

# **No Mental Life after Brain Death: The Argument from the Neural Localization of Mental Functions**

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**Abstract:** *The paper samples the large body of neuroscientific evidence suggesting that each mental function takes place within specific neural structures. For instance, vision appears to occur in the visual cortex, motor control in the motor cortex, spatial memory in the hippocampus, and cognitive control in the prefrontal cortex. Evidence comes from neuroanatomy, neurophysiology, neurochemistry, brain stimulation, neuroimaging, lesion studies, and behavioral genetics. If mental functions take place within neural structures, mental functions cannot survive brain death. Therefore, there is no mental life after brain death.*

We will argue that the mind is located in the brain in such a way that there is no mental life after brain death. A fortiori, there is no mental life after the body decays. Our conclusion is overwhelmingly supported by neuroscience. Before we can present samples of the evidence, some preliminaries are in order.

First, whether there is an afterlife is an empirical question, which we can attempt to answer on empirical grounds to the best of our ability. We will rely on empirical evidence. Believers in the afterlife often discuss empirical evidence too, but sometimes they also appear to engage in wishful thinking.

Many people wish to survive their bodily death. But wishing doesn't make it so. Wishful thinking is an understandable human proclivity that nevertheless has no role to play in determining how things are. Because of this, we establish from the outset that whenever we encounter a conjecture about the afterlife that is completely unsupported by empirical evidence, we may dismiss it as wishful thinking:

**No Wishful Thinking Principle:** Empirically unsupported conjectures about empirical questions need not be taken seriously.

The No Wishful Thinking Principle rules out two kinds of conjecture. First, there are conjectures that are empirically testable but for which there is currently no evidence whatsoever. Examples from other areas of inquiry include the hypotheses that there are unicorns and fairies. Second, there are conjectures that are not empirically testable even in principle. Examples include the hypothesis that the universe was created five minutes ago complete with memories, fossil records, etc. and the hypothesis that we all live in a perfect computer simulation (like the movie *The Matrix*, except that each of us is just a piece of software with no physical body).

Sometimes it is difficult to determine whether an empirically unsupported conjecture about the afterlife is empirically testable in principle. It may depend on whether divine actions must follow accepted physical principles and whether divine actions are physically detectable.

The No Wishful Thinking Principle generates different verdicts depending on whether a hypothesis is empirically testable. If a hypothesis is empirically *untestable* in principle, it is dismissible for good on methodological grounds. If it is empirically testable but currently lacks evidence, it is dismissible as wishful thinking so long as evidence in its favor is lacking. If evidence were to be presented, the status of the hypothesis should be reevaluated in light of the evidence.

A second caveat pertains to the metaphysics of mind. Different naturalistic accounts of the mind-body relation maintain that mental states are related to brain states by different metaphysical relations, such as type identity, realization, token identity, fundamental correlation, or what-have-you. We are neutral on this point. What the evidence shows is that mental functions take place within the brain in a way that rules out substance dualism.<sup>1</sup> That's enough for our purposes.

The argument we present is entirely analogous to arguments to the effect that non-mental functions are localized in non-neural organs and are a manifestation of their causal powers. We begin with a phenomenon—say, the digestion of food, the breathing of air, or the motion of blood through the body. Through observation and experimentation, we find that the activity of certain internal structures—the digestive, respiratory, and circulatory systems, respectively—explains those phenomena. We conclude that the phenomena occurs (mostly) within those structures and are the manifestation of those structures' causal powers: digestion occurs in the digestive system and is a manifestation of the digestive system's causal powers; breathing occurs in the respiratory system and is a manifestation of the respiratory system's causal powers; blood movement occurs in the circulatory system and is a manifestation of the circulatory system's causal powers. By the same token, we will argue that mental functions occur (mostly) in neural structures and are a manifestation of neural structures' causal powers.<sup>2</sup>

Third, substance dualism does not entail an afterlife. Even if there were a nonphysical mind, it may well cease to function when the brain dies. So even if there were nonphysical minds, afterlife believers still have the daunting burden of showing that such nonphysical minds survive brain death. We will not discuss arguments to that effect. As far as we are concerned, arguments to the effect that nonphysical minds survive brain death are rendered moot by our conclusion that the mind is a manifestation of the brain and therefore there are no nonphysical minds.

Fourth, ours is not a definitive refutation of substance dualism. We cannot prove the negative claim that nonphysical minds don't exist anymore than we can prove that unicorns or fairies don't exist. But the burden of proof is on the believers. If you want to affirm that something exists, it's your job to produce evidence for it. Our point is that there is none. What evidence there is supports the conclusion that the mental functions are localized in the brain.

Fifth, we are entirely neutral about the degree to which the mind-brain is modular. Some mental functions, such as early sensory processing and late motor control, appear to be neatly localized in well-defined regions of the brain. Other mental functions may well be distributed over vast networks of neural systems. It also appears that some neural systems participate in many neural functions. As far as we are concerned, the neural structures that implement a

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<sup>1</sup> For present purposes, the distinction between Cartesian substance dualism, non-Cartesian substance dualism, dualistic hylomorphism (e.g., Leftow 2010), the doctrine of "astral body," various notions of the soul, and other dualistic doctrines makes no difference. For simplicity, we will subsume all these doctrines under the labels "substance dualism" and "nonphysical mind".

<sup>2</sup> For simplicity, we will use either of these claims interchangeably, without repeating both each time.

mental function need not have sharp boundaries, need not be contained within a contiguous spatial region, and need not stay the same over time. All that matters for our purposes is that any given mental function has a neural basis. That, we contend, is very plausible—furthermore, there is no evidence to the contrary.

Sixth, it has become popular to point out that the mind is *situated* at least in part in the body and the environment (Robbins and Aydede 2009). From this, some authors conclude that the mind is not *located* solely in the brain. Undoubtedly, the mind is situated. But so is the brain. The brain is situated within the nervous system, the body, and the environment. Thus, the mind being situated may or may not go against the mind being located in the brain. Now suppose for the sake of the argument that the mind is situated in such a way that the mind is located not only in the brain but also in physical structures outside the brain. This highly contentious assumption would not change the nature of our argument and would not support in any way the existence of nonphysical minds let alone an afterlife. Since the situatedness of the mind makes no difference to our argument, we set it aside.

Seventh, we have one more caveat that is tricky enough to require its own section. In the next section we'll discuss whether physicalism is consistent with an afterlife. After that, we'll finally present evidence that the mind is located within the brain. Finally, we'll respond to some objections to our conclusion that there is no mental life after brain death.

## 1. Physicalism and the Afterlife

Localizing mental functions within the brain, by itself, does not entail that there is no afterlife. In fact, there are physicalists who believe in the afterlife. If this surprises you, you haven't been paying attention to the literature on the afterlife. (Which is good for you, probably.) There are two ways for a physicalist to believe in the afterlife. We will briefly address them in turn.

The first way is to suppose that an appropriate physical replica of you comes into being after the destruction of your physical body. Either someone creates a physical replica of your body (e.g., Baker 2011) or someone creates a functionally equivalent replica of your brain in some other medium, such as a computer (e.g., Martin 1971).

The obvious problem with the replica approach is that replicas are not numerically identical to the person they replicate. In other words, your replica is not the same individual as you; your replica is a distinct individual that happens to be qualitatively *exactly similar* to you. Thus, creating a replica of you is not a way for *you* to survive. This should be obvious (cf. van Inwagen unpublished), but for some people it isn't. For those who don't see it as obvious, consider the following.

If there is a method to make a replica of you, presumably the same method can be used to make multiple replicas. The replica approach maintains that your replica is you. But suppose that as you are destroyed, multiple replicas are made. Which one is you? The answer cannot be that they all are. For by the transitivity of identity, if they are all numerically identical to you, then they are also numerically identical to one another. But by hypothesis, they are numerically distinct individuals. Since there is no reason to pick one among the many replicas as the one that is numerically identical to you (by hypotheses, all your replicas are created using the same method, so they all resemble you equally), the only remaining answer is that none of your replicas is numerically identical to you. Therefore, making a replica is not a way for you to survive.

To see this more vividly, imagine that teleportation is invented. A teleporter disintegrates your current body, extracts precise information about the location of each particle that constitutes you, and makes an exact particle-by-particle replica of you in another location. To go from New York to Paris, says the advertisement, you can take a plane, which takes seven hours and costs \$1,000, or take the teleporter, which takes only a minute and costs \$100. Which one would you take? If you are in doubt, consider a more advanced teleporter. It makes a copy of your body by scanning your present body without destroying it. Now it should be pretty clear that after you enter and exit the teleporter in New York, you are the person who is still in New York, while the new body in Paris is a mere replica distinct from you. Regardless of how many replicas are made and whether making replicas requires the destruction of your current body, your replica is not *you*. No one can make your replica numerically identical with you—not even god (contra Baker 2011).

Someone may object by postulating that physicalist afterlife is not based on mere replicas but replicas\*. A replica\* is just like a replica except that by definition, it is impossible to make more than one replica\* (cf. Hitch 1976). Reply: this is just a relabeling of the problem rather than a solution. Establishing by definitional fiat that there can only be one replica\* does nothing to make a replica\* numerically identical to what it replicates. In addition, anyone who wants to press this objection needs a convincing account of what prevents multiple replicas\* from being made.

Enough about replicas and replicas\*. But there is a second approach to physicalist afterlife. The second approach is to suppose that, contrary to appearances, your body is not destroyed when other people think it is. Perhaps god steals your body and preserves it on a cold planet, while placing an exact replica of your body in its stead (van Inwagen 1978). At an appropriate time, god can resuscitate your body, bringing you back to life. This may be seen as just an extension of medical technology, whereby people are kept alive in spite of injuries that used to be deadly only a few years ago.

Actually, it's not that simple. For starters, there is brain death. Even if god takes away your body, once your brain is dead it cannot function again. And if god somehow restored your brain to function, this would be more akin to building a replica brain, with a mental life that replicates you, than to bring *you* back to life. The mental life that is genuinely yours ended when your brain died.

One way to avoid the problem of brain death is for god to snatch your body before the brain actually dies. But this raises two new problems. Problem 1: what if you were in a coma or had dementia, etc. and any meaningful mental life had actually ceased way earlier? We are back to where we were before. Problem 2: if god has to replace your live body with a replica before you die, then god needs a live replica of you to put in your place. But then, presumably, your live replica really does die without having an afterlife. In order to save you, god needs to let someone else die in your stead. That's a pretty cruel way to give you an afterlife.

Another solution is for god to employ some unspecified means by which he can preserve some causal physical continuity between your old brain (which dies and decays) and your resurrected body (van Inwagen unpublished). In the absence of more details about the unspecified means by which god does this, it is hard to discuss this option—or to take it seriously. We have so far refrained from invoking the No Wishful Thinking Principle, but the Principle is now overdue.

Suffice it to say that in looking for ways that god might preserve you consistently with physicalism, we left long ago the realm of empirically based conjecture to enter the realm of

wishful thinking. More generally, an afterlife consistent with physicalism is mere wishful thinking. And with that, let's go back to earth.

## **2. The Neural Localization of Mental Functions**

The study of the neural localization of mental functions is by no means a finished enterprise. Neuroscientists are still in the process of uncovering where mental functions are located in the brain and how they are neurally realized. Nevertheless, the trend has been clear for a long time: the more neuroscience advances, the more we learn about how the brain gives rise to the mind.

### **2.1 Perception and Motor Control**

Neural localization of perception has been perhaps most dramatically demonstrated with respect to vision. Visual processing has been localized to the visual cortex, which can be divided into multiple regions (V1, V2, V2, V4, etc.), which each have specific roles in the processing of incoming information. Most striking perhaps are the ocular dominance columns in the V1 area, which can be visualized via intrinsic optical signal imaging as vivid stripes of regions receiving input from each eye when the mammalian brain is exposed and the subject is alternately shown images to its left and right eye (Bonhoeffer and Grinvald 1996). Interestingly, the development of ocular dominance columns is highly plastic and experience-dependent; if a young animal has one of its eyes sutured shut, the columns corresponding to the occluded eye will not develop.

Following the identification of ocular dominance columns, Hubel and Wiesel made another remarkable discovery. In 1959, they demonstrated that individual neurons in the cat's visual cortex respond to visual stimuli at specific angles. For example, some neurons will respond only to a bar moving across the animal's visual field at an angle of  $0^\circ$ , other neurons to a stimulus at  $10^\circ$ , still others at  $20^\circ$ , and so on (Hubel and Wiesel 1959). Some thirty years later, optical imaging allowed scientists to visualize the areas of the brain in which these directionally sensitive neurons are localized. Bonhoeffer and Grinvald showed in 1991 that these "iso-orientation domains" are located in pinwheel-like structures in the visual cortex, with a  $0^\circ$  domain adjacent to a  $10^\circ$  domain, and so on, with a  $340^\circ$  domain adjacent to the  $0^\circ$  domain, completing the circle (Bonhoeffer and Grinvald 1991). The exquisite sensitivity of the visual cortex is hardly limited to the perception of stimulus orientation, however; for example, specific sub-regions of V1 and V2 have been identified as processing color, brightness and contour (Lu and Roe 2008).

The visual cortex's astounding sensitivity in mapping the external world onto the brain, as dramatic as it may seem, is not entirely unexpected: the scientific understanding of the structural organization of the brain dates well back to the early days of the last century. In 1937,<sup>3</sup> Penfield and Boldrey described a structured mapping of the human body onto the sensorimotor<sup>3</sup> cortex. Stimulation of one area of the sensory cortex led a subject to experience a sensation in their pinkie finger; stimulation of an immediately adjacent area led to sensation in their ring finger, and so on. This led to the concept, often presented visually as a rather horrifyingly distorted cartoon with immense hands, of the "Penfield homunculus" – an image of the human body's topography represented within the brain. The distortion arises from the fact that larger

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<sup>3</sup> Areas of the cortex processing somatosensory and motor information are very close to each other, and are therefore often referred to as the sensorimotor cortex.

areas of the brain are dedicated to receiving input from more sensitive areas of the body (fingers, tongue, genitalia, etc.).

The “homunculus” is now known to be significantly more complex than Penfield originally envisioned, but it remains a cornerstone of both motor and sensory neuroscience (Schott 1993). From the motor perspective, a revealing symptom of some epileptic seizures is the so-called Jacksonian march, in which tremors move through the limbs in the precise order in which those limbs are encoded in the motor cortex; these areas are sequentially activated as the seizure activity moves through the brain. Neurosurgeons use a related concept during intraoperative testing, delivering weak electrical stimuli to areas of the motor cortex in order to precisely localize specific functions prior to surgery.

Highly-localized mapping of the “receptive fields” that respond to precise bodily stimuli can be seen vividly in the so-called “barrel cortex” of whiskered mammals (best studied in the rodents). In these animals, the grid of whiskers maps directly onto a grid of barrel-shaped groupings of neurons in the somatosensory cortex. These cortical structures can be visualized by histological staining or by optical imaging (Masino et al. 1993). More recently, it has been shown that neurons respond selectively to the direction of whisker deflection which may be key to a rodent’s ability to navigate in situations where vision is of little use (Andermann and Moore 2006).

Similar intricate organization is observed in other senses. For instance, the mammalian auditory cortex has been shown by both electrical recording and imaging to consist of regions that respond to different tones. The auditory cortex thus contains a *tonotopic map* of auditory input (Kalatsky et al. 2005).

The sensory and motor maps described above, while extremely intricate, are relatively uncontroversial. Other types of sensory responses are more complex still. They remain the subject of intense scientific debates. The perception of pain (called nociception), for example, appears to involve a number of brain areas, such as the primary and secondary somatosensory cortices (called S1 and S2) as well as the cingulate cortex and the insula. Collectively, these regions are often described as the “pain matrix”. They all appear to be activated in human subjects during the experience of pain, as determined by functional magnetic resonance imaging (fMRI) and other imaging methods (Legrain et al. 2011). Nevertheless, the degree to which these brain areas differentiate between pain *per se* and simply unusual, intense or salient stimuli is not fully resolved. Some studies show that the magnitude of the response in the pain matrix correlates with the amount of pain perceived by the subject. Yet other studies show that non-painful stimuli can cause activity in the same set of brain areas. Legrain et al. (2011) have suggested that the pain matrix might be part of a more complex network of brain areas involved in mediating an individual’s perception of their body and its surroundings.

## 2.2 Memory

The neurophysiology of memory appears to be even more complex than that of pain. How memories are transferred from short-term to long-term memory, and what governs recall of long-term memory, is far from fully understood. What is clear, however, is that the hippocampus plays a key role in short-term memory, memory consolidation, and spatial navigation. This evidence comes from a large number of animal studies and from imaging studies in human subjects.

O’Keefe and Dostrovsky (1971) observed that certain cells in the rat hippocampus fired only when the animal was at a certain location in its environment. This gave rise to the concept

of hippocampal *place cells*, which appear to play a key role in forming cognitive maps of the local environment (Best et al. 2001). The hippocampus also appears to be critical to memorizing new spatial environments, as shown, for example, by the homing pigeon experiments of Bingman and Yates (1992): pigeons with hippocampal lesions were able to navigate by “dead-reckoning”, but were unable to learn how to navigate to and from a new home loft.

The Bingman and Yates study points to the relationship between place and memory, and the two are indeed linked in the hippocampus. A landmark study showed that rats given a maze to learn actually appeared to dream about the maze: hippocampal place cells, which were active as the animals navigated the maze while awake, were re-activated *in the same temporal order* during REM sleep (Louie and Wilson 2001). The rats are thus replaying their waking experience in their dreams by reactivating the precise neural patterns that had been active during the day. This also points to a possible role of sleep in consolidating memories. Other studies also demonstrate the important role of awake “replay” for memory consolidation (Carr et al. 2011).

All of these studies relate to the concept of Hebbian learning, in which neural circuits which are repeatedly activated will grow stronger; neuroscientists often describe this colloquially as “neurons that fire together, wire together” (Cooper 2005). The Louie and Wilson study showed that neurons can practice “firing together” even in an animal’s dreams. Note, however, that it remains unclear whether Hebbian learning can explain the consolidation of long-term, as well as short-term, memories (Arshavsky 2006).

Significant evidence supports the role of the hippocampus in spatial memory in human subjects. A study by Maguire et al. (2000) showed that London taxi drivers have larger volumes of hippocampal gray matter than a group of control subjects. Hippocampal volume has also been shown to correlate with years of driving experience. Moreover, a comparison to London bus drivers, who follow fixed routes on large streets and do not need to memorize the 25,000 streets in the city, do not share this hippocampal enlargement (Maguire et al. 2006). This suggests that the hippocampus is particularly important for complex and detailed spatial navigation. Studies in patients who have experienced hippocampal lesions corroborate the same conclusions: a London cabman who suffered hippocampal damage sustained his ability to navigate the larger ‘A’ roads in the city, but could no longer negotiate the myriad side-streets (Spiers and Maguire 2007).

In contrast to the London data, hippocampally-damaged residents of Toronto – a city with a far more grid-like street layout than London – did not experience significant deficits in navigational ability, and fMRI studies of normal Toronto natives showed no hippocampal activity, but rather activity in other cortical areas, when the subjects mentally navigated a city map (Rosenbaum et al. 2004; Hirshhorn et al. 2011). Combined with the London data, this suggests that the hippocampus is necessary for the processing detailed spatial memories, while coarser-grained memories, initially processed by the hippocampus, are ultimately stored as long-term memories elsewhere in the cortex. The identification of specific locations in the cortex for such coarser-grained spatial memory storage is a topic of current active research (Spiers and Maguire 2007).

### **2.3 Emotion**

The processing of emotional responses may be even more complex than perceptual processing and motor control. A large number of studies, beginning with the pioneering work of Papez (1937a,b), point to brain regions such as the amygdala and the insula as key to the processing and integration of many emotions. Interestingly, these regions lie deeper in the brain,

and are evolutionarily much older, than the neocortex, where the sensorimotor homunculus and other structures discussed in Section 2.1 reside.

Using fMRI studies, the insular cortex has been implicated in major depression (Sprengelmeyer et al. 2011). The insula and amygdala have also been shown to have greater activity in patients suffering from post-traumatic stress disorder (PTSD), social anxiety disorder, and various phobias, as well as in normal subjects experiencing fear (Etkin and Wager 2007). Further suggesting specificity in the complex regulation of emotion, PTSD patients also showed decreased activity in the anterior cingulate cortex and the ventromedial prefrontal cortex, which the other subjects did not. These brain regions have been implicated in the control of emotion, which is often a problem for PTSD sufferers.

It has been known for some time, based both on animal and human studies, that the amygdala is involved in mediating fear. A recent study parses fear even further, differentiating between the brain responses to different *types* of fear. Alvarez et al. (2011) conducted fMRI studies of human volunteers playing a virtual reality game in which they experienced both predictable and unpredictable threats. Subjects showed increased amygdala activity when experiencing predictable frightening conditions, but *also* showed increased activity in their forebrains only when experiencing unpredictable (and therefore far more anxiety-inducing) aversive events. Other recent work has focused on the further separation of the neural circuitry underlying the distinction between anxiety and fear, and on the role of memory in triggering both these emotions, which suggests that the hippocampus is involved (Shin and Liberzon 2010).

While the studies just described focus on negative emotions, not all the research is so grim. A number of recent studies have investigated the brain regions activated in human subjects when viewing loved ones. One study attempted to differentiate between brain regions involved in maternal vs. romantic love (Bartels and Zeki 2004). Another (Zeki and Romaya 2010) studied brain responses when subjects viewed images of their partners (as compared to control pictures of friends to whom they were romantically indifferent), comparing the response of those with same-sex and opposite-sex partners. They found similar brain responses in both groups.

Moving back down the emotional scale, Stoessel et al. (2011) found less activity in unhappy vs. happy lovers in several brain regions (anterior cingulate cortex, posterior cingulate cortex, and insula). And finally, Zeki and Romaya present evidence (2008) that hate activates the medial frontal gyrus, premotor cortex, medial insula, and the right putamen. These must be considered preliminary studies, however, given that the neural processes they involve are exquisitely multilayered and complex.

While all evidence points to neural localization of mental functions, we remain a long way from understanding how Keats was able to compose "*Bright star! Would I were steadfast as thou art...*" or Coleridge found these words to express depression: "*A grief without a pang, void dark and drear / A stifled, drowsy unimpassioned grief...*" For starters, writing poetry requires not only emotion but also language.

## 2.4 Language

The neural substrates of language have been studied carefully since the 19<sup>th</sup> century. Following Joseph Gall's unsuccessful attempts at the cerebral localization of mental functions via "phrenology", a series of astounding discoveries sparked a revolution in our understanding of neural localization of mental activity. These discoveries centered on the cortical areas responsible for processing language. In 1861, Broca identified two patients with lesions in the region of the temporal lobe now known as Broca's area. These patients could utter a few words,



but were incapable of assembling sentences. Yet they both retained language comprehension and attempted to make themselves understood through gestures. The inevitable conclusion (confirmed by a host of later studies, including observations of patients with strokes in this brain region) was that Broca's area was involved in the assembly of words into coherent grammatical structures.

A decade later, Wernicke identified another group of patients with a complementary neurological problem: they could talk grammar ad nauseam, but had immense difficulty finding the right words. They would use the wrong word in the wrong place, or invent words entirely. They retained grammar, but not meaning. Unlike Broca's patients, these appeared unable to comprehend the speech of others around them. Subsequent autopsies showed that they all suffered from damage to a brain area adjacent to Broca's, now called Wernicke's area. (For vivid descriptions of these studies, see Schiller 2002 and Pinker 2000.)

In the years since the work of Broca and Wernicke, data have continued to accumulate indicating that the temporal region of the brain plays a key role in language processing. Specific regions and sub-regions clearly mediate specific aspects of language construction and comprehension, but how all these areas are integrated together remains a puzzle. The range of examples of mental localization of different pieces of the language puzzle touch the imagination even more than some of the visual cortex studies described above, perhaps because language is so uniquely human. In another jarring example of brain specificity, Ojemann (1991) showed that direct electrical stimulation of precise regions of the language cortex could disrupt an individual grammatical function, such as the naming of objects. However, the location of these regions did not appear to be as neatly organized as the "homunculus" studied by Penfield, and varied from one patient to the next.

The current literature involving studies of language processing is vast. To consider one example in detail, let's turn to the problem of what you are doing now: reading. Reading obviously involves the language areas of the brain, but must also involve visual processing. Wernicke originally hypothesized that the visual system had only a minimal role in reading, capturing the raw data of the word forms and immediately sending them to the language areas for more detailed processing. But more recent studies suggest that a region within the ventral occipitotemporal (VOT) cortex, located near the visual areas we visited in section 2.1, does more than just "capture the images of words" (Wandell 2011).

Based on fMRI and electrophysiological studies, Dehaene and Cohen have suggested that an area they call the visual word form area (VWFA), located in the VOT cortex, is "tuned to reading-specific processes" (Dehaene and Cohen 2011). The left VWFA (typically on the left side since the left brain is language-dominant in most humans) has been shown to be consistently activated during reading. This area is the first cortical location to be activated when a human subject is exposed to words that look different in upper vs. lower case (Dehaene et al. 2001, 2004). The area is activated regardless of whether the text is printed or handwritten (Qiao et al. 2010) and is even activated when blind subjects read in Braille (Reich et al. 2011), suggesting that it is involved in perceiving shapes regardless of the modality in which they are initially presented.

This point is critical when one considers how an area such as the VWFA might have been recruited to play a dominant role in reading. This brain region has been also shown to be involved in processing of shapes and contours in the environment, as well as in the recognition of faces (Mei et al. 2010). While some authors have argued that this indicated that the VWFA is thus proven to be "not specific" for reading, Dehaene and Cohen (2011) make an interesting

counterargument. They suggest that the VWFA is a region of the brain originally evolved for other tasks (such as shape, contour and face recognition), which has been “recycled” for use in processing words. They point out first that the development of reading in human society has been far too recent for a reading-specialized area to have actually evolved; indeed, it has only been in the last few hundred years at most that a majority of some human populations have been readers, and thus it is within this time span, rather than thousands of years since the invention of reading by elites, that any reading-related genes could have begun to be selected for in the human gene pool. Thus if we read, it can only be by recycling brain areas originally evolved for other tasks.<sup>4</sup> Now, note that most of the symbols used in human writing systems involve shapes and contours similar to the structures we see in daily life (Changizi et al. 2006). This is likely no accident: it is natural for humans to appropriate familiar shapes and structures as symbols. If that is a natural process, however, what could be a more natural location in the brain for our invented symbols to be processed than the areas where their natural symbolic cousins are already processed?

How is the information which appears to receive some degree of pre-processing in the VWFA passed to the language areas? The route connecting these regions is not completely known, in part due to limitations on brain imaging techniques. It is only recently that techniques like diffusion tensor imaging (DTI), which allows imaging of white matter (axon) tracts connecting brain regions, have been available. Preliminary results suggest that the VWFA may connect to other language areas through pathways in the corpus callosum, the area that also connects the two brain hemispheres. Another important question, not yet answered, is the degree to which information travels as feedback *to* the VWFA *from* the language areas. A host of similar questions will arise if we begin to ask how the auditory cortex communicates with language areas and aids in the processing of spoken language (say, in responses to poetry vs. prose, or to song). This area is under intense investigation; a recent review of studies of the “architecture” of the language cortex turned up 100 articles published in 2009 alone (Price 2010).

## 2.5 Thinking

Some of the neural processes we have already described, such as the complex processing of visual and semantic information that occur when we read and understand language, may be classified as “thinking”. Likewise, some of the hippocampal processes involved in memory when taxi drivers navigate through the winding streets of London may be called “thinking”. Needless to say, thinking—what scientists call higher cognitive functions—includes a lot more.

Three things are clear: first, thinking often occurs through the integration of various processes taking place within different neural structures; second, we are far from a detailed understanding of the neural structures and processes involved in the many different types of thinking; third, our current evidence and scientific knowledge supports the conclusion that thinking is a product of the brain.

In this section, we will describe a number of recent studies that shed light on which brain areas are involved as human subjects process various types of information. The field of research is immense (see Kanwisher 2010); our examples are far from exhaustive and are merely intended to give the reader a feeling for the current range of topics being experimentally studied.

A large number of studies have investigated the neural processes involved in object recognition. Among recent examples, EEG (Philiastides and Sajda 2006) and fMRI (Heekeren et

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<sup>4</sup> This argument would not necessarily hold for brain areas such as Broca's and Wernicke's, since spoken language arose in human societies far in advance of written writing systems.

al. 2004) studies have investigated how human subjects discriminate between images of variable blurriness representing objects (cars, houses) or faces; the dorsolateral prefrontal cortex appears to be one of the primary brain regions involved in such tasks in humans and also in other primates (Kim and Shadlen 1999). Such studies allow the investigation of visual recognition and also of decision-making processes, as subjects must decide whether the image they are viewing is a face or not. (Note that other studies have identified a region in the primate cortex consisting entirely of cells sensitive to face-recognition (Tsao et al. 2006).)

Other recent studies have investigated even more specifically the brain areas involved in particular styles of thinking, logic and problem-solving. For example, a recent fMRI study by Wendelken and Bunge (2010) showed that the rostralateral prefrontal cortex is strongly activated when subjects perform tasks that require relational integration. Bonnefond and Van der Henst (2009) have shown that different EEG patterns correspond to subjects' response to different temporal sequences of cognitive steps when reasoning by inference. Krawczyk et al. (2010) have identified particular areas of the prefrontal cortex involved in reasoning by analogy.

Another group of scientists has taken the problem of the neural basis of decision making in a different direction, investigating how the brain functions during "economic" decision making. The ventromedial prefrontal cortex (VFM) has been implicated in decision-making under conditions of economic uncertainty, as when subjects are given a gambling task (Bechara et al. 1999). A more recent study suggests that damage to the VFM may even impair the ability to make decisions that do not involve risk or ambiguity (Fellows and Farah 2007). Damage to the VFM has also recently been shown to impair decisions that involve the maximization of value (Camille et al. 2011). Another study suggests that the insular cortex, as well as the VFM, is involved in economic decision making. Clark et al. (2008) found that patients with insular lesions had difficulty, during a gambling task, adjusting their bets as the odds of winning changed. These studies form part of a growing field now called "neuroeconomics" (Hasler 2011).

Wright et al. (2011) have investigated how the human brain deals with value judgments of a different kind, though still in an economic context. They imaged brain activity during subjects' evaluation of the fairness of different situations. In this case, subjects participated in a variant of the so-called "ultimatum game", in which subjects offered to split a sum of money, and the first subject had to decide whether or not to accept the proposed split. The study was designed so that certain offers would appear more or less fair depending on the context. For example, a poor or unfair offer (a proposed 10% - 90% split, for example) might be made within a string of other poor offers, or might be interspersed among offers of a fairer 40% - 60% split. Wright et al. found that the perception of such social inequality corresponds to activity in the posterior insular cortex, and also with the subjects' perception of social context, which is processed in the posterior and mid insula. Thus the subjects' perception of fairness appears to be calibrated to the social environment.

Turning now from neuroeconomics to neuroaesthetics -- yes, there is such a field (Di Dio and Gallese 2009) -- it should come as no surprise that the visual cortex is activated during viewing of paintings, sculpture or architecture. Many other brain areas are involved as well, such as the face-recognition regions when viewing representational rather than abstract art. But other recent studies have addressed the involvement of somewhat less obvious brain regions in the process of viewing visual art. Cupchik et al. (2009) demonstrated the activation of the insula, suggesting a substrate for the emotional response to art. They also observed the activation of the

prefrontal cortex, suggesting a top-down attentional control as a person focuses on a work of art (see Section 2.6 for more on attention).

From a more practical perspective, Long et al. (2011) noted increased activation of color-selective areas in painting students vs. students majoring in other fields. Perhaps most curious of all is a recent study by Lacey et al. (2011), which demonstrated that viewing art activated the ventral striatum, a key node in the brain's reward circuitry. Interestingly, these areas were activated whether or not the subjects liked the works of art they were viewing: the activation seemed to be triggered by awareness of artistic status alone, independent of the viewer's aesthetic preference. Lacey et al. (2011) also observed activation of the orbitofrontal cortex, which other studies have shown to be preferentially activated by viewing images perceived as beautiful rather than ugly (Kawabata and Zeki 2004), and to be activated proportionally to the aesthetic rating a subject gives to a viewed image (Kirk 2008).

Bringing us back full circle to neuroeconomics, Lacey et al. (2011) note that the ventral striatum is also the reward center activated when human subjects view objects associated with wealth, such as sports cars, and that ventral striatum activity also "correlates with product preference and predicts purchasing decisions". This suggests a neural substrate for the so-called "art infusion" effect, where advertising elicits a stronger response when it employs artistic images. Can neuromarketing be far behind? In fact, it has already arrived (Plassman et al. 2007).

As these examples illustrate, complex brain processes involving many different functions have been studied in great depth. The examples merely skim the surface of a vast literature. There are studies of the brain's response to music, involving complex brain networks extending far beyond the auditory cortex (Janata 2005), and of how the brain processes mathematical concepts with increasing finesse as it matures (Rosenberg-Lee et al. 2011). A search through scientific research databases such as the NIH-maintained PubMed (<http://www.ncbi.nlm.nih.gov/pubmed>) yields thousands of studies of how the brain carries out various "thinking" tasks.

## **2.6 Attention and Consciousness**

One of the most challenging questions in neuroscience concerns the neural basis of consciousness. Is consciousness localized to a particular neural structure or does it involve many structures? Of course, consciousness is a somewhat nebulous notion. Defining "consciousness", let alone localizing it, would require many volumes to do it justice.

Within these few inadequate pages, we will understand consciousness to be the difference between the way we feel when we are normally awake or dreaming—when we undergo conscious experience—and the way we (do not) feel when we are in a non-dreaming sleep, fainted, or a coma—when we experience nothing. Current evidence suggests that consciousness arises from the coordinated activity of many brain structures in specific functioning modes.

The more specific question of identifying the mechanisms by which the brain "pays attention to something", or how it "shines the light of consciousness" on a particular experience has been the subject of illuminating experimental study. To begin with, it is important to realize that we are aware of only a small portion of our experience at a time. To a large extent, we operate in what neuroscientists call "zombie mode" (Koch and Crick 2001). Were you aware of locking your door when you left for work this morning? When you type, are you aware of deliberately and consciously orchestrating every keystroke? These processes are controlled by the brain, but they rarely rise to the surface of consciousness, and, in the case of some processes, it is far better that they don't, since automatic processes can become much less efficient, and in

some cases impossible, if we try to perform them in a deliberate, self-conscious way. If we often do things without paying attention, consider the neural basis of *attention*.

In the past decade, a large number of studies have found that an increase in gamma oscillations (~40 Hz) in the cortex correlates with an increase of attention to a particular subject or task. Fries et al. (2001) showed that individual neurons in the V4 region of the macaque monkey's visual cortex showed increased firing rates in the gamma range when they attended rather than ignored particular visual stimuli. Soon afterward, Tallon-Baudry et al. (2004) showed a similar result in human epileptic patients, in whom electrodes had been implanted as part of pre-surgical screening. Subsequent studies have shown correlations between attention and increased gamma-band activity correlating with attention in the human auditory and somatosensory cortices as well (reviewed in Womelsdorf and Fries 2007). It has also been shown that gamma-band activity also plays a role in both short- and long-term memory (Jensen et al. 2007). Gamma activity has been implicated in selective attention, implying a voluntary, top-down rather than reactive, bottom-up role for these oscillations (Fell et al. 2003). Gamma-band oscillations have also been hypothesized to play a role in another key issue in perception, the binding problem (Fell et al. 2003), which refers to the means by which the mind associates different attributes, sometimes of different sensory modalities, with a single object.<sup>5</sup>

The studies described above indicate that the 40 Hz oscillations can occur in various regions of the cortex depending on the current object of attention. Could these oscillations, then, constitute what it takes for a mental state to be consciously experienced? This idea might at first appear intriguingly attractive, especially in light of the *dynamic core hypothesis* for consciousness proposed by Tononi and Edelman (1998). They define the dynamic core as a cluster of groups of neurons that, firing in a coordinated way on a timescale of hundreds of milliseconds, correlates with consciousness. The term "dynamic core," they emphasize, does not refer to an invariant brain area (or areas), but rather can change composition over time, weaving and unweaving itself in the brain.

As attractive as it might be to identify the dynamic core with 40 Hz oscillations, Crick and Koch (2003) make a strong argument that attention is not sufficient for consciousness. Their framework for a neural theory of consciousness posits "coalitions" of neurons that function in a similar way to the neurons participating in the dynamic core suggested by Tononi and Edelman. Like the dynamic core, the coalitions of neurons in which consciousness is localized are variable, malleable, and constantly in flux. Moreover, Crick and Koch emphasize that there may be multiple such coalitions which compete with each other for precedence in our experience, trying to rise to the surface of consciousness. They suggest that coalitions in the frontal cortex may be more involved in a "top-down" experience of authorship of and agency over one's choices and actions, while coalitions in the back of the cortex may be more involved in sensory experiences. In this view, attention might consist of increased oscillations of neurons participating in a coalition, thus biasing the competition toward that particular coalition. However, such oscillations might not always be needed, for example when the visual input is quite simple (e.g., one salient object in an otherwise empty space). Likewise, once a coalition has, so to speak, risen to dominance at the surface of consciousness, it might be able to remain there for some time without the need of synchronized oscillations to help it compete with other coalitions.

As complicated as all this sounds, note that the discussion thus far in this section has concerned structures only within the cortex. The thalamus and thalamocortical connections also

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<sup>5</sup> An example would be the "binding" in your perception of the shape of the cat moving toward you, its black color, and the sound of its meow.

play important roles in mediating attention (Tononi and Edelman 1998, Mayo 2009). Also important in regulating key aspects of consciousness are various reticular structures, such as the thalamic reticular nucleus (TRN) and the midbrain reticular formation (MRF). These structures are essential for functions such as mediating the sleep-wake cycle; bilateral lesions in these nuclei can cause complete loss of consciousness (Koch 2008). Indeed, the TRN was initially thought to play a sufficiently important role in mediating attention that Crick suggested in 1984 that it was the site of the “internal attentional searchlight”, prior to developing his more cortically-based models of NCC with Christof Koch (Pinault 2004).

The idea of reticular structures playing a role in attention and consciousness goes back almost a century, and highlights the multilayered complexity of the brain’s control over its own arousal. Studies by von Economo following the 1918 influenza pandemic showed that patients suffering from encephalitis lethargic, which left them in a permanently drowsy state, had experienced a loss of cells in the midbrain reticular formation.

Later studies by Moruzzi and Magoun showed that damage to another reticular area, adjacent to the one identified by von Economo, could induce the inability to sleep. This led to the identification of the so-called reticular activating pathways,<sup>6</sup> which play a crucial role in regulating the sleep-wake cycle (Siegel 2004). The identification of these reticular pathways, in particular the ascending reticular activating system (ARAS), with the control of *wakefulness*, led Penfield and Jasper, in the 1950s, to infer that the ARAS was also the brain area that controlled *consciousness* (Hudson 2009).

Subsequent studies, such as those described above, have shown that the mediation of consciousness is far more complex than the picture envisioned by Penfield and Jasper. In particular, consciousness and attention appear to require significant involvement of the cortex, not just the reticular structures in the midbrain. A simplistic summary of the situation might be described in the following terms: *arousal* of the brain is mediated by the ARAS, but *awareness* is mediated within the cortex. The ARAS could be considered, then, as necessary but not sufficient for consciousness.

These issues have important medical implications with regard to definitions of brain death. Current definitions of brain death generally define it as permanent and irreversible damage to the brainstem, which includes the reticular formation. Patients with severe damage to the cortex and other neural structures, but with brainstem and reticular formation intact, can often still breathe on their own, and do maintain a sleep-wake cycle. These patients are said to be in a vegetative state, which the public often conflates, incorrectly, with brain death (Laureys 2005).

## 2.7 Spirituality

A connection between spiritual or “transcendent” experience and temporal lobe function has been known to neurologists for some time. Interestingly, much of this evidence comes from studies of epileptic seizures. As many readers of Dostoevsky know, seizures can occasionally be preceded or accompanied by an “ecstatic” feeling rather than painful or disturbing symptoms; Dostoevsky described this in vivid detail in recounting the experiences of his character Prince Myshkin in *The Idiot*, drawing on his own experiences with epilepsy.

Electroencephalographic (EEG) studies of epilepsy patients in more recent years have localized such “ecstatic” seizures to the temporal lobe. In 1983, Persinger suggested that

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<sup>6</sup> The TRN is a part of the reticular system, but located more rostrally than the midbrain structures studied by von Economo.

religious and mystical experiences in general might be artifacts of temporal lobe microseizures (Persinger 1983). More recently, a wealth of brain imaging studies have complemented the early EEG studies, confirming the temporal localization of such events (Åsheim Hansen and Brodtkorb 2008). Other studies suggest that mystical experiences are not solely localized to the temporal lobe, however, and that they may involve a large and complex network of activations in the brain. Urgesi et al. (2010) found that lesions in the inferior posterior parietal regions led to a feeling of “self-transcendence” in patients.

Against the background of these studies of the relation between spiritual experience and brain pathology, a number of recent studies have directly set out to investigate the brain areas activated during spiritual experiences in healthy subjects. Beauregard and Paquette (2006, 2008) performed fMRI and EEG studies of Carmelite nuns reliving mystical experiences they had in the past. The authors noted that since (as the nuns informed them!) mystical experiences cannot be summoned at will, they asked their subjects to visualize their most mystical experience; as a comparison condition the subjects were also asked to visualize their most intense connection with another human being, and, as a control (baseline) condition, to sit quietly with their eyes closed.

In the EEG study, Beauregard and Paquette found increased theta (8-12 Hz) activity in the frontal cortex during the “mystical” condition, as well as increased gamma (30-40 Hz) activity in the temporal and parietal regions. (Recall that EEG activity in the gamma range has been associated with attention and consciousness, as discussed above in Section 2.6.) In the fMRI study, increased activity during the “mystical” condition was observed in a large network of brain areas (right medial orbitofrontal cortex, right middle temporal cortex, right inferior and superior parietal lobules, right caudate, left medial prefrontal cortex, left anterior cingulate cortex, left inferior parietal lobule, left insula, left caudate, and left brainstem). This is consistent with the idea that certain complex and multimodal mental processes involve the organized cooperation of many brain structures.

In parallel with the studies of mystical or religious experiences just described, a number of studies have been conducted in recent years on the neural correlates of another spiritual practice: meditation. Here, the actual experience itself, rather than a memory of it, can be induced during EEG recording or even (for those focused meditators who can tune out the loud noise of an fMRI machine) during brain imaging. These studies have shown a wide range of brain areas, including frontal regions (which involve attention) and temporal / limbic regions (which involve emotion) to be activated during meditation.

For example, an fMRI study by Wang et al. (2011) studied the differences in brain areas activated in experienced meditators participating in different kinds of meditation (focus-based vs. breath-based). They found that the frontal cortex and anterior cingulate cortex, as well as the limbic system and parietal lobes (i.e., areas involved in both attention and emotion) were activated in both meditation states, but that the patterns of activation differed between the two meditative techniques. They also observed a correlation between (self-reported) depth of meditation and the degree of activation of certain brain areas, and found that activation in areas such as the anterior insula persisted even after the meditation was over.

Other studies have shown that alpha (8-12 Hz) and theta activity during meditation increases with proficiency of meditative practice (Cahn and Polich 2006). Another recent study compared Theravada Buddhist monks with lay novices (Manna et al. 2010). The authors found far more activity in the practiced monks than the novices during meditation, noting that the

monks were able to dramatically *self-regulate* the activity of their fronto-parietal and left insular areas.

Turning to general religious practices, as opposed to specific spiritual experiences, Kapogiannis et al. (2009a) found that an increased volume of right middle temporal cortex was involved in the experience of an intimate relationship with God, while an attitude of pragmatism and religious skepticism correlated with increase volume of the right precuneus. An fMRI study (Kapogiannis 2009b), however, pointed out that many of the brain areas involved in processing specific components of religious belief are also involved in processing of social cognition (e.g., “theory of mind”). This suggests possible evolutionary origins of the brain processes underlying religious belief: such beliefs may have co-evolved with other aspects of human sociality (Culotta 2009).

Harris et al. (2008, 2009) have investigated the interaction between religious perceptions and cognitive processes separate from social cognition, focusing on brain activations in response to propositions to which subjects respond with belief, disbelief or uncertainty. They found that activation of the anterior cingulate cortex and caudate seems key to the difference in brain response to propositions which can be evaluated as true or false, compared with those to which a subject responds with uncertainty (Harris et al. 2008). The perception of the distinction between the truth or falsity of a proposition appears to involve the medial prefrontal cortex and the anterior insula. Noting the role of the insula in mediating the feeling of disgust, Harris et al. (2008) note ironically that “truth may be beauty, and beauty truth, in more than a metaphorical sense, and false propositions may actually disgust us”. Harris et al. (2009), in an fMRI study of fifteen Christians and fifteen non-believers, demonstrated that brain responses to belief and disbelief appear to be independent of context: the ventromedial prefrontal cortex was activated in both subject groups when they evaluated statements they believed to be true rather than false.

Once again, the current neuroscience of spirituality is just the beginning of the story. Much remains to be understood about how the brain gives rise to our mental life—especially when it comes to experiences as rare and complex as spirituality. Some studies can only show little more than which neural structures are activated when certain experiences take place. Nevertheless, many other studies—especially, for ethical reasons, animal studies—show that specific mental functions are carried out by specific (networks of) neural structures, and there is no reason to expect exceptions to this rule. All the evidence points in the same direction: mental functions are a manifestation of the brain.

### **3. Objections**

Like every philosophically interesting conclusion, the thesis that the brain is the seat of the mind has encountered objections. We’ll address some prominent ones.

#### **3.1 Linguistic Dualism**

Some philosophers are fond of pointing out that, in our ordinary discourse, we typically attribute mental states to (whole) persons not their brains (Bennett and Hacker 2003). From this, they infer that attributing mental states to the brain is a category mistake. This objection cuts no ice for two reasons.

First, the objection is a non sequitur. Just because we typically attribute mental states to whole persons, it doesn’t follow that mental states are located somewhere other than the brain.



Consider that, in our ordinary discourse, we also attribute to whole persons all kinds of states and activities that we have no trouble locating in specific parts of their body. People breathe air, digest food, and excrete waste. Still, there is nothing wrong with locating those activities in specific parts of their bodies and explaining those activities by the action of those specific parts. By the same token, there is nothing wrong with attributing mental states and activities to the brain (or parts thereof) and explaining them by the action of the brain.

The second reason to dismiss this objection is that, even if it were sound, it would do nothing to establish that there are nonphysical minds let alone an afterlife. Even if for some reason we should reserve ordinary mentalistic language for whole persons as opposed to their brains (something that there is actually no good reason to hold), it wouldn't follow that persons have a nonphysical mind.

### 3.2 Mere Correlation

Some authors argue that neuroscience establishes at most correlations between mental functions and neural structures (e.g., Robinson 2011). It does not and cannot *explain* mental functions or establish that mental functions are *manifestations of* neural structures. But, these authors argue, only the latter claim rules out a nonphysical mind. A mere correlation does no such thing. A nonphysical mind may even be located *within the same spatial location as* the brain. So even if we are right that mental states are located in the brain, all this means is that they are located inside the spatial region that also contains the brain. All of this is compatible with mental states belonging in a nonphysical mind.

This objection is bolstered by the tendency among some neuroscientists to claim that they are searching for the neural *correlates* of consciousness. If neuroscientists themselves admit that they are merely looking for correlates, surely correlates is the best they can find. But neuroscientists' talk of neural correlates is just a terminologically unfortunate way of avoiding the sticky metaphysical debate about the exact relationship that obtains between consciousness and the brain (more on consciousness below); it should not be construed as leaving room for substance dualism. Properly understood, the neuroscience of consciousness is searching for the neural basis of consciousness just as much as the neuroscience of any more specific mental function is searching for its neural basis. Thus, neuroscientists' talk of neural correlates provides no support for the "mere correlation objection".

This objection misconstrues what it takes to show that a phenomenon is the manifestation of a given structure. Consider, say, the weather. Meteorological phenomena used to be explained by the intentions and actions of immaterial beings such as spirits and gods. Eventually, those explanations were ruled out in favor of physical forces acting on physical media throughout our atmosphere. Or were they? Someone might object that all that physicists and meteorologists established is a correlation between the physical properties of the atmosphere and the weather. It doesn't follow that there are no immaterial spirits at work.

Or consider epilepsy. Ironically, epilepsy is mentioned by a proponent of the "mere correlation objection" (Robinson 2011, 62-3), who misses the way the history of epilepsy undermines his very objection. Epileptic seizures used to be explained by demonic possession. Nowadays, they are explained by excessive synchronous neuronal activity. By the "mere correlation objection," it should be concluded that the neural explanation of epilepsy is actually a mere correlation that does not rule out demonic possession.

The point of these analogies is to show how ludicrous the "mere correlation objection" is. True, explaining a phenomenon naturalistically does not rule out the involvement of spirits. But

first, this doesn't mean that no genuine explanation—a mere correlation—is provided. Naturalistic explanation may well be partial or sketchy (explanation by spiritual intervention is even sketchier, by the way), but it's perfectly legitimate explanation. Second, once it's empirically established that certain concrete structures are sufficient to generate the observed phenomena, *there is no longer any need* to postulate nonphysical agents at work. The phenomena themselves are now understood as the action of concrete structures. The burden of proof has been shifted to those who wish to postulate nonphysical agents. And since the evidence that they used to invoke (i.e., the phenomenon, which used to be otherwise unexplained) has just been taken away by the existence of an empirically supported naturalistic explanation, they are left with no empirical support.

The situation with respect to mental phenomena is analogous to the situation with respect to meteorological phenomena, epilepsy, and any other phenomenon that has been naturalistically explained, including other physiological phenomena such as blood circulation, respiration, and digestion. When we discover that digestion is a function of the stomach, intestine, and other digestive organs, we are not left wondering whether we've left out some nonphysical factor that is involved in digestion. By the same token, when we discover that mental phenomena are produced by neural structures, any previously assumed support for a nonphysical mind thereby vanishes.

If anything, we have a more fine grained ability to intervene and experiment with the brain than with the weather. We cannot change the weather, but we can produce specific mental events by exquisitely precise manipulation of neural structures. The ability to manipulate variables within a system is our most secure source of causal knowledge (cf. Woodward 2003). Thus, our evidence for the neural basis of mental functions is even stronger than our evidence for the physical basis of the weather.

A last ditch attempt at salvaging the nonphysical mind might go as follows: ok, so the brain can do the job of the mind, but nevertheless there is a nonphysical mind that can also do the same job, and *it* can exist without the brain (cf. Dilley 2004). Reply: why on earth do we need to postulate such a nonphysical mind, besides wishful thinking? This desperate move is ruled out by the No Wishful Thinking Principle.

Much remains to be discovered about where exactly specific mental functions are localized and how they are carried out. The situation is analogous to the way in which much remains to be understood about how exactly specific weather phenomena come about. There is no reason to believe that anything but the nervous system (*mutatis mutandis*, the physics of the atmosphere) needs to be invoked to explain mental phenomena (the weather).

### **3.3 Neural Plasticity**

The brain is constantly reorganizing itself. Existing neural structures are always in the process of learning and fine tuning their response properties. Even more impressively, when a brain structure is damaged and some mental functions are thereby lost, it is often possible for those mental functions to be restored by recruiting or reorganizing other parts of the brain. Someone might argue that this type of neural plasticity shows that the original neural structures were inessential to the mental functions that used to be lost (cf. Braude 2005). Therefore, this objection concludes, neural functions are not localized in specific neural structures after all.

This objection is based on a misunderstanding and is ultimately self-defeating. We never claimed, nor does our argument require that we claim, that the neural basis of each mental function always stays the same. On the contrary, neural plasticity is more evidence for our

conclusion. For neural plasticity shows that at all times mental functions are the manifestation of some neural structure or another. The fact that changes in mental functions—including the loss and restoration of mental functions—are the result of specific changes in neural structures shows once again that the mind is a function of the brain.

An anxious dualist might attempt to reply that neural plasticity cannot be explained in neural terms alone. The reorganization of brain structures that results in the restoration of lost mental functions must be the result of the nonphysical mind's action on the brain. The nonphysical mind must somehow (without conscious awareness, of course) direct brain re-growth and reorganization to allow mental functions to be “expressed” again.<sup>7</sup>

Needless to say, there is not the slightest shred of empirical evidence supporting the above conjecture. All the evidence on neural plasticity points at the amazing ability of the brain to reorganize and restructure itself (Wang and Sun 2010). The claim that neural plasticity is the effect of a nonphysical mind is on a par with the claim that god preserves our body upon death: wishful thinking, which there is no need to take seriously.

### 3.4 Intentionality

Mental states have the remarkable ability to represent. You can think about your mother, you can think that your mother makes a good pie, and you can even think that your mother makes a better pie than your fairy godmother. This ability to think *about* things—to *represent* them—goes under the name of intentionality. Some authors argue that intentionality cannot be explained naturalistically (in a way consistent with our argument). Therefore, intentionality must be due to the nonphysical mind at work.

There are three problems with this objection.

First, the dualist “explanation” of intentionality in terms of a nonphysical mind does not actually explain anything; it is just the postulation of a putative entity that is capable of intentionality but says nothing about how such an entity achieves intentionality. Therefore, even if the physicalist were completely unable to explain intentionality, the dualist would not have any advantage here.

Second, during the last three decades considerable progress has been made in developing naturalistic explanations of intentionality. While there is no room to review them here, suffice it to say that there are now imperfect yet plausible naturalistic sketches of how intentionality might come about (e.g., Rupert 2006).

Third, cognitive neuroscience is replete with findings of neural structures that represent various aspects of the world. The type of neural representation that is commonly invoked in the neurosciences may not amount to full-blown intentionality, but it goes at least somewhat in the direction of explaining it.

The bottom line is that intentionality is surely hard to explain, but naturalists are much farther along in explaining it than dualists are. Therefore, intentionality is no reason to postulate a nonphysical mind.

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<sup>7</sup> “Expressed by” is the dualist’s term for the relation between mind and brain, not to be confused with what we mean by “localized within” or “being the manifestation of”.

### 3.5 Phenomenal Consciousness

Some authors argue that phenomenal consciousness—the qualitative character of consciousness—cannot be explained naturalistically. Therefore, phenomenal consciousness must be due to a nonphysical mind at work.

As in the intentionality case, the dualist “explanation” doesn’t actually explain anything. It just postulates a nonphysical mind for which there is no independent evidence without saying how the nonphysical mind achieves phenomenal consciousness. As in the intentionality case, some good metaphysical work can go a long way in addressing these concerns, although opinions vary (Velmans and Schneider 2007, Part III). And again, neuroscience has made considerable progress that can help at least in some respects (Section 2.6). The bottom line is the same as in the intentionality case: phenomenal consciousness affords no advantage to the dualist.

### 3.6 Subjectivity

Some authors argue that mental states are subjective (there is a way it is like to be in them) whereas neural structures and their states are objective. Therefore, mental states cannot be manifestations of neural structures and must be states of a nonphysical mind.

This is a straightforward non sequitur. If mental states are manifestations of neural structures, as the evidence overwhelmingly suggests, then some manifestations of neural structures have a subjective dimension; there is a way it is like to be in them.

### 3.7 Self-Knowledge

Some authors argue that mental states are known directly, privately, and with a special authority (e.g., Lund 2009, 37). Neural structures and their states are not known that way. Therefore, mental states cannot be manifestations of neural structures and must be states of a nonphysical mind.

This is another non sequitur. Let’s assume for the sake of the argument that some mental states are known directly, privately, and with a special authority and that under ordinary circumstances neural structures and their states are not known in that way. If mental states are manifestations of neural structures, as we’ve been arguing, then there are circumstances in which at least *some* manifestations of neural structures are known directly, privately, and with a special authority. None of this is a reason to postulate a nonphysical mind.

### 3.8 Free Will

Some authors argue that human beings have free will and this is incompatible with their mind being fully realized in the brain. For the brain is a physical structure beholden to natural laws and thus cannot give rise to free will. Therefore, the mind must be nonphysical.

This objection begs the question. If free will is incompatible with the mind being realized in the brain, so much the worse for free will. But in fact, it is more plausible that the kind of free will that is worth having is due to the action of our brain (e.g., Dennett 2003).

## 4. Conclusion

Mental functions are located in the brain—that is, mental functions are the manifestations of neural structures. Therefore, without functioning neural structures, mental functions cannot be performed. When the brain dies, neural structures cease to function. Therefore, there is no mental life after brain death. Any supposition to the contrary is wishful thinking.

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