognitive systems and processes.

McGilchrist bases his discussion of attentional opposites by selective citation of the visuospatial attention literature (i.e., a literature addressing one sensory mode) and then generalizes, without careful additional scholarly work, to hemispherically opposed supramodal or amodal versions of attention that transcend sensory (i.e., embodied) modalities of perception, knowledge, and understanding. McGilchrist seems to simultaneously fail to understand that his move from visuospatial attention to amodal attention is a radical contradiction of his endorsement of the assertion that “everything we know is embodied and cannot be abstracted without distorting its essential nature,” and to fail to understand that there is good evidence in the literature suggesting that auditory attention and somatosensory attention do not follow the often-claimed hemispheric divisions between local and global attention in vision. For example, in auditory processing, relative differences in local and global attention seem to follow dorsal-ventral lines rather than divisions between RH and LH (Sanders & Poeppel, 2007). Of course, this is only one study, but a thorough and comprehensive assessment of attentional processes in multiple sensory modes must precede anything like McGilchrist’s sweeping claims about amodal versions of understanding based on attentional poles in the hemispheres. Even if, as is highly unlikely given present evidence, strong evidence in favor of the RH and LH exhibiting directly opposed versions of amodal attention were discovered, this would undermine McGilchrist’s assertions linking RH, but not LH, processes to embodiment and grounded cognition.

**Empathy and emotion**

Similar to his account of oppositional hemispheric attentions, McGilchrist generalizes about oppositional modes of emotion and empathic connection, such that “[e]ach hemisphere … appears to have not just different cognitive strategies, but different goals, values, opinions and emotional timbre.” (target article) Not surprisingly, the RH has all of the good versions and modes of emotion and empathic connection, while the left inhibits those:

> most animal species, intense emotional responses are related to the right hemisphere and inhibited by the left. (McGilchrist, 2009, pp. 760–761)

And it also turns out that the capacities that help us, as humans, form bonds with others – empathy, emotional understanding, and so on – which involve a quite different kind of attention paid to the world, are largely right-hemisphere functions. (McGilchrist, 2009, pp. 789–791)

The right temporal lobe deals preferentially with memory of a personal or emotionally charged nature, what is called episodic memory, where the left temporal lobe is more concerned with memory for facts that are ‘in the public domain’. Interestingly the right hemisphere’s concern with the personal past may be directly linked to something else we will come to, its tendency towards feelings of sadness. (McGilchrist, 2009, pp. 1476–1479)

The right hemisphere has by far the preponderance of emotional understanding. It is the mediator of social behaviour. In the absence of the right hemisphere, the left hemisphere is unconcerned about others and their feelings: ‘social intercourse is conducted with a blanket disregard for the feelings, wishes, needs and expectations of others.’ (McGilchrist, 2009, pp. 1572–1575)

Again there is a failure to address the broad and more recent literature, where McGilchrist often relies on an older set of findings that no longer represents our best understanding of emotion and the brain. Recent metaanalyses have shown that not only is hemispheric lateralization of emotional systems generally unsupported (Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012), but when evidence suggests some lateralization, it is far from a straightforward and all-encompassing division according to the hemispheres (Wager, Phan, Liberzon, & Taylor, 2003). Further, there is no evidence from comprehensive metaanalyses that empathy for pain—understood as a cognitive system or as a cognitive set during a given task—is strongly right-lateralized, either (Lamm, Decety, & Singer, 2011). To this growing body of evidence against the sweeping claims about oppositional hemispheric modes of emotion and empathic connection, one must add McGilchrist’s continued lack of clarity about what constitutes a mode or version, versus a function or system, in terms of the available
neural evidence. Empathic modes and versions of intersubjective connection in particular play a strong role in McGilchrist's entire analysis of the history of Western culture and again in the target article, while the evidence for these constructs remains lacking.

**Metaphorical and figurative language**

McGilchrist advances new assertions in the target article regarding the RH and LH and their oppositional and perhaps complementary roles in religious and spiritual life. Specifically, he attacks the LH for its being governed by a mode that lacks the capacity to understand any religious language other than literal and universal claims:

> Despite its relative lack of capacity to engage with the qualities I have considered above, it [i.e., the LH] must also have a way of approaching the divine. This would be less congenial to the mystical, more to the systematic. It would prize the written word over the visual image or music, and would tend to take the written word literally. It would be relatively uneasy with un-knowing and would claim certainty. It would lack an understanding of embodied worship, including the metaphorical nature of icons and statues.

These new assertions appear without any citations to literature investigating the recruitment of systems in the right and left hemispheres while persons either generate or comprehend metaphorical, non-literal, figurative language. One might be forgiven for thinking that there are as yet no clear findings in this regard. Yet the number of such studies is growing, even making possible recent meta-analytic insight into how the brain supports figurative language. According to several recent studies, which draw on methods ranging from experimental behavioral psychology to neuroimaging, there is no strong evidence that the right hemisphere plays any exclusive role in processing novel, non-literal metaphorical language (Forgacs, Lukacs, & Pleh, 2014), and indeed mounting evidence for a slightly left-lateralized system in the comprehension of non-literal language (Rapp, Mutschler, & Erb, 2012). One study reported a stronger role for right hemispheric systems in processing metaphors that required integration of highly semantically dissimilar information (Yang, 2014).

Once again, McGilchrist put forward sweeping claims that, if they were true, would have profound implications for understanding the evolution and the brain’s support of symbolic, poetic, and potentially paradoxical religious and spiritual language. The literature, however, shows no evidence to support his claims and, in fact, presents evidence that at least provisionally contradicts the claims he makes about the dominance of an RH mode for non-literal understanding and the lack of capacity for such understanding supported by systems in the LH.

**Specificity and seeing the other as individual**

McGilchrist relates the RH mode or version of holistic, global, gistic apprehension to a benefit for a fuller engagement with and betweenness among others. The links he makes imply that seeing people in less detail, focusing less on what makes them unique and special as individuals, actually enhances relationships and potentially moral cognition and action. However, this implication is highly problematic, for several reasons. First among them is the notion that broad, impressionistic experiences of others may in fact be what is wrong with much of moral cognition and could in fact stand in the way of authentic relationship. Global attention may diminish details or swamp nuances that are important in establishing authenticity and real meeting between persons. Even betweenness may require focused attention, after all, especially to overcome prevailing social expectations in current Western culture. It may require some directed, executive overriding of typical everyday interpersonal encounter to begin to experience what Maurice Friedman described in his account of Martin Buber’s theory of knowledge:

> Thus I-Thou and I-It cut across the lines of our ordinary distinctions to focus our attention not upon individual objects and their causal connections but upon the relations between things, the dazwischen (“there-in-between”). (Friedman, 1954, pp. 268–269, emphasis added)

If betweenness and refocusing on relation rather than on illusions of “the atomistic idea of the self” require focused attention, then it may be beneficial and perhaps even necessary for moral formation
that there be neural systems supporting attention and perception that can override everyday social expectations of ingroup and outgroup relations. McGilchrist would do well to spend much more time to consider just how far global attention brings to our perception the authentic uniqueness of ourselves and of others.

Assessment

To this point, the signs pointing to the potential of McGilchrist’s work for generative interdisciplinary inquiry and understanding are not encouraging. There is a lack of clear specification of modes or versions—distinct from functions or systems—of the brain, a failure to consider the bridge laws that could provide such distinctions, a failure to link sweeping claims about hemispheric opposition to sound review of the available evidence, and an absence of concern for just how global and local processing and focused attention in particular might both be critical for authentic meeting with and moral consideration of others. The next sections attempt to outline and follow a method that can, in as unbiased and thorough a manner as possible, assess whether any of the sweeping claims that McGilchrist requires for his neurally grounded cultural and historical account of Western history show evidence from the literature. These methods are necessarily somewhat technical, and by no means without problems. Their adoption here is a sincere attempt to add to the analysis above by more comprehensive consideration of both McGilchrist’s text and of the neuroimaging literature, yielding estimates of semantically preferred hemispheric assignments of specific cognitive systems and of metaanalytic estimates of the asymmetries of neural measures associated with those systems.

Methods

Estimation of preferential hemispheric assignment of function in McGilchrist’s text

Semantic distance using cosine similarities allowed a relatively unbiased assessment of how McGilchrist’s major text (McGilchrist, 2009) associates important key terms of cognitive system or mode with either the left or right hemisphere. This approach sidesteps uncertainties about McGilchrist’s various references to cognitive processes, functions, systems, or modes, since it looks only at the occurrence of specific terms (e.g., emotion, empathy, imitation).

Word embedding

The analysis applied the word2vec algorithm developed by teams at Google, Inc. (Mikolov, Chen, Corrado, & Dean, 2013; Mikolov, Sutskever, Chen, Corrado, & Dean, 2013) to the entire introduction and main text of *The Master and His Emissary* (McGilchrist, 2009), leaving out the bibliography and index, along with any word that occurred fewer than five times in the text (i.e., the McGilchrist corpus; word2vec parameters: skip-gram, negative sampling, 300 features, a window size of 200). The word2vec algorithm implements a neural network for shallow learning of words in their local contexts, resulting in a matrix in which the number of rows is the number of unique words in a textual corpus, while the number of columns is the size of the semantic vector for each word. The semantic vector contains the numerical features defining that word (Dyer, 2014; Goldberg & Levy, 2014; Rong, 2014) and the meaning of the word is operationalized as its word vector. Importantly, word2vec goes beyond standard “bag of words” approaches such as latent semantic analysis (LSA; Landauer et al., 2007; Landauer, Foltz, & Laham, 1998; Landauer, Laham, & Derr, 2004; Mehl & Gill, 2010) that fail to represent words in a document according to their local context. In particular, in word2vec’s skip-gram model, the neural network predicts the occurrence of a word, based on the occurrence of the surrounding words in a context window of a given size. For example, applying a skip-gram trace model with a window size of five attempts to predict word_i by sampling words from those occurring five places before (i.e., word_{i-5}) to five places after (i.e., word_{i+5}) word_i. Closer words receive more frequent sampling since more distant words are less likely to be closely related to the word at the center of the window. The number of features used by word2vec corresponds to the number of hidden units.
in the neural network, and the features themselves are the weights on those units. Implementation of word2vec used the gensim package (Rehůřek & Sojka, 2010) in Python (Rossum, 1995).

**Textual preparation**

Prior to applying the word2vec model to the text, the nltk (i.e., natural language toolkit; Bird, Loper, & Klein, 2009) and string functions in Python separated it into sentences, removed punctuation, removed numerals, placed all words into lowercase, and lemmatized the words according to lemmas provided by the WordNet database (Fellbaum, 1998; Miller, 1995). A lemma is the shortest form of a word that still retains the meaning of that word. Lemmatization of each word yielded meaningful word forms for further analysis, while at the same time minimizing redundancies due to multiple word forms that have nearly the same meaning. This approach yielded 2,920,700 initial words and 1,859,180 effective words, resulting in a total unique vocabulary of 4,632 lemmas. Importantly, word2vec recognizes and identifies lemmas involving two or more terms, such as “righthemisphere” and “lefthemisphere”, both of which appear in the unique vocabulary.

**Semantic similarity**

Analyses examined similarities between terms for cognitive functions, systems, modes, etc., and the two lateralization terms “righthemisphere” and “lefthemisphere.” Similarities between any two words resulted from calculating the cosine of the angle between their two semantic space vectors, where the vectors result from the weights on the hidden units, or features. Cosine similarity is defined as the dot product between two word vectors, $w_1$ and $w_2$, divided by the Kronecker normalization product of those two vectors, as in:

$$\text{CosSim}_{w_1w_2} = \frac{w_1 \cdot w_2}{\text{Norm}(w_1) \times \text{Norm}(w_2)}$$ (1)

where the dot product between the two word vectors is,

$$\text{dot}(w_1, w_2) = w_1 \cdot w_2 = \sum_{\text{feature}_j=1}^{N_{\text{features}}} (w_{1\text{feature}_j} \times w_{2\text{feature}_j})$$ (2)

and the normalization of a word vector, say $w_1$, is the vector magnitude, given by,

$$\text{Norm}(w_1) = |w_1| = \sum_{\text{feature}_j=1}^{N_{\text{features}}} \sqrt{(w_{1\text{feature}_j})^2}$$ (3)

Values range between +1 for perfect congruence and −1 for perfect incongruence between words.

**Estimation of hemispheric asymmetries using metaanalyses of published studies**

Semantic similarities indexing associations between (a) terms signifying the right and left hemispheres and (b) terms signifying cognitive functions, systems, or modes, can be directly compared with the results of novel metaanalyses that include published neuroimaging analyses. This approach is more rigorous than examining a limited number of hand-picked studies for review, since it allows analyses of up to several hundred studies or more. By this method, one can move beyond simply reviewing several single studies or metaanalyses that have already been published (see Introduction).

Metaanalyses used the neurosynth database of 11,406 published studies with over 150,000 reported peak voxel activation coordinates, via the neurosynth package in Python (https://github.com/neurosynth/neurosynth) (Yarkoni et al., 2011). Neurosynth allows quantitative, rather than purely speculative, reverse inference by assessing thousands of studies to determine the probability of the appearance of a given term signifying cognitive processing (probability of a feature, pF) given an activated voxel (probability of activation, pA). Rather than simply looking at the probability of
activation when a given term is present (i.e., pA | pF), neurosynth reveals the probability of a term occurring in a study given an activated cluster (i.e., pF | pA), controlling for the occurrences of all other terms. Thus, quantitative reverse inference in neurosynth allows a greater quantitative understanding of the specificity of association between cognitive process and activation pattern than is typically the case when proceeding only by predicting activation patterns given one or more terms. All neurosynth analyses in Python used false detection rate correction (Genovese, Lazar, & Nichols, 2002) at \( p < 0.01 \), followed by thresholding at a z-score of 4 and a cluster size threshold of at least 160 mm\(^3\) (~10 voxels) (Chumbley & Friston, 2009). Resulting images had a 2 mm voxel resolution and are shown as overlays on the 0.5 mm voxel resolution MN152 nonlinear symmetric brain template (i.e., 2009b; Fonov et al., 2011). Because the z-scored maps and not the posterior probability maps informed the clusters, the results cannot be interpreted as showing evidence for exclusivity of cognitive system associated with area of activation (see: http://www.talyarkoni.org/blog/2015/12/05/no-the-dorsal-anterior-cingulate-is-not-selective-for-pain-comment-on-lieberman-and-eisenberger-2015/ and http://www.talyarkoni.org/blog/2015/12/14/still-not-selective-comment-on-comment-on-comment-on-lieberman-eisenberger-2015/).

Image display and cluster analyses used the neuroimaging processing software Mango (http://ric.uthscsa.edu/mango/; Lancaster et al., 2010; Lancaster et al., 2012). To quantify relative hemispheric contributions associating with a given term, the sizes of surviving clusters (in mm\(^3\)) in the left hemisphere were subtracted from the cluster sizes in the right hemisphere, for all clusters that had defined centroids either in the right or left hemispheres (i.e., \( x \geq |2\) mm\( | \)). A volumetric difference of 1000 mm\(^3\), for example, indicates that the right hemisphere included approximately 1 mL more activated brain tissue for a term of interest, compared to the left hemisphere. The neurosynth database search terms were as follows (see also Table 1): 1) for attention, (attention OR attention network); 2) for emotion, (emotion OR emotional); 3) for empathy, (empathy OR empathic); 4) for global attention, (global AND [attention OR attention network]); 5) for imitation, (imitation); and 6) for intersubjective, (interpersonal).

Results

Semantic analyses for preferred hemispheric asymmetries

The distribution of cosine similarities in the McGilchrist corpus was Gaussian, allowing accurate calculation of its central tendency and standard deviation (Figure 1). Table 1 shows that the McGilchrist corpus generally showed greater similarity between the term “righthemisphere” and terms that are critical to McGilchrist’s interpretation of the right hemisphere as “open to whatever it is that exists apart from ourselves, as much as possible without preconceptions,” and requiring “a mode of attention that is broader and more flexible than that of the left hemisphere” (McGilchrist, 2009, pp. 1037–1039). Note that these semantically preferred hemispheric asymmetries are the direct result of quantitative analysis of a broad collection of statements in the McGilchrist corpus, and so would be expected to detect patterns consistent with whether the McGilchrist corpus really does express the view that, “Each hemisphere is involved in absolutely everything we do” (McGilchrist, 2017).

| Cognitive System | SimRightHemisphere—SimLeftHemisphere | SizeRightHemisphere—SizeLeftHemisphere (Number of Studies) |
|-------------------|------------------------------------|----------------------------------------------------------|
| attention         | 0.02                               | 4274 mm\(^3\) (1447)                                      |
| emotion           | 0.02                               | −8443 mm\(^3\) (1609)                                    |
| empathy           | 0.12*                              | 0 mm\(^3\) (163)                                        |
| global (global attention) | 0.10*                                | 423 mm\(^3\) (42)                                      |
| imitation         | 0.06                               | −2026 mm\(^3\) (67)                                    |
| intersubjective   | 0.07                               | 1870 mm\(^3\) (260)                                    |

* Differences of >1 standard deviation of cosine similarity.
Importantly, two of these semantically preferred right hemispheric asymmetries, those for empathy (0.12) and for global attention (0.10), exceed one standard deviation of the distribution (SD = 0.08). This finding is consistent with the analyses in the Introduction of particular statements about these modes or functions, both in the McGilchrist corpus and in the target article. In the target article, the “LH version [of the world]” is, as it was in the original 2009 book (McGilchrist, 2009), again portrayed as “relatively untroubled by the complexity of empathy,” while the “RH version [of the world]” includes “empathy and emotional depth, [which] help us to intuit meaning that lies beyond the banality of the familiar and everyday.” The question remains whether the available neural evidence generally supports or does not support these speculations. A handful of studies specially chosen may show evidence either way without being conclusive. Metaanalyses of hundreds of studies not specially chosen for the task, involving thousands of human participants and reporting thousands of brain activations, hold greater promise in resolving this question.

**Metaanalyses revealing preferred asymmetries**

Hemispheric asymmetries appeared for all of the metaanalyses except for empathy, which showed no overall hemispheric difference in activated clusters (Table 1; Figure 2C). Note that this bilateral recruitment of neural systems during empathy is consistent with at least one published metaanalysis of empathy (Lamm et al., 2011) and with a metaanalytic connectivity analysis examining self-vs. other-orientation (Murray, Debbane, Fox, Bzdok, & Eickhoff, 2015). There is no prevailing evidence to support the observed semantic right-hemispheric preference for empathy (Table 1), nor to support strong statements from the McGilchrist corpus regarding empathy’s exclusive association with the right hemisphere:

> Because of the right hemisphere’s openness to the interconnectedness of things, it is interested in others as individuals, and in how we relate to them. It is the mediator of empathic identification. If I imagine myself in pain I use both hemispheres, but your pain is in my right hemisphere. (McGilchrist, 2009, pp. 1540–1543; emphasis added)

Global attention showed only a small hemispheric asymmetry favoring the right hemisphere, amounting to less than 0.5 mL, or approximately 26 voxels, compared to the strong semantic
preference for the right hemisphere. Neither empathy nor global attention presented metaanalytic evidence consistent with the strong semantically preferred hemispheric asymmetries. Interestingly, in contrast to the semantically preferred asymmetries and in contrast to statements from the McGilchrist corpus, emotion showed large (∼8 mL) and imitation smaller (∼2 mL) left hemisphere asymmetries.

**Discussion**

The introduction of two methods aimed at more comprehensive assessment of how McGilchrist’s claims relate to the neuroscientific evidence yielded results that offer no support for McGilchrist’s central claims about the hemispheres and their sweeping and oppositional modes of attention and apprehension. In almost every case, the semantically preferred asymmetries of cognitive systems had no similarity with the metaanalytic findings. Taken together with the considerations raised in the Introduction, there is little indication that McGilchrist’s, 2009 book or the target article offers useful guidance to interdisciplinary scholars seeking to seriously engage the neurosciences in the service of understanding the myriad complex problems facing scholarship and society.

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I would like to thank all the respondents for their comments, which offer me the opportunity for a number of clarifications. Many relate to the topic of generalization. “To generalize is to be an idiot,” warned Blake: “to particularize is the alone distinction of merit.” The only trouble with that is that it is a generalization. One needs details, and nuances, which are what get shorn off in summary papers; and it is certainly more comfortable to remain with the details. But in science no progress is made that way. As the great evolutionary biologist and palaeontologist George Gaylord Simpson wrote:

Science, truly to be such, must centre not on descriptions and names but on principles—that is, generalizations, theories, relationships, interconnections, explanations about and among the facts. (Simpson, 1963, p. 82)

That requires imagination, making analogies, seeing connections—and the willingness to stick your neck out. Again I quote, this time from Sir Peter Medawar:

Scientists should not be ashamed to admit, as many of them apparently are ashamed to admit, that hypotheses appear in their minds along uncharted by-ways of thought; that they are imaginative and inspirational in character; that they are indeed adventures of the mind. (Medawar, 1964, p. 43)

No generalization can go unqualified—even this one. While some are unfounded, some are the result of years of experience, reflection and research. When the research is shorn off and the conclusions...