The Cartesian Folk Theater:

People conceptualize consciousness as a spatio-temporally localized process in the human brain.

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Abstract

The present research (total *N* = 2,057) tested whether people's folk conception of consciousness aligns with the notion of a "Cartesian Theater" (Dennett, 1991). More precisely, we tested the hypotheses that people believe that consciousness happens in a single, confined area (vs. multiple dispersed areas) in the human brain, and that it (partly) happens *after* the brain finished analyzing all available information. Further, we investigated how these beliefs are related to participants' neuroscientific knowledge as well as their reliance on intuition, and which rationale they use to explain their responses. Using a computer-administered drawing task, we found that participants located consciousness, but not unrelated neurological processes (Studies 1a & 1b) or unconscious thinking (Study 2) in a single, confined area in the prefrontal cortex, and that they considered most of the brain *not* involved in consciousness. Participants mostly relied on their intuitions when responding, and they were not affected by prior knowledge about the brain. Additionally, they considered the conscious experience of sensory stimuli to happen in a spatially more confined area than the corresponding computational analysis of these stimuli (Study 3). Furthermore, participants' explicit beliefs about spatial and temporal localization of consciousness (i.e., consciousness happening after the computational analysis of sensory information is completed) are independent, yet positively correlated beliefs (Study 4). Using a more elaborate measure for temporal localization of conscious experience, our final study confirmed that people believe consciousness to partly happen even after information processing is done (Study 5).

Keywords: Cartesian Theater; Neuropsychology; Consciousness; Lay Theories; Philosophy of Mind

Introduction

Questions about the nature of consciousness have puzzled the minds of scholars for centuries, from philosophers such as Aristotle and René Descartes to modern-day neuroscientists and experimental psychologists. While experts are preoccupied with what has been coined the "hard problem" of consciousness—that is, how physical matter can give rise to conscious experience—little is known about how do lay people explain and conceptualize consciousness. What are lay people's intuitions about where and when consciousness happens, and do they view consciousness as distinct from other psychological processes?

Psychologist frequently invoke the metaphor of people as lay scientists, who generate hypotheses about the world and gather supporting or contradictory evidence for these hypotheses through observation or mental simulation (Gopnik & Meltzoff, 1997; Gopnik & Wellman, 1992). Given that lay people's observation of the world typically involves conscious experience of these observations, it is rather surprising that (with a few exceptions) little is known about specific belief systems that lay people have about the nature of consciousness. Therefore, in the present article, our goal was to investigate which neuropsychological beliefs people hold about consciousness. Specially, we focused on two lay beliefs that roughly correspond to what Dennett (1991) referred to as a belief in a (neurological) "Cartesian Theater": The belief that consciousness happens in a single location in the human brain and that conscious experience happens *after* the brain is done computing all relevant information. In addition, we sought to determine where precisely in the brain people would locate consciousness, as well as possible rationales that may underlie their responses.

The "Cartesian Theater"

One of the most influential philosophers discussing the nature of consciousness was the French philosopher René Descartes, who argued that although the material body was essential for human beings to function, conscious experience could only be attributed to the soul. Specifically, Descartes believed that so-called "animal spirits" project information (e.g., sensory signals) onto the pineal gland—a pine-nut-sized organ located in the epithalamus, roughly in the center of the brain between both hemispheres. The pineal gland, he reasoned, is the "place in which all our thoughts are formed" (Descartes, 1640/1991, p. 143), and at which the soul connects to the body. In other words, conscious experience is information arriving at the pineal gland, "which the rational soul united to this machine will consider directly" (Descartes, 1632/1985, p. 106). Descartes was thus among the first to posit that humans consciously experience information (with the help of the soul) in the order at which they arrive at a specific, centrally located spot in the human brain. While Descartes views may not reflect an adequate understanding of neurological processes, they are still a perfect example of how one's intuitions (based on one's subjective experiences) may influence neuropsychological lay beliefs pertaining to conscious experience.

In fact, the idea that everything arrives at a single location in the brain where consciousness happens (even without the help of a soul) seems to be intuitively appealing to many people—even today. Dennett (1991) suggests that lay people tend to subscribe to an idea referred to as "Cartesian materialism", "[…] the view that there is a crucial finish line or boundary somewhere in the brain, marking a place where the order of arrival equals the order of "presentation" in experience because what happens there is what you are conscious of." (p. 107).

For Dennett, the "Cartesian Theater" is a metaphor for how lay people (in his view wrongly) conceptualize consciousness in the brain: All sensory information originating from the corresponding organs is processed and analyzed by the brain upon which the results of this computation are chronologically brought together in a single location "somewhere in the center" (Dennett, 1996, p. 160), where consciousness takes place. Yet, in Dennett's view, without a *res cogitans*, a magical perceiving entity, there is no need for information in the brain to "come together" in single location—in fact, he would consider it a waste of valuable resources. According to this view, there is no neurological gateway to consciousness. The processing and analyzing of inputs itself *constitute* conscious experience, rather than *cause* it (Dennett & Kinsbourne, 1992; Damasio, 1989).

Modern neuroscientific research on the neurological correlates of consciousness, however, reveal a more complicated picture: There is still ongoing debate about which specific patterns of brain activity are correlated with being conscious of specific phenomenal content. These correlates are distinct from the neural correlates of *being conscious* (as opposed to unconscious) and of unconscious processes that contribute to the conscious experience (Rees et al., 2002). Likewise, it is still not clear how many distinct neural systems are necessarily involved in conscious perception, or whether there is some kind of "hub" for consciousness. In contrast to Dennett's view, many contemporary neuroscientists argue in favor of certain brain areas fulfilling this function. While some consider the prefrontal cortex primarily causally responsible for conscious experience (e.g., Global Workspace Theory; Baars, 1997), newer work suggests that areas further back in the brain, such as the posterior cerebral cortex (Koch et al., 2016), the lateral occipital cortex, or the intraparietal sulcus (Hutchinson, 2019) play the key role in conscious perception of phenomenal content (Boly et al., 2017, but see Odegaard, 2017, for a different view). Yet regardless of which area it may be, the idea of a brain area that is primarily responsible for consciousness has widespread support.

More importantly for the present research, however, is the question of how lay people understand consciousness. There are different reasons for why they may reveal a belief in a neurological "Cartesian Theater". For one, the idea of a central locus of subjectivity that similarly manifests on a neurological level may be appealing, because they subjectively experience a chronologically consistent stream of consciousness, comprising a sequence of points in spacetime, each representing a phenomenal state that maps onto the objective state of the world around them at that particular moment. As such, the belief may be a result of an intuition, based on phenomenological experience. In addition, such a belief may be related to how we speak of the mind, consciousness, or the self in everyday language: We speak of these constructs as if they are single, coherent entities, not as emergent properties or epiphenomena. Such a construal might facilitate the localization of consciousness in a single, confined, brain area. Likewise, research found that people intuitively dissociate minds from bodies (e.g., Forstmann & Burgmer, 2015). As a result, this dualism, in combination with acquired knowledge about the physical origins of mental states, might foster a tendency in people to locate consciousness in a single, smaller brain area (as most of it takes place "elsewhere"), similar to Descartes' viewpoint. Finally, the neurological Cartesian Theater could be the result of learning. That is, it could be due to neuroscientific knowledge that people acquired—for example if they learned that a certain part of the brain is a "hub" for consciousness, or culturally-learned naïve reasons, for example pertaining to spiritual or religious beliefs that place special importance to certain bodily parts (e.g., the eyes) or brain regions.

As with neuroscientific evidence for the location of consciousness in the brain, there is considerable research on the temporal order of conscious states. While Dennett considers the *subjective temporal order* itself an illusion, as he believes it does not correspond to a chronological sequence of distinct neurological states (some computational processes take longer than others, leave different amounts of residual activity, are non-conscious, etc.), modern views likewise have a more nuanced perspective on the matter. The human brain is capable of accurately identifying the temporal order of sensory events down to 20 millisecond differences between stimuli, and actively accounts for lags in arrival and processing times of the various sensory information (Vroomen & Keetels, 2010). It was suggested that it utilizes a temporal integration mechanism that binds multiple chronological events into a string of perceptual units (Pöppel, 1997). Related to the question of localization, there is ongoing debate about whether this temporal information processing across senses relies on a centralized or multiple, locally independent systems (e.g., Ivry and Spencer, 2004; Mauk & Buonomano, 2004).

Yet, regardless of these neuroscientific debates, Damasio (1992) posits that the concept of a Cartesian Theater aligns so well with our intuitions that "[it] is certainly the common-sense concept of the nonscientist and nonphilosopher in the street." (p. 208). Whether this claim is indeed true, however, has not yet been thoroughly established. The present research aims at gathering the first empirical evidence for whether the notion of such a "Cartesian folk theater" is valid, that is, whether there are specific lay theories about the neuropsychological underpinnings of consciousness.

Notably, as becomes apparent in the theoretical considerations outlined above, there are two aspects to a belief in a Cartesian Theater: an intuitive, experience-based belief in a perceiving entity (such as a soul), as well as corresponding assumptions about the brain. While Descartes believed there was a soul that "actively considered" the information arriving at the pineal gland—as if there was a tiny metaphysical homunculus sitting on a chair, observing on a screen what is seen by the eyes and hearing through speakers what is heard by the ears (hence the term "theater")—it is possible that even without a dualistic belief in a "ghost in the machine" (Ryle, 1949), lay people intuitively conceptualize consciousness in the brain as if there really was such a "theater". In the present research, we were interested in this latter phenomenon. In other words, for the present purposes, we define a lay belief in a Cartesian Theater as neuropsychological lay belief in spatial (and temporal) confinement of consciousness in the brain, regardless of people's metaphysical assumptions about whether there is a perceiving entity at or connected to this location.

As such, the presently investigated lay beliefs would not just align with a non-dualistic Cartesian Theater, but would similarly match to other theoretical constructs (briefly mentioned above), such as Baar's (1997) concept of a global workspace in memory, comprising "momentarily active, subjectively experienced" events, which is also frequently described using the metaphor of a theater (e.g., Blackmore, 2005), albeit without the dualistic component of a metaphysical perceiving entity.

Past research on Lay Theories about the Location of Consciousness

While there have—to our knowledge—been no direct investigations into where people locate consciousness or conscious experience in the brain, some research has investigated the related lay belief about the location of the "self", that is, people's beliefs about where "they" are located within their bodies. James (1890) distinguished two aspects of the self, the me-self, a conglomerate of thoughts, feelings, and beliefs a person has about him- or herself (the *self-as-known,* as for example used in "self-concept"), and the I-self, the experiencing subject (the *self-as-knower*). According to Leary and Tangney (2003), the I-self can be understood as the "inner psychological entity that is the center or subject of a person's experience… [the] experiencing "thing" inside their heads that registers their experiences, thinks their thoughts, and feels their feelings… [the] mental presence [that] is at the core of who they really or most essentially are" (p. 5). This description of the I-self seems related to the concept of conscious experience, suggesting that lay people could make similar judgments with regard to consciousness as they do with regard to the self. Further, it defines the I-self as a "thing" in the head that experiences—a notion closely matching Descartes' views on the role of the soul and the pineal gland in the brain. Given that the notion of a center of conscious experience is so intuitively appealing that it may be responsible for a lay belief in a Cartesian Theater (as defined above), past research on people's beliefs about the physical location of the self seems especially relevant for the present research questions.

In the past, philosophers located the self, the soul, or consciousness in various bodily organs, such as the heart or—as discussed above—the pineal gland. From the early 20^{th} century on, scholars tried to identify the *factual* location of people's egocenter, that is, a point in space that constitutes the center of their conscious experience. They found that, for the non-visually-impaired, the audio-visual egocenter lies on the ocular axis, somewhere between the eyes—like a cyclopian third eye behind the bridge of the nose (e.g., Merker, 2007; Barbeito & Ono, 1979).

However, this research did not address where lay people themselves believe their self (or consciousness) to be located. Past research shows that people are intuitively able to locate certain conscious experiences within the physical realm. Presenting them with an outline of a human body, Nummenmaa and colleagues (2014) asked participants to colorize where in their body they felt various emotions. They found that people locate emotions differently throughout the body, and that the location seemed to depend on certain features of the respective emotion. However, for nearly all emotions, people also colorized the head of the human body, presumably representing the mental component of the emotional experience. That is, people feel “changes in the contents of mind triggered by the emotional events.” (p.3), and answer accordingly.

More closely addressing the question of the location of consciousness, Limanowski and Hecht (2011) asked participants to locate the self in human and non-human entities by placing crosshairs on the respective silhouettes. They found that people tended to locate both the self and the *phenomenal self* (corresponding to the aforementioned I-self, i.e., the center of subjective experience) of humans in the brain and the heart, yet only in the brain for abstract creatures. Importantly, when explicitly asked, most participants (72%) stated that they believed there was a *single* location inside the human body where the self is located.

Similarly, using structured interviews, Bertossa and colleagues (2008) found that people intuitively understand the concept of locating consciousness, and 83% of their participants located their consciousness (here defined as the “I-that-perceives”) at a precise point inside the head (i.e., somewhere in the center, but behind the eyes). This was the case for both blind and seeing people. Likewise, Alsmith and Longo (2014) used a variation of an egocenter task to investigate where people locate their selves. Specifically, participants were asked to change the angle of a rod positioned in front of them so that it points to where “they” are. Although the sample size was small, the authors found that people tended to point the rod to their upper face. Some participants, however, oriented the rod towards their heart, yet it remains unclear whether they indeed intended to locate their self in their heart, or whether they chose the torso as the largest defining region and center of the entire body (i.e., they may have understood the “self” in terms of a physical body rather than the center of conscious experience).

Using a more indirect measure, Starmans and Bloom (2012) found that people seem to locate the self in a “precise location within the body, at or near the eyes” (p. 313). Both children and adults consistently indicated that an object was closest to a person if it was in front of their eyes (as opposed to, for example, their feet or torso). Interestingly, this was also the case when the eyes were not in the head of the being displayed (in this case, an alien species). Yet the studies provide no evidence for whether people locate the self in front of, *in*, or behind the eyes (as suggested by Bertossa and colleagues, 2008), or whether they assumed the presence of a brain behind the eyes. Likewise, it remains unclear how people conceptualize the self in these studies: as a body (which the instructions suggest) or as the “I-that-perceives”.

Lastly, Anglin (2014) found that 94% of people associated the term “mind” (as opposed to “soul” or “self”) with thoughts and consciousness, and when asked an open question about the location of the mind in the body, 97% of participants located it in the head or brain. In turn, participants were equally likely to indicate that the “self” was located in the head, in the chest, or “unlocalized” (each roughly 25%).

Based on these studies, it seems evident that most people believe that the “seat” of the self (in some cases understood as consciousness) is the human brain or the head. Some initial evidence suggests that they roughly locate it in the frontal part of the head—most likely somewhere behind the eyes. Yet, the methodologies employed in these studies did not allow for a more precise assessment of where people locate their consciousness, that is, whether they truly believe in a Cartesian Theater as we defined initially. For example, both Descartes and a modern neuroscientist—who may consider consciousness a complicated process involving different brain regions—would choose the brain as the seat of consciousness, albeit with potentially vastly different ideas about which parts of the brain are involved at which point in time, and for which reason.

In other words, no study has thus far directly investigated people's lay theories about which parts of the brain play a role in consciousness, and whether they in fact believe that there is a single location in space and time where everything "comes together" to form conscious experience. In addition, in most studies to date, participants were prompted to name or select a *single* location where they thought the self was located. To test whether people truly subscribe to the idea of a Cartesian Theater, however, they would also need to have the option of selecting multiple areas involved in consciousness, as well as the ability to select areas of different sizes. After all, it remains a realistic possibility that—contrary to Dennett's suggestion—acquired knowledge about the intricacies of the human brain leads people to develop a "network-theory" of consciousness, in which multiple interconnected areas of the brain contribute to consciousness.

Further, past studies did not tap into lay people's beliefs about the temporal aspects of consciousness. A crucial element of a lay belief in a Cartesian Theater is the idea that consciousness happens not as a byproduct of (i.e. a simultaneously-occurring phenomenon), but as a result of (i.e., a subsequently-occurring downstream consequence) the processing and analyzing of information—since it happens at the final destination of all signals. Yet, whether people believe in such a temporal localization, and whether it is associated with a corresponding belief in a spatially localized consciousness is still unknown.

Hypotheses

Our definition of a lay belief in a Cartesian Theater allows for various predictions. Specifically, we hypothesized that people would, on average, locate consciousness in a single (as opposed to multiple) areas of the human brain, and that people would consider most of the brain

(> 50%) not to be involved in consciousness[1]. In line with Damasio's (1992) suggestion and past research on lay beliefs about the self, we further hypothesized that they would locate consciousness in the frontal part of the brain (relative to the mid-coronal plane), and that people would locate unconscious or specific functional processes (e.g., motor control) elsewhere. Further, we hypothesized that when comparing two aspects of a sensory experience—the computational analysis of sensory information in the brain and the corresponding conscious experience—people would consider the latter be more spatially confined in the brain than the former, again based on the assumption that consciousness is a result rather than the byproduct of these computations.

Addressing the temporal aspects of consciousness, we predicted that, on average, people would consider consciousness to (partly) happen after the brain is done computing all information pertaining to a given sensory experience, and that explicit belief in spatial and temporal confinement of consciousness would constitute unique, albeit positively correlated beliefs.

The Present Research

Using computer-administered drawing tasks, Studies 1a and 1b investigated where in the brain people locate consciousness (in comparison to motor control) and investigated people's rationales for their choices as well as how responses were affected by neuroscientific knowledge. Further ruling out alternative explanations, Study 2 tested whether people differentially locate conscious versus unconscious thinking. In Study 3, we sought to determine whether people

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[1] We did not have specific hypotheses about the absolute size of the brain area people consider responsible for different faculties in the brain, as this is likely to be affected by specifics of the drawing task participants completed (see General Discussion).

consider the conscious experience of a stimulus to be more spatially confined than the underlying computational analysis of sensory information in the brain. Studies 4 and 5 investigated temporal beliefs about consciousness. Specifically, using a newly-developed questionnaire, Study 4 tested whether the belief in consciousness happening at a specific location in the brain and the belief in consciousness happening *after* processing of all relevant information is done constitute independent, yet correlated beliefs. Finally, Study 5 used a more elaborate slider-based measure to investigate intuitions about the temporal order of information processing and conscious experience.[2] The present studies were not preregistered. Data and analysis code for all studies are available from the authors upon request. Questionnaires can be found in the SOM.

Study 1a: Locating Consciousness

To test whether participants believe in a Cartesian Theater, in the first study[3], our goal was to examine which parts of the brain participants thought would contribute to consciousness, using a drawing task especially designed for this purpose. Specifically, based on our definition of a belief in a Cartesian Theater, we tested whether participants would a) locate consciousness, but not another specific process (in this case voluntary motor control), in the frontal part of the brain (relative to the mid-coronal plane), b) that they would colorize a brain area smaller than 50%, and

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[2] Studies 1b and 2b (SOM) received formal ethics approval from the University of Kent (IDs 202016061537846797; 202016069334986862). The remaining studies (including informed consent, data storage, etc.) were designed and executed in accordance with the ethics guidelines provided by the German Science Foundation (DFG).

[3] See supplementary materials for a very similar pilot study, in which we asked participants to colorize where in the brain they thought consciousness was *located*.

c) that they would consider a single, confined area (as opposed to multiple unconnected areas) responsible for conscious experience.

Method

Participants and design. A total of 452 participants were recruited via the online crowd-sourcing platform Amazon Mechanical Turk (MTurk) and participated in exchange for modest monetary compensation. Of those participants, 51 were excluded for admitting having answered randomly or in a purposefully wrong manner, or because they indicated that they completed the survey on a mobile device (they were previously informed that only users of desktop or laptop computers were eligible to participate). This left us with a final sample of 401 participants (202 female, 199 male, M_{Age} = 37.66, *SD* = 13.05). All participants worked on a computer-administered drawing task, asking them to locate brain areas responsible for motor control (control item) and consciousness (critical item). This was followed by two personality questionnaires assessing belief about mind-body relations as well as in free will/determinism (results for these questionnaires can be found in the SOMs).

Materials and procedure. Upon consent, participants were first asked to indicate the type of device they used to complete the survey. They were then introduced to the drawing task. Specifically, they first completed a tutorial designed to familiarize them with the different tools they could use to colorize the image, followed by the two main drawing tasks.

Drawing task tutorial. In the tutorial, participants were presented with a white canvas measuring 300 by 300 pixels, with the black outline of a triangle with an edge length of 200 pixels displayed in its center. They were then told that they "*could now use [their] mouse as a brush to paint red color onto the canvas.*" Specifically, they were told that they could draw "on the areas outside of the triangle, onto the triangle, as well as into the triangle." Right above the canvas, three buttons labeled “small”, “medium”, and “large” were displayed. Using these buttons, participants could select and switch between differently-sized paint brushes, with the three buttons corresponding to round brushes with diameters of 5, 10, and 30 pixels, respectively. In addition, they were provided with two buttons labeled “clear all” and “fill all”. They were told that the “clear all” button would erase everything they had drawn so far, in order for them to start anew if they so desired. The “fill all” button could be used to fill the entire object that was displayed on the canvas with red color. Participants were then instructed to try out all the different features and to familiarize themselves with the mechanics of the task before proceeding to the main drawing tasks.

Main drawing task (control). On the following screen, participants were introduced to the first drawing task, intended to assess the control dimension. They were once more presented with a canvas and the five control buttons. However, instead of a triangle, the canvas displayed the lateral outline of a human brain (Figure 1). Correspondingly, the “fill all” button filled the entire brain with red color. The actual purpose of the “fill all” button was to avoid a confound, in that providing a response in line with a non-localized view of a consciousness (for example, the belief that consciousness happens in the entire brain) would require more drawing effort than a hypothesis-conform response. Thus, by including this button, we tried to implement a conservative test of our hypothesis, with the most effortless response a participant could give (i.e., filling the entire brain with one click) working against our hypothesis.

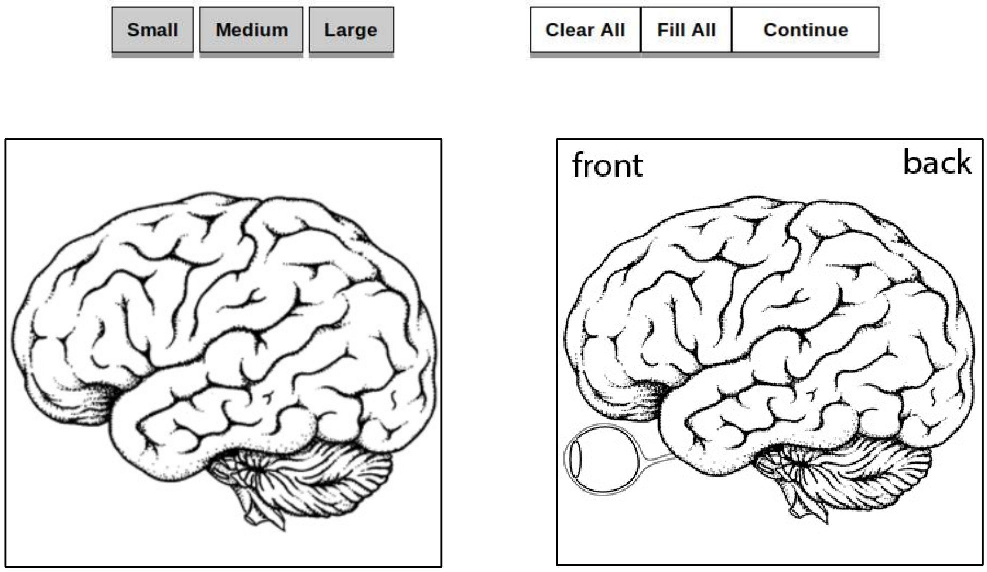

Figure 1. Controls of the drawing task (top), and brain outlines presented to participants in Studies 1a, 2, and 3 (left), and 1b (right).

Participants were told: "*Below you see a picture of the human brain. Please imagine that this was a picture of your brain. For this first task, please use your brush to colorize the area(s) of your brain which you think contribute to controlling your body movement. Please do not look up the answer on the internet, as we are interested in people's intuitions. You can paint as much or as little as you deem necessary*."

We made sure to mention to participants the possibility of colorizing either a little or a lot of the brain, in either one or multiple locations ("area(s)"). This control item served the purpose of testing whether participants would locate *any* neurological process in the same (or a similar) location, or whether they had distinct beliefs about different brain regions being responsible for different mental faculties.

Notably, we had participants imagine it was *their* brain that was displayed on the canvas in order to circumvent issues related to the epistemological "problem of other minds", pertaining to the lack of definite knowledge about other people's conscious experience, that might lead to biased responses on the critical item.

Main drawing task (critical). Following this initial task, all participants proceeded to a second drawing task, assessing our main dependent variable—lay beliefs about the location of consciousness. They were once more presented with the (identical) outline of a human brain on the now-familiar drawing canvas. Only this time, participants were asked to "*use [their] brush to colorize the area(s) of [their] brain [they] think contribute to[their] consciousness.*". Upon completion of this task, participants' drawings were encoded in base-64 format and saved as string variables for offline reconversion into images.

Table 1

Activation	Total number of pixels colorized by participants
Location	Descriptive location where in the brain participants colorized pixels (e.g., the front or back)
Orientation	Value indicating the relative "leftness" / "rightness" (or "upness" / "downness") of the colorized area(s) within the brain
Dispersion	Number of individual (i.e., not connected) colorized areas
Confinement	Average distance between all colorized pixels, with lower values representing the degree to which the colorized area(s) converge(s) to a single pixel

Notes. Terms used in the analysis of participants' drawings

Results

Data preparation. After completion of data collection, participants' drawings were reconverted into 300 by 300 pixel images that did not include the outline of the human brain, but rather only what they drew onto the canvases. For data analysis, these images were then converted into 300 by 300 number matrices, such that pixels that were colorized by a participant were assigned a value of 1, while uncolorized pixels were assigned a value of 0. For each participant, we therefore ended up with two numerical matrices comprised of zeros and ones, representing the drawings they created in both trials. These matrices were used for all the following analyses and visualizations. Pixels outside of the boundaries of the brain outline that were colorized by participants (which mostly happened when they slightly drew over the edges while colorizing), were automatically coded as uncolorized and hence assigned a value of 0.

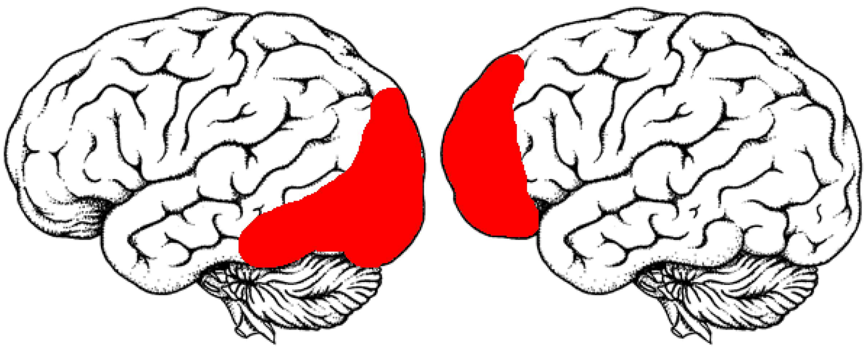

Figure 2. Examples of participant drawings in the control (left) and consciousness (right) trials (Study 1a).

Activation. As a first step, we analyzed the total number of pixels colorized by participants inside the brain outline, both for the control item and critical item. The maximum number of pixels that could be colorized was 46,887, determined by the size of the brain outline. To test whether participants on average considered consciousness to happen in a part (vs. the entirety) of the brain, we compared the mean numbers of pixels colorized by participants to 50% of the total number of available pixels.

Most frequent were responses in the 5000 – 7500 pixels range (see Figure 5). On average, participants colorized 26.18% (*M* = 12,274.29, *SD* = 12,458.34) of all available pixels when asked to mark brain areas contributing to consciousness, a number significantly smaller than 50%, $t(400) = -17.95$, $p < .001$, 95% CI = [11,051.22, 13,497.36], $d = -0.90$. The same was true for the control task, where participants on average colorized 18.08% of all available pixels (*M* = 8,477.57, *SD* = 10,169.67), a number significantly smaller than 50%, $t(400) = -29.47$, $p < .001$, 95% CI = [7,479.18, 9,475.96], $d = -1.47$. In line with results of a pilot study (see SOMs), participants considered a larger part of the brain to contribute to consciousness than to motor control, $t(400) = 5.65$, $p < .001$, 95% CI_{Δ} = [2,475.99, 5,117.45], $d_z = 0.28$. In sum, in line with our hypotheses, results show that people believe that more parts of the brain *do not* contribute to consciousness (and motor control) than *do* contribute to it.

Location. For a descriptive understanding of participants' beliefs about consciousness, we averaged all matrices for the critical and the control trials and converted the results back into images. As pixels were always coded 0 or 1, each pixel's mean value represents the percentage of participants who colorized it. We further *z*-transformed the average pixel matrix and highlighted those pixels that were colorized significantly more often than others (Figure 3).

Further, to compare participants' responses to the critical task and the control task, we created a difference matrix, representing relatively more frequent colorization of a pixel in one as compared to the other trials (Figure 4). For each pixel, we analyzed whether it was colorized significantly more frequently in one condition compared to the other using Fisher's exact test (as chi^2 approximations for some of the less frequently colorized pixels may be inaccurate).

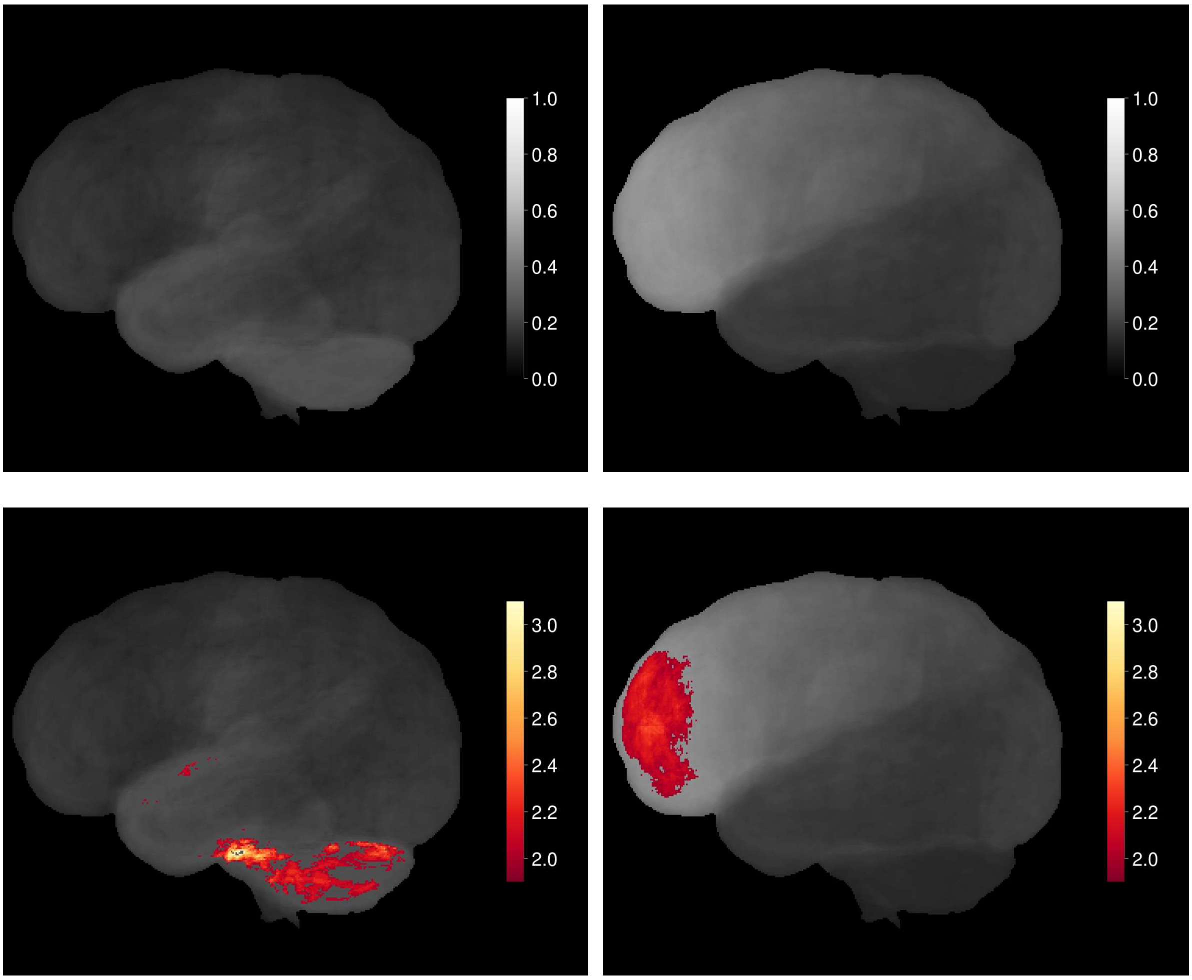

Figure 3. Average drawings created by participants in the control (left) and consciousness trials (right) in Study 1a. Brightness of each pixel indicates the frequency with which it was colorized by participants (in percentages). Highlighted pixels (bottom row) are pixels colorized significantly more often by participants than others (alpha = .05), with values representing *z*-scores.

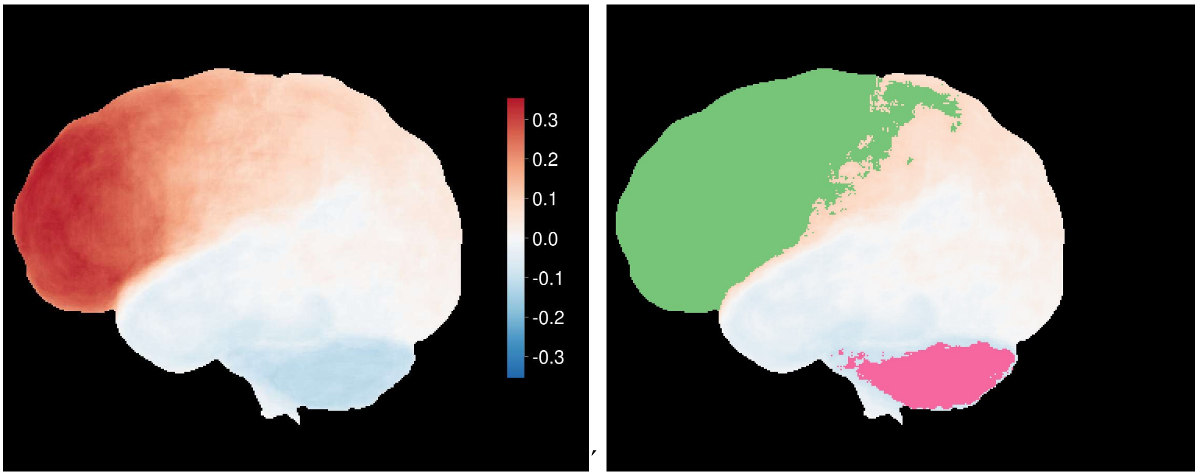

Figure 4. Differences between control and critical trials in Study 1a. Red colors indicate a greater relative colorization of a pixel in the critical trial, whereas blue indicates more frequent colorization in the control trial (left). Highlighted pixels indicate pixels that were significantly more frequently colorized in the critical trial (green) or in the control trial (pink), as determined by Fisher's exact test (right).

Spatial orientation. For each participant drawing we calculated two individual scores representing its relative position on the X and Y axes of the brain outline. Specifically, we fitted a rectangle around all pixels colorized by each participant and determined the coordinates of the mid-point of this rectangle, resulting in values ranging from -1 to 1 for each spatial dimension. Negative values correspond to the midpoint of a drawing being oriented more towards the left side (on the x axis) or top (on the y axis) of the brain, while positive values correspond to drawing being placed further to the right or the bottom. Consistently, colorizing the entire brain produced two scores of zero. This approach allowed us to compare the relative orientation of two drawings, as well as to quantify the spatial orientation of a drawing by assessing its divergence from the midpoint of the brain.

Analyzing these scores, we found that on average participants located consciousness more frontal (M = -0.15, SD = 0.44) than motor control (M = 0.06, SD = 0.40, $t(393) = -6.43$, $p < .001$, 95% CI_{Δ} = [-0.28, -0.15], d_z = -0.22. As can be assumed from looking at Figure 4, they also located motor control further down (M = 0.05, SD = 0.41) than consciousness (M = -0.12, SD = 0.33), $t(393) = 6.81$, $p < .001$, 95% CI_{Δ} = [-0.13, 0.23], d_z = 0.34. Interestingly, the left-right orientation ($r(392) = -.27$, $p < .001$, 95% CI_r = [-0.36, -0.17]), but not the up-down orientation ($r(392) = .02$, $p = .725$, 95% CI_r = [-0.08, 0.12]), of the two drawings was negatively correlated: regardless of where on the X-axis of the brain participants located consciousness, they tended to locate motor control at a different location, suggesting that they indeed have distinct views about the location of mental faculties in the brain.

To test our hypothesis that people locate consciousness in the frontal part of the brain, it is possible to test the orientation vectors of the two faculties against 0, that is, against the mid-coronal and mid-axial plane, respectively. Results of these analyses reveal that participants indeed have tendency to locate consciousness in the front $t(396) = -6.82$, $p < .001$, 95% CI = [-0.19, -0.11], d = -0.34, and up, $t(396) = -7.35$, $p < .001$, 95% CI = [-0.16, -0.09], d = -0.37, while they tend to locate those areas contributing to motor control in the back, $t(395) = 3.15$, $p = .002$, 95% CI = [0.02, 0.10], d = 0.16, and down, $t(395) = 2.68$, $p = .008$, 95% CI = [0.01, 0.09], d = 0.13.

Dispersion. To test whether participants indeed located consciousness in a *single confined* location we computationally determined and analyzed the number of independent pixel clusters participants colorized using density-based spatial clustering for noisy data (DBSCAN, Ester et al., 1996). In line with our hypothesis, for consciousness, 92.4% (n = 367) of participants colorized only one single cluster of pixels when being asked to colorize brain areas that contribute to consciousness, while only 7.6% (n = 30) colorized more than one cluster, a ratio significantly different from randomness; binominal test: $p < .001$, 95% CI_{prob} = [0.89, 0.95]. The same was true for motor control, with 89.4% (n = 354) colorizing a single cluster of pixels (vs. 10.6%, n = 42); binominal test: $p < .001$, 95% CI_{prob} = [0.86, 0.92]. The two proportions did not significantly differ from one another, $\chi^2(1) = 1.88$, $p = .170$.

Discussion

Supporting our hypothesis of a lay belief in a Cartesian Theater, results of our initial study show that people on average consider consciousness to take place in a single, confined region in the frontal part of the brain. Yet, they do not consider just any mental process to happen there, as participants located the brain areas contributing to motor control elsewhere. Unexpectedly, we found that participants also considered a larger part of the brain responsible for consciousness than for motor control. One reason for this finding could be that they considered consciousness to be a more complex phenomenon than controlling one's limbs, which could in turn be associated with greater neural activity.

Study 1b: Addressing Confounds & Exploring Rationales

We conducted a further study to confirm the findings from Study 1a. In addition, we sought to rule out various potential confounds, investigate people's rationales behind their colorization choices, and explore how differences in neuroscientific knowledge, cognitive reflection, and experience with neurosciences would predict their responses.

Specifically, to validate our paradigm, we created a version of the drawing task in which participants had to *erase* color from a fully pre-colorized brain outline rather than adding color to a canvas, with the goal of ensuring that the findings from Study 1a were not due to participants trying to minimize effort, or any other demand associated with the previous drawing task. We also modified the brain outline to include the eyes (oftentimes associated with the soul), and added labels indicating the front and back of the brain, in case people were previously confused about which direction the outline was facing (Figure 1).

Further, in this study, we sought to explore why precisely people chose to colorize the brain region they colorized—be it for scientific reasons, naïve reasons (i.e., deliberate assumptions that are not based on a scientific rationale), or purely based on intuition (i.e., based on a vague feeling that something is correct, rather than on deliberate assumptions)—and whether they mostly relied on their knowledge about the brain or gut feeling about consciousness when working on the task. In the same vein, we assessed how strongly a more reflective or intuitive information processing style (assessed with the cognitive reflection task, CRT; Frederick, 2005) was predictive of participants' responses.

Lastly, it is possible that people's acquired knowledge about the brain affected their responses. Therefore, we assessed both self-reported and objective knowledge about the brain (using a short quiz), as well as how much people's education or profession was related to the neurosciences.

Method

Participants and design. 452 British participants were recruited using Prolific Academic. 65 participants were excluded based on them indicating that they responded randomly to one or multiple items (n = 14) or on the consciousness drawing task (n = 51). Further, as we used a new survey provider for this study, we had all consciousness drawings rated by two independent coders blind to hypotheses on whether the respective participant completed the task in a serious manner or not (binary judgment). Ten additional participants were identified by both coders as having failed to do so and were excluded from data analyses, leaving a final sample of 377 participants (287 female, 85 male, 5 other/none, $M_{\text{Age}} = 34.68$, $SD = 12.37$).

Materials and procedure. The order of tutorial and drawing tasks (once more asking about motor control and consciousness, respectively) was the same as in Study 1a. The only difference in this study was that participants were instructed to use an eraser, rather than a brush, to *remove* color from the canvas. In both drawing tasks, they were presented with a pre-colorized brain outline (i.e., entirely colorized in red), and were instructed to remove color so that what was left in the end represented their idea of which brain region(s) contribute to consciousness/motor control.

Knowledge about the brain. To test, whether neuroscientific knowledge played a role in participants' localization of consciousness and motor control, we then assessed both subjective and objective knowledge about the brain. Subjective knowledge was assed via self-reported agreement with seven statements on a scale from 1 (*completely disagree*) to 7 (*completely agree*), including statement such as "*I would consider my knowledge about the brain to be very good*" or "*I feel knowledgeable enough to discuss the human brain with other people*" (see SOM for the full list of items).

Objective neuroscientific knowledge was assessed via a short 11-item quiz, in which participants had to indicate on a binary scale whether each item statement was true or false. Items were taken from Herculano-Houzel (2002). We selected eleven items that had an agreement of at least 70% among neuroscientists with regards to what the correct response was (the same criterion used by the original author), and that were among the more difficult items for lay people. Items included statements such as "*Memory is stored in the brain much like in a computer, that is, each remembrance goes in a tiny piece of the brain.*" (false) and "*Mental effort raises oxygen consumption by the brain*" (true) (see SOM for the full list of items).

Rationales for colorization. Subsequently, we assessed participants rationales for colorizing the brain area they colorized in the consciousness trial. Specifically, we provided them with a list of nine rationales, presented in the form of statements and in randomized order, and asked them to indicate their agreement with each statement with regard to whether it played a role in their response to the consciousness localization task, on a scale from 1 (*completely disagree*) to 7 (*completely agree*). The list comprised three scientific rationales (e.g., "*I learned that these brain regions are associated with higher level thinking*"), three naïve rationales (e.g., "*It subjectively feels like this is where "I" am in my head*"), one intuitive rationale ("*I just had a vague feeling that this is where consciousness takes place, but I don't know why*"), one item pertaining to random responding ("*I just picked a random spot in the brain*"), and one item pertaining to no clear rationale ("*I had to colorize something, and this was my first idea*") (see SOM for all items and question wording).

We then presented participants with the same nine rationales again (once more in randomized order) and asked them to select the one rationale that was their *primary* reason for colorizing the area(s) they chose.

Reliance on knowledge/reflection vs. intuition/gut feeling. To assess participants reliance on knowledge/reflection, as opposed to intuition/gut feeling when completing the tasks, we employed both a subjective, self-report measure of this tendency, as well as an objective measure. For the former, we asked participants to indicate on two 7-point scales ranging from *not at all* to *very much* how much they relied on their knowledge about the brain and their gut feeling about consciousness, respectively, when working on the colorization task. For the “objective” measure, participants completed a 4-item version of the MCQ-4 (Sirota & Juanchich, 2018)—a multiple choice variant of the CRT. Typically, the CRT is comprised of a set of questions with an intuitively incorrect response, whereas arriving at the correct response requires a certain degree of reflection (e.g., “A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost?). In the present case, participants were given the choice between four fixed answer options (presented in random order) for each of the four questions (likewise presented in random order). The four answers options always included one option representing the (correct) reflection-based response (the ball costs 5 cents more), and one representing the (incorrect) intuitive response (the ball costs 10 cents more). Reflection-based and intuition-based responses were summed up across the four items to create two separate indices.

Finally, participants provided demographic information, including a binary item asking them whether they cheated by looking up information on the internet (none indicated yes), and an item asking them how much (if at all) their field of study or current profession is related to the neurosciences, on a scale ranging from 1 (*not at all*) to 5 (*exclusively*).

Results

Activation. Importantly, in the consciousness trial, the numbers of pixels people colorized using the eraser paradigm was similar to the number reported for Study 1a (M = 14,394.13 (approx. 30.7%), SD = 11,455.16), a number once more significantly lower than half of all available pixels, $t(376) = -15.34$, $p < .001$, 95% CI = [13,234.07, 15,554.18], $d = -0.79$. As in Study 1a, most frequent were responses in the 5000 – 7500 pixels range (see Figure 5 for a comparison). As such, it seems as if the localization of consciousness in a confined part of the brain that we found in Study 1a was not due to the effort involved in giving a response that would reject this notion (see SOM for results regarding the control trial).

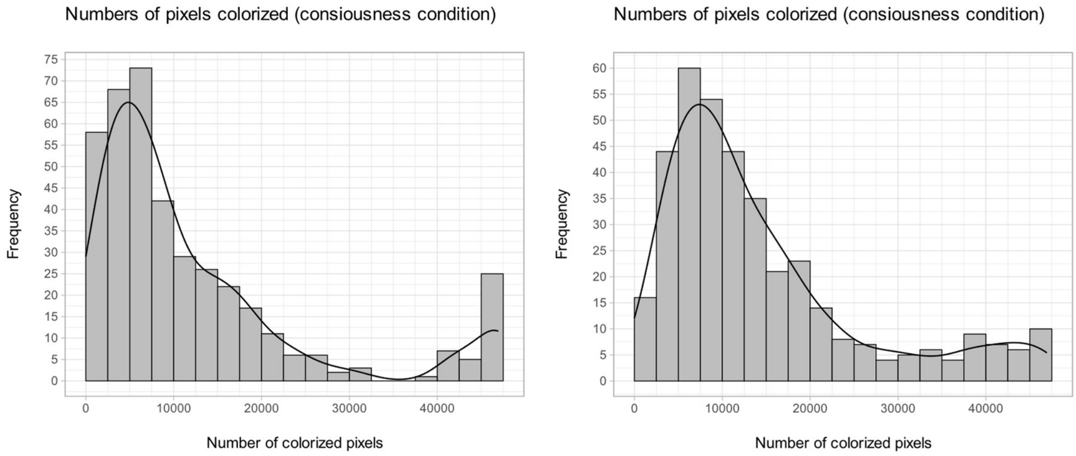

Figure 5. Histograms of number of pixels colorized in the regular version of the colorization task (Study 1a, left) or the eraser version of the task (Study 1b, right), including density curve.

Location and Spatial Orientation. Across participants, location of consciousness and motor control revealed results highly similar to Study 1a, with consciousness located in the frontal part of the brain, and motor control in the back and further down (roughly where the cerebellum is located). Analyses of the spatial orientation vectors confirm that participants on average located consciousness in the frontal part of the brain. The consistency of results across unlabeled and labeled brain outlines also increases confidence that participants did not need the labels to correctly identify the front and the back. Details on the corresponding analyses and various composite pictures can be found in the SOM.

Dispersion. Similar to Study 1a, 82.4% (n = 311) of participants colorized a single cluster of pixels when being asked to leave brain areas that contribute to consciousness colorized, while 17.0% (n = 64) left more than one cluster colorized, a ratio significantly different from randomness; binominal test: $p < .001$, 95% CI_{prob} = [0.79, 0.87].[4] Supporting our hypothesis, the results show that most participants clearly favored a one cluster response.

Rationales for colorization. Next to ruling out effort as an alternative explanation for our findings, we sought to find out more about people's rationale for their responses to the consciousness colorization task.

Main rationale. As displayed in Figure 6, the single most selected main rationale for the localization of consciousness was the intuition-based response "*I just had a vague feeling that this is where consciousness takes place, but I don't know why",* with 50.7% of participants selecting this option. Notably, responses based on a scientific rationale (15.6%), or a naïve rationale (14.9%) were much less common. Yet, among these 6 rationales, "*It subjectively feels like this is where "I" am in my head*", was the most common choice, suggesting that subjective experience does play an important role in people's responses. 18.9% indicated no clear rationale for their response.[5]

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[4] Notably, the number of participants producing more than one cluster of pixels might be marginally higher as in Study 1a, due to some participants using the eraser in a sloppy manner, which may leave some "pixel islands" unintentionally colorized (which was not possible in Study 1a).

[5] Some participants indicated a completely random response (11.9% of the full sample, who were excluded from the remaining data analyses).

In sum, it is evident that most participants primarily locate consciousness in the frontal part of the brain, because they intuitively think that this is where it takes place (without exactly knowing why), or because it subjectively feels as if their selves are located there.

Agreement with individual rationales. We also assessed the degree to which participants subscribed to the nine rationales. We created mean scores for agreement with the three scientific rationales (α = .77) and naïve rationales (α = .61). Responses reveal a similar pattern as for the main rationale (see Figure 6 for the distribution and Table 2 for the mean scores). These scores were further used to correlate them with the other variables introduced in this study (see below).

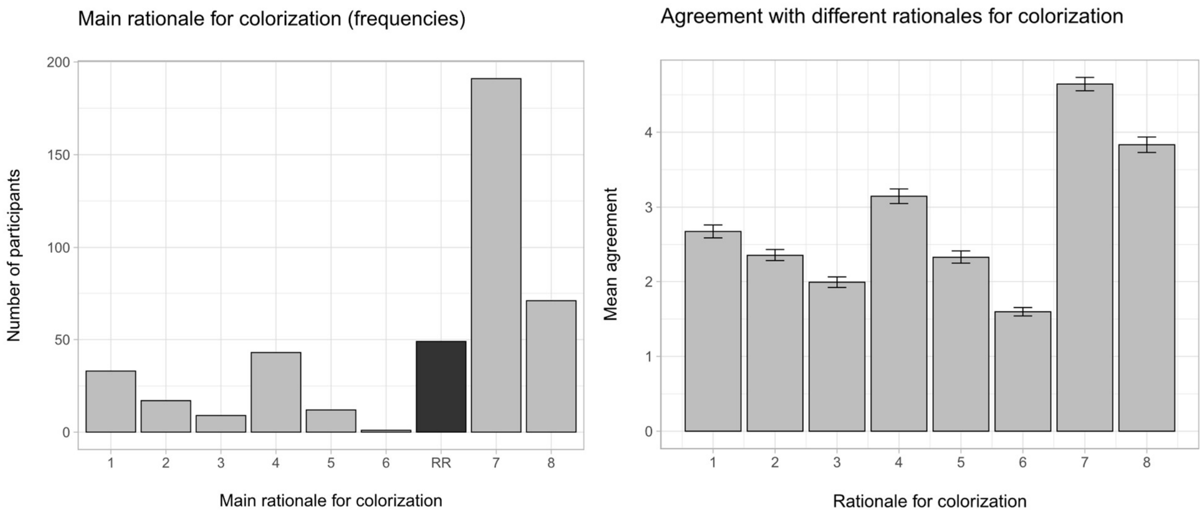


Figure 6. Left: Frequency of main rationales selected by participants. Right: Degree to which individual rationales played a role in colorization choices, as indicated by participants responses on a scale from 1 (completely disagree) to 7 (completely agree). Rationales were coded as follows: 1 = associated with higher-level thinking (scientific), 2 = known as hub for consciousness (scientific), 3 = evolutionarily newest (scientific), 4 = feels like where I am (naïve), 5 = closest to the eyes (naïve), 6 = in line with my spiritual/religious beliefs (naïve), RR

= random response [excluded from analyses], 7 = vague feeling, but don't know why (intuitive), 8 = my first idea (no clear rationale)

Confinement. To attain a score representing the degree of "confinement" of each drawing, corresponding to the notion that consciousness happens in a single, confined area in the brain, we analyzed the mean distance between any two colorized pixels in the drawing. Calculating the mean distance between colorized pixels takes into account the absolute number of pixels colorized, the number of and position of unconnected clusters of pixels, as well as the shape of these clusters. We computed this score by repeatedly drawing random pairs of colorized pixels (100,000 times per image, with replacement) and calculating their average Euclidean distance. Thereby, we arrived at a single score indicating participants' degree of conceptualizing consciousness (or motor control) as being confined to a single, confined area in the brain. Higher values on this measure indicate *lesser* confinement. We used this score in the subsequent analysis of the correlates (i.e., how strongly these correlates predict confinement of drawings), as well as in the following studies in order to compare degrees of confinement when applicable.

Correlates.

Knowledge about the brain. For subjective knowledge about the brain, we created a mean score from participants' responses to the seven items ($\alpha = .94$). On average, self-reported knowledge was comparably low, significantly below the mid-point of the scale, ($M = 2.45$, $SD = 1.27$, $t(376) = -23.72$, $p < .001$, 95% CI = [2.32, 2.56], $d = 1.22$

For objective knowledge, we created a sum score of correct responses to the neuro quiz for each participant. On average, participants answered 6 out of 11 questions correctly, with the number of correct responses ranging from 2 to 11. Both subjective and objective knowledge were significantly positively correlated with one another, as well as with experience with neuroscience on an educational or professional level (Table 2). In addition, both scores were meaningfully correlated with reliance on knowledge and intuition, respectively, as well as with the cognitive reflection and intuition scores assessed via the CRT.

However, neither objective nor subjective knowledge about the brain predicted confinement, dispersion, or horizontal/vertical orientation of consciousness localizations—the key variables describing participants' responses. Likewise, experience with neuroscience did not predict any of those key variables.

When it comes to the rationales for localizing consciousness, both knowledge scores positively correlated with agreement with scientific rationales for localization choices. In addition, subjective knowledge negatively correlated with the intuitive rationale, while objective knowledge negatively correlated with naïve rationales (Table 2). Experience with neuroscience, positively predicted the scientific rationales, while it negatively predicted both naïve and intuitive rationales.

Reliance on knowledge/reflection vs. gut feeling/intuition. The self-report items for reliance on knowledge and gut feeling were expectedly negatively correlated. In line with their indicated rationales for colorization, participants reported relying more on their gut feeling about consciousness than on their knowledge about the brain when working on the task. $t(370) = 10.51$, $p < .001$, 95% CI = [1.34, 1.95], $d = 0.55$ (see Table 2 for descriptives).

Reliance on gut feeling negatively correlated with scientific rationales, but positively correlated with naïve and intuitive rationales. Conversely, reliance on knowledge positively correlated with scientific rationales, but negatively correlated with naïve rationales.

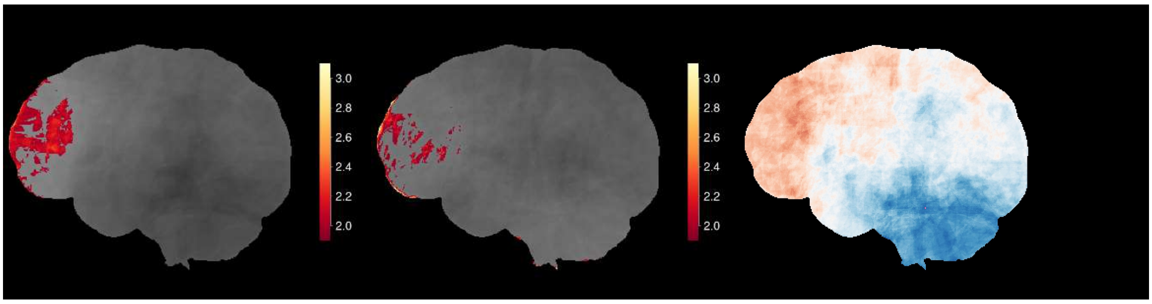
More importantly, while reliance on knowledge about the brain was negatively related to confinement of the drawing (i.e., reliance on knowledge predicted a more spread-out conceptualization of consciousness), reliance on gut feeling correlated with a localization of consciousness further down on the canvas—that is, closer to the eyes in the brain outline.

The two CRT scores were meaningfully correlated with the two self-report items assessing reliance on knowledge and gut feeling, respectively (i.e., one positive and one negative correlation for each score, see Table 2), providing convergent validity of these measures. In addition, the intuition score of the CRT was positively correlated with agreement with naïve rationales, while the reflection score was negatively correlated with this variable. Importantly, however, neither CRT score predicted any of our key variables describing the localization of consciousness.

Comparison of low vs. high degrees of neuroscientific knowledge.

To further analyze how interindividual differences predicted participants' localization of consciousness, we created mean brain images for participants scoring high or low on the respective variables (with reflection/intuition and reliance on knowledge/gut feeling each separated into two categories via a k-means cluster analysis). In addition, we created mean images across participants who selected a scientific, naïve, or intuition-based rationale as their main rationale. All pictures can be found in the SOM. Across measures, it becomes evident, that the localization of consciousness in the frontal part of the brain does not so much depend on knowledge about the brain, reliance on intuitive versus reflective thinking, or experience with neuroscience, but seems to be present among all groups of participants (and sometimes even more clearly for participants with higher scores on knowledge-related variables). Rather, as one may expect, it was the localization of motor control in the cerebellum that was primarily found for participants high in knowledge about the brain, or who relied more on cognitive reflection (see Figure 7), whereas low neuroscientific knowledge revealed a more diffuse localization of motor control within the brain. This finding, together with the high intercorrelations of the various knowledge and thinking-style measures, increases confidence that the current study provided a valid and reliable assessment of these variables, but that they did not strongly predict participants' localization of consciousness.

Low degree of neuroscientific knowledge (Quiz)



High degree of neuroscientific knowledge (Quiz)

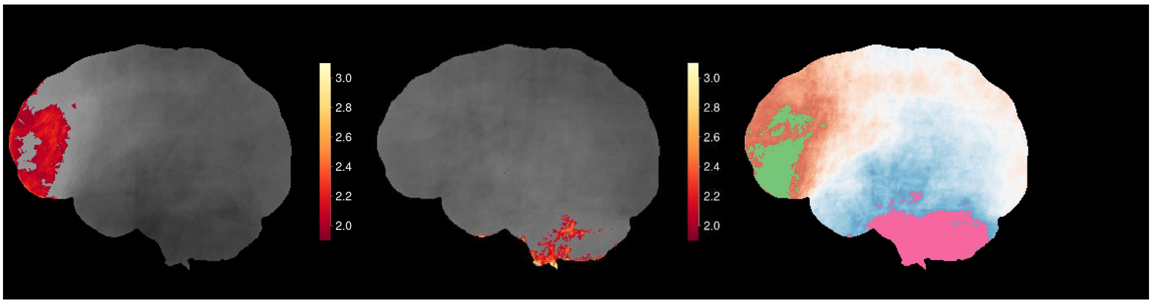


Figure 7. Location of consciousness (left) vs. motor control (middle), as well as their difference (right), for participants low (upper row) vs. high (lower row) in objectively assessed neuroscientific knowledge (based on a median split of participants' quiz scores).

In sum, results of Study 1b primarily show that the results obtained in Study 1a replicated in a paradigm in which participants had to remove color form a canvas rather than add to it, ruling out colorization effort as a potential confound. Further, participants saw a slightly modified brain outline, ruling out that they were unaware of which side of the brain was the front or back or where the eyes were located. Once more, participants on average revealed a localization of consciousness in a single are in the frontal part of the brain, while they located motor control further in the back.

In addition, we investigated the rationales participants followed when localizing consciousness. Most participants indicated that they followed their intuition, provided no clear rationale, or stated that they chose the area because this is where they felt their self was located. People's localization of consciousness was not affected by their rationale for colorization, their objective or subjective neuroscientific knowledge, or their reliance on intuitive or reflective information processing. Study 2 was designed to rule out other potential confounds as well as to extend the present findings.

Table 2. *Correlations with confidence intervals between our key variables (1-4) and additional correlates in the critical trial (consciousness) (Study 1b)*

			Key variables				Correlates								
Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Confinement (rev.)	66.49	25.30													
2. Orientation (L-R)	141.98	34.79	-.06												
			[-.16, .05]												
3. Orientation (U-D)	136.07	64.49	**.14****	**.23****											
			[.04, .24]	[.13, .32]											
4. Dispersion	1.42	1.70	**.18****	.03	.02										
			[.08, .27]	[-.07, .13]	[-.08, .12]										
5. Neuro-quiz score	6.20	1.46	-.00	-.02	-.06	.03									
			[-.11, .10]	[-.12, .08]	[-.16, .04]	[-.07, .13]									
6. Self-reported knowledge	2.45	1.27	.09	.08	.01	.00	**.15****								
			[-.01, .19]	[-.02, .18]	[-.10, .11]	[-.10, .11]	[.05, .25]								
7. CRT (reflection)	1.80	1.46	-.03	-.00	-.06	.01	**.15****	**.14****							
			[-.13, .07]	[-.10, .10]	[-.16, .04]	[-.09, .11]	[.05, .25]	[.04, .24]							
8. CRT (intuition)	1.69	1.31	.04	-.02	.01	.01	**-.17****	**-.16****	**-.88****						
			[-.07, .14]	[-.12, .09]	[-.09, .11]	[-.09, .11]	[-.27, -.07]	[-.26, -.06]	[-.90, -.85]						
9. Reliance on knowledge	3.35	1.79	**.12***	.06	-.02	.01	**.19****	**.55****	**.16****	**-.18****					
			[.02, .22]	[-.04, .16]	[-.12, .08]	[-.09, .11]	[.09, .28]	[.48, .62]	[.06, .26]	[-.27, -.08]					
10. Reliance on gut feeling	5.00	1.73	.08	-.01	**.15****	.06	**-.14****	**-.31****	**-.12***	**.11***	**-.48****				
			[-.02, .18]	[-.11, .09]	[.05, .25]	[-.04, .16]	[-.24, -.04]	[-.40, -.22]	[-.21, -.01]	[.01, .21]	[-.55, -.39]				
11. Rationale (scientific)	2.34	1.26	.07	.04	-.09	.06	**.13***	**.56****	.08	-.09	**.49****	**-.34****			
			[-.03, .17]	[-.06, .14]	[-.19, .01]	[-.05, .16]	[.03, .23]	[.48, .62]	[-.03, .17]	[-.19, .01]	[.41, .57]	[-.42, -.24]			
12. Rationale (naïve)	2.36	1.18	.04	.03	-.01	**.11***	**-.11***	-.04	**-.18****	**.15****	**-.15****	**.28****	**.23****		
			[-.07, .14]	[-.07, .13]	[-.11, .09]	[.01, .21]	[-.20, -.00]	[-.14, .06]	[-.27, -.08]	[.05, .25]	[-.24, -.04]	[.18, .37]	[.14, .33]		
13. Rationale (intuitive)	4.64	1.73	.05	-.01	.07	-.02	-.06	**-.11***	-.06	.04	-.10	**.30****	**-.11***	**.22****	
			[-.06, .15]	[-.11, .09]	[-.04, .17]	[-.12, .08]	[-.16, .04]	[-.21, -.01]	[-.16, .04]	[-.06, .14]	[-.20, .00]	[.21, .39]	[-.21, -.01]	[.13, .32]	
14. Neuro experience	1.28	0.65	.06	.01	-.02	-.03	**.13***	**.55****	.02	-.02	**.34****	**-.19****	**.32****	**-.12***	**-.15****
			[-.05, .16]	[-.09, .12]	[-.12, .08]	[-.13, .07]	[.02, .22]	[.47, .61]	[-.08, .12]	[-.13, .08]	[.24, .42]	[-.28, -.09]	[.23, .41]	[-.22, -.02]	[-.24, -.04]

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. Confinement is reverse coded, so that high values represent *less* confinement; * $p < .05$; ** $p < .01$.

Study 2: Conscious vs. Unconscious Thinking

Study 2 was designed replicate and rule out an additional potential confound in Studies 1a and 1b. Specifically, our goal was to test, whether people would locate any kind of mental activity that they associate with “thinking” in the brain area established in Studies 1a and 1b, or whether this location would be uniquely associated with *conscious* thinking. To that end, we decided to ask participants to locate both, the area(s) of the brain responsible for conscious thinking and the area(s) of the brain responsible for unconscious thinking. In line with our hypothesis that participants have specific lay beliefs about the location of consciousness, we predicted that only conscious thinking would be located in the area identified in Studies 1a and 1b and that people would reveal a different response pattern for unconscious thinking.[6]

Method

Participants and design. 451 participants were recruited from MTurk and participated for modest monetary compensation. 45 participants were excluded based on the same criteria outlined in Study 1a, leaving a final sample of 406 participants (234 female, 169 male, 3 other, $M_{\text{Age}} = 35.49$, $SD = 11.73$). After the tutorial, all participants worked on two drawing tasks, assessing location of conscious and unconscious thinking, respectively. To circumvent potential order effects, both drawing tasks were presented in random order.

Materials and procedure. The basic design of the study was identical to that of Study 1a. In this study, however, we randomized the order in which participants were presented the two main drawing tasks, in order to avoid potential order effects that might otherwise arise when

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[6] We also replicated this study with the eraser paradigm from Study 1b, with a somewhat smaller ($n = 201$) British student sample. Findings are highly similar and can be found in the SOM.

participants are asked to locate two rather similar mental processes. That is, even if they thought both processes happened in the same location(s), participants might be inclined to locate the second process differently, in an attempt to provide more varied responses. Therefore, half of the participants in this study were first asked to locate the "*area(s) of [their] brain which [they] think are involved in unconscious thinking*", while the other half was first asked to locate the "*area(s) of [their] brain which [they] think are involved in conscious thinking*". We decided to not speak of "consciousness", but rather of "conscious thinking", as we did not find "unconsciousness" or "sub-consciousness" to be adequate counterparts, and rather opted for "unconscious thinking" as the control process.

Results

Activation. In line with our hypothesis that participants believed consciousness to happen in a specific *part* of the brain, for conscious thinking, participants colorized an area (M = 13,761.03, SD = 12,628.33, number of pixels) smaller than half of all available pixels, $t(405) = -15.45$, $p < 001$, 95% CI = [12,528.97, 14,993.09], $d = -0.77$. Likewise, when locating unconscious thinking, people also colorized less than half of all available pixels, M = 9,616.99, SD = 9,654.90, $t(405) = -28.86$, $p < 001$, 95% CI = [8,675.03, 10,558.95], $d = -1.43$, a number that was also significantly smaller than that for conscious thinking, $t(405) = -6.64$, $p < 001$, 95% CI_{Δ} = [2,917.30, 5,370.77], $d_z = -0.33$.

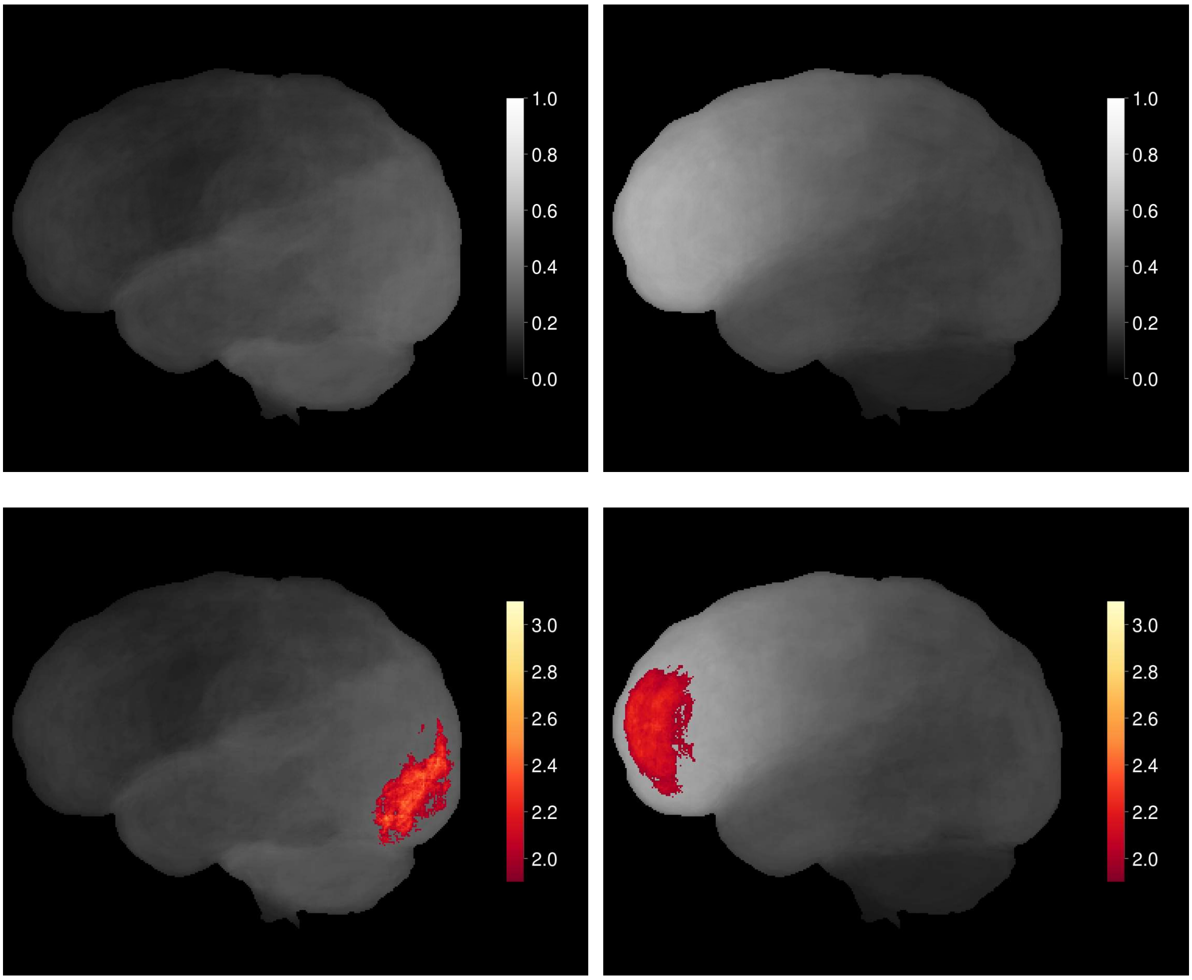

Figure 8. Average drawings created by participants in the unconscious (left) and conscious (right) thinking trials in Study 2. Brightness of each pixel indicates the frequency with which it was colorized by participants (in percentages). Highlighted pixels (bottom row) are pixels colorized significantly more often than others (alpha = .05), with values representing *z*-scores.

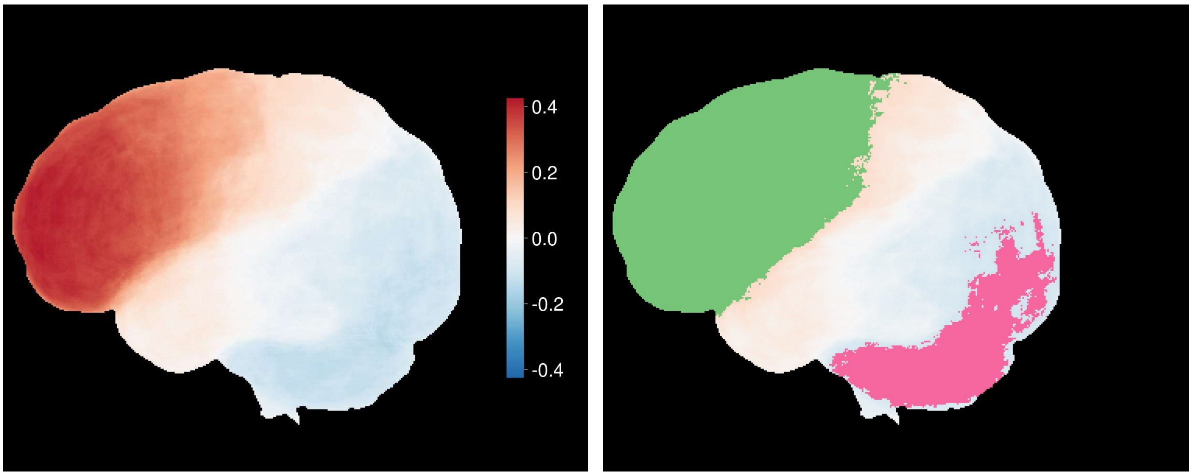

Figure 9. Differences between location of conscious and unconscious thinking (Study 2). Red colors indicate a greater relative colorization of a pixel for conscious thinking, whereas blue indicates more frequent colorization for unconscious thinking (left). Highlighted pixels indicate those pixels that were significantly more frequently colorized for conscious (green) or unconscious (pink) thinking, as determined by Fisher's exact test (right).

Location. Figure 8 displays the location of conscious and unconscious thinking across participants. As hypothesized, we once more found that people locate conscious thinking in the frontal part of the human brain. Unconscious thinking, on the other hand, was predominately located in the occipital part of the brain, corresponding to the colloquial use of keeping something "in the back of one's head". Differences in drawings for conscious and unconscious thinking are displayed in Figure 9.

Spatial orientation. Supporting the hypothesis that participants would locate conscious thinking in a *different* location than unconscious thinking, both the up-down ($r(401) = -.10$, p = .045, 95% CI_r = [-.196, -.002]) and left-right orientation vectors ($r(401) = -.52$, $p < .001$, 95% CI_r = [-.58, -.44]) were negatively correlated. In other words, regardless of where participants located conscious thinking, they thought that unconscious thinking would take place in a different brain region.

As a result, similar to Studies 1a and 1b, participants located conscious thinking more frontal (*M* = -0.22, *SD* = 0.40) than they did unconscious thinking (*M* = 0.19, *SD* = 0.40), $t(402) = -11.61$, $p < .001$, 95% CI_{Δ} = [-0.47, -0.34], $d_z = -0.58$. Likewise, they located conscious thinking (*M* = -0.14, *SD* = 0.27) more upward than unconscious thinking (*M* = 0.04, *SD* = 0.37), $t(402) = -7.37$, $p < .001$, 95% CI_{Δ} = [-0.22, -0.13], $d_z = -0.37$.[7] Individually comparing the orientation vectors against the mid planes (i.e. a non-preference for left/right and up/down orientation), analyses confirmed our previous results, showing that conscious thinking was indeed located in the front, $t(403) = -10.86$, $p < .001$, 95% CI = [-0.26, -0.18], $d = -0.54$, and up, $t(403) = -10.22$, $p < .001$, 95% CI = [-0.16, -0.11], $d = -0.51$, while unconscious thinking was rather located in the back, $t(403) = 9.36$, $p < .001$, 95% CI = [0.15, 0.23], $d = 0.47$, and slightly down, $t(403) = 2.11$, $p = .036$, 95% CI = [0.003, 0.074], $d = 0.10$.

Dispersion. Critically, as in Study 1a, most participants colorized a single (as opposed to multiple) cluster of pixels when asked to highlight areas responsible for conscious thinking (88.9%, $n = 359$ vs. 11.1%, $n = 45$), a number significantly greater than chance; binomial test: $p < .001$, 95% CI_{prob} = [0.85, 0.92]. For unconscious thinking those numbers were comparable (86.9%, $n = 351$ vs. 13.1%, $n = 53$; binomial test: $p < .001$, 95% CI_{prob} = [0.83, 0.90]). Both ratios were not significantly different from one another, $\chi^2(1) = 0.57$, $p = .451$.

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[7] To rule out that these effects can be attributed to demand effects caused by our repeated measures design, we reran our analysis only including participants' first drawings in a between-subjects analysis. Both independent-sample *t*-tests revealed comparable significant differences.

Confinement. As trials in Study 2 were designed to contrast participants' conception of two kinds of mental faculties (conscious vs. unconscious thinking), we decided to test whether confinement differed between the two conditions. Participants revealed greater confinement of unconscious (M = 57.83, SD = 27.21, average pixel distance) than of conscious thinking (M = 65.36, SD = 27.87), $t(402) = -5.13$, $p < .001$, 95% CI_{Δ} = [4.56, 10.23], $d_z = -0.26$.

Discussion

Conceptually replicating and expanding on Studies 1a and 1b, Study 2 found additional support for a lay belief in a Cartesian Theater. Once more, participants on average located a conscious process (i.e., conscious thinking) in a single, confined region in the frontal part of the brain, while they located an unconscious process elsewhere. As such, participants did not merely locate any kind of "thinking" in the prefrontal brain area determined in Study 1a, but specifically *conscious* thinking. In line with common sayings, participants tended to locate unconscious thinking in the back of the head, far away from where they believed conscious processes to take place. Surprisingly, and in contrast to the predominant view that most mental processes happen unconsciously (e.g., Augusto, 2010), participants revealed greater confinement of unconscious than of conscious thinking. One possible reason for this effect could be that participants consider conscious thinking a more complex phenomenon than unconscious thinking which therefore requires the use of larger parts of the brain (see analysis for general activation above). This explanation is also consistent with Studies 1a and 1b, where we observed greater confinement for the arguably less complex process of motor control compared to consciousness.

Study 3: Processing vs. Experiencing Stimuli

Thus far, we established that people locate consciousness and conscious processes (such as conscious vs. unconscious thinking) in a single, confined location in the frontal part of the human brain. Study 3 was designed to further expand on these findings. While Study 2 already found that people seem to locate unconscious processes elsewhere in the brain, Study 3 was designed to directly compare participants' beliefs regarding two components (one conscious and one unconscious) of the *same* mental faculty. We thereby sought to test the hypothesis of a lay belief in a Cartesian Theater by even more closely following the original description of this phenomenon. Specifically, one mental faculty that is typically evoked when describing the concept of the Cartesian Theater (e.g., Dennett, 1991) is the perception of sensory stimuli, which comprises two distinct components: the computational analysis of sensory information in the brain, and the corresponding conscious experience of this information.

According to Dennett's argument (1991), the Cartesian Theater arises, because people believe that, after the brain is done processing and analyzing sensory stimuli it encounters (including all necessary computations), everything arrives at a single location in the brain where then "consciousness happens". Such an understanding necessarily entails that processing and experience of a perceived stimulus either A) happen in different parts of the brain altogether, or B) that it happens in approximately the same parts of the brain, but that a larger area is responsible for the processing and analysis of sensory stimuli, while conscious experience takes place in a smaller segment of this area.

The present study was designed to test which of these two notions (if any) best represents participants' lay beliefs. While results of Study 2 suggest that participants locate unconscious processes in different brain areas than consciousness (which could favor hypothesis A), we predicted that—given that the present study investigates two components of the same mental faculty (namely sensory perception)—participants would locate both components in roughly the same, single area in the frontal part of the brain, but that they would consider conscious experience to be a more spatially confined process (hypothesis B). We further expected participants to locate conscious experience of the stimuli in the same, single location in the frontal part of the brain we determined in Studies 1a, 1b, and 2.

Method

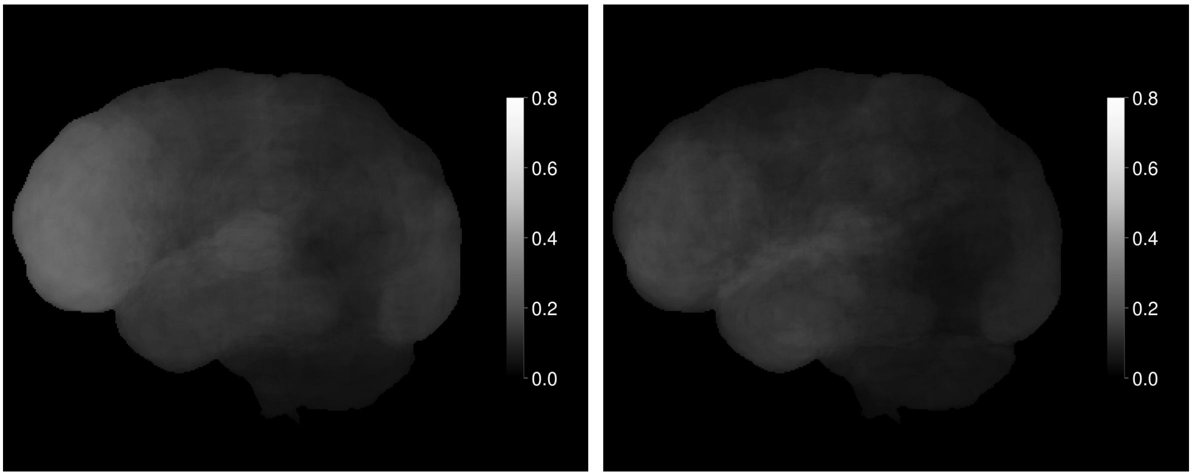
Participants and design. As in the other studies, we recruited 452 participants from MTurk. Of those, 44 participants were excluded based on the same exclusion criteria introduced in the previous studies. This left us with a final sample of 408 participants (237 female, 171 male, $M_{\text{Age}} = 34.78$, $SD = 10.74$) who were randomly assigned to one of four sensory conditions: *sight*, *hearing*, *touch*, or *smell* (between subjects). Within each condition, participants were asked to work on two similar drawing tasks, presented in random order, assessing where in the brain participants believed the processing/computation of the respective sensory information takes place (*processing)*, and where they believed the corresponding conscious experiences takes place (*experience*) (within subjects). As we had no hypothesis with regard to the different sensory stimuli, we decided a priori to merge the four sensory conditions to arrive at average images representing location of general sensory processing and conscious experience.

Materials and procedure. We followed the same general outline of the previous studies. Depending on condition, after the tutorial for the drawing task, participants were once again prompted to colorize certain brain areas, either pertaining to the sense of vision, hearing, touch, or smell. For example, in the *sight* condition, we first told participants: "*In this task, we are interested in the sense of sight.*" Depending on order condition, we then asked them to either "*use [their] brush to colorize the area(s) of [their] brain which [they] think are involved in [their] subjective conscious experience of seeing*" (assessing the *experience* component), or *"which [they] think are involved in the computational processing and analyzing of all visual* *information*" (assessing the *processing* component). This was followed by a second drawing task with the corresponding alternative instructions. In the remaining between-subjects conditions, the words "seeing" and "visual" were replaced with hearing/auditory, touch/tactile, and smell/olfactory, respectively.

Finally, participants provided demographic information and responded to the binary exclusion item querying them about random or purposefully wrong responding.

Results

Activation. In line with the theoretical rationale of both hypotheses, people thought that a larger part of the brain was required for the computational analysis (M = 6,469.69, SD = 6,975.92 pixels; 13.80%) of sensory stimulus than for the corresponding conscious experience (M = 4,754.04, SD = 4,327.60; 10.14%), $t(404) = 4.43$, $p < .001$, 95% CI_{Δ} = [2.39, 6.19], $d_z = 0.25$. As we were asking each participant about only one specific sensory experience, those numbers were expectedly lower than for overall "conscious thinking" or "consciousness" activation investigated in Studies 1 and 2.



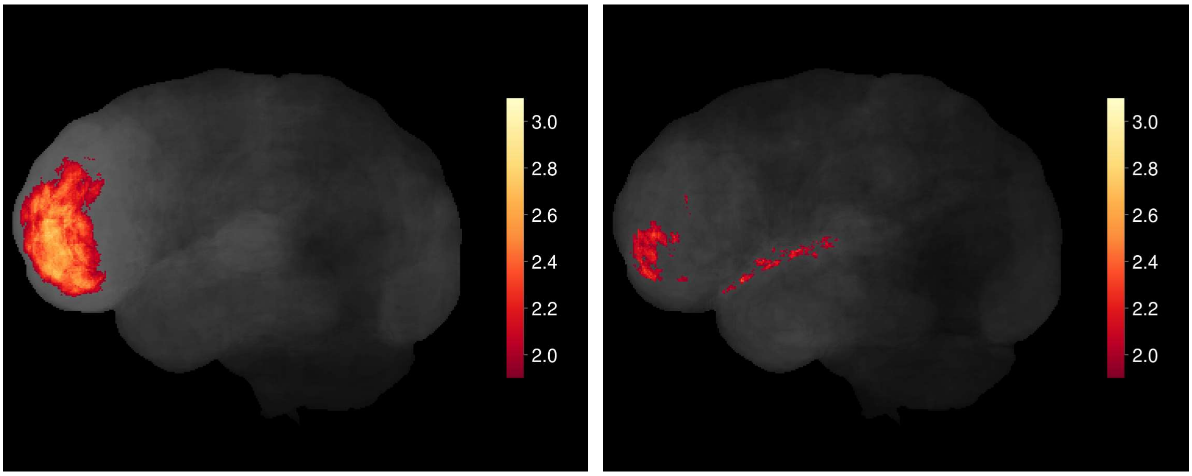


Figure 10. Mean pixels colorized for processing (left) and experience (right) of a stimulus. As general activation levels for each pixel were lower than in Studies 1a, 1b, and 2, we amplified the colors so that 100% white pixels correspond to 80% activation. Highlighted pixels (bottom) were colored significantly more frequently than others (based on *z*-scores; alpha level = 0.05).

Location. Figure 10 shows participants' location of brain areas involved in computational processing versus conscious experience of sensory stimuli. While differing in the degree of activation, we found that people located both in the frontal part of the human brain.

Spatial orientation. Comparing the two components of sensory perception, we did not find that people located them differently on the X and Y axes of the brain. Specifically, while the horizontal orientation of drawings was uncorrelated, $r(403) = .02$, $p = .649$, 95% $CI_r = [-0.07, 0.12]$, the vertical orientation of drawings was positively correlated, $r(403) = .14$, $p = .005$, 95% $CI_r = [0.04, 0.23]$. In other words, people considered the processing and conscious experience of stimuli to (roughly) happen at a similar location in the brain. Correspondingly, we did neither find an overall trend for participants to locate processing (X: $M = -0.11$, $SD = 0.48$; Y: $M = -0.08$, *SD* = 0.34) or experience (X: *M* = -0.06, *SD* = 0.44; Y: *M* = -0.05, *SD* = 0.37) further in the front or the back of the brain than the other, $t(404) = 1.44$, $p = .151$, 95% CI_{Δ} = [-0.02, 0.11], $d = 0.07$, nor further up or down than the other, $t(404) = 1.51$, $p = .132$, 95% CI_{Δ} = [-0.01, 0.08], $d = 0.07$.

In line with results for the non-differentiated faculty “consciousness” investigated in Studies 1a and 1b, as well as “conscious thinking” investigated in Study 2, both the conscious experience ($t(405) = -2.77$, $p = .005$, 95% CI = [-0.10, -0.02], $d = -0.14$) and processing components of sensory stimuli ($t(405) = -4.52$, $p < .001$, 95% CI = [-0.15, -0.06], $d = -0.22$) were located significantly in the front of the brain’s mid-coronal plane. Processing was located more upwards ($t(405) = -4.91$, $p < .001$, 95% CI = [-0.12, -0.05], $d = -0.24$), as was conscious experience, $t(405) = -2.59$, $p = .001$, 95% CI = [-0.08, -0.01], $d = -0.13$.

Dispersion. Once more supporting the hypothesis of a general lay belief in a Cartesian Theater, the vast majority of participants colorized a single cluster of pixels, both when locating computational processing (91.4%, $n = 371$ vs. 8.6%, $n = 35$, binomial test: $p < .001$, 95% CI_{prob} = [0.88, 0.94]) and conscious experience of sensory stimuli (91.9%, $n = 373$ vs. 8.1%, $n = 33$, binomial test: $p < .001$, 95% CI_{prob} = [0.89, 0.94]). Both ratios were not significantly different from one another, $\chi^2(1) = 0.02$, $p = .900$.

Confinement. More importantly, however, we again used average pixel distance to determine the confinement of participants’ drawings. Confirming our hypothesis, we indeed found that confinement was stronger for conscious experience (*M* = 41.25, *SD* = 21.46) than for computational processing of sensory information (*M* = 45.52, *SD* = 23.04), $t(404) = -4.43$, $p < .001$, 95% CI_{Δ} = [-6.19, -2.38], $d_z = -0.22$. In other words, supporting hypothesis B, although people roughly located processing and conscious experience in similar brain regions, they considered the conscious component of perception to happen in a smaller, more confined area. As the conservative approach of averaging across senses was likely to add noise to the data, we also exploratorily analyzed responses to each of the four individual senses. We found that people considered conscious experience to take place in a more spatially confined area for all but one of the senses (visual: $t(96) = -0.09$, $p = .930$, 95% $CI_{\Delta} = [-5.05, 4.62]$, $d_z = -0.01$; auditory: $t(99) = -4.55$, $p < .001$, 95% $CI_{\Delta} = [-10.99, -4.32]$, $d_z = -0.46$; tactile: $t(109) = -3.18$, $p = .002$, 95% $CI_{\Delta} = [-8.64, -2.00]$, $d_z = -0.30$; olfactory: $t(97) = -1.95$, $p = .054$, 95% $CI_{\Delta} = [-7.43, 0.07]$, $d_z = -0.20$).

Discussion

Study 3 tested the hypothesis that people will reveal a general lay belief in a Cartesian Theater (as defined initially), even when considering only one mental faculty (as opposed to two different faculties as in Studies 1a, 1b, and 2). Specifically, Study 3 found that participants tended to locate both conscious (i.e., experiential) and unconscious (i.e., computational) components of sensory perception in a single, confined area in the frontal part of the brain. However, supporting the idea of a lay belief in a Cartesian Theater (specifically, hypothesis B), they considered conscious experience to take place in a more spatially confined area than the corresponding computational processing of sensory impressions.

Study 4: Spatial vs. Temporal Localization

In our remaining set of studies, our goal was to investigate the second component of the Cartesian Theater that we specified in accordance with Dennett and Kinsbourne's argument (1992): temporal localization/isolation of consciousness. According to these authors, people seem to believe that only *after* the brain is done analyzing and processing information, everything arrives at a single, confined area in the brain where consciousness happens. The present study was designed to investigate the relationship between explicit belief in specific spatial and temporal localization of consciousness, using a newly developed questionnaire assessing both constructs. Specifically, we hypothesized that spatial and temporal confinement of consciousness would constitute unique beliefs that are positively correlated.

Method

Participants and design. 301 participants were recruited from MTurk and participated for modest monetary compensation. Out of those participants, 43 were excluded from analyses for indication of having responded randomly, or for failing an additional attention check item (see below), leaving a final sample of 258 participants (156 female, 101 male, 1 other, $M_{\text{Age}} = 37.34$, $SD = 12.27$). All participants completed a newly developed questionnaire intended to assess beliefs about temporal as well as spatial localization of subjective conscious experience.

Materials and procedure. In order to familiarize participants with the concepts at hand, they were first presented with an introductory screen (Figure 11). On this screen, they were told: "*When you encounter sensory stimuli (e.g., the light beams that hit your eyes after being reflected off a tree), two things happen in your brain next:*". Below, this text was illustrated with a diagram and two info boxes, next to one another, that explained the two consequences mentioned in more detail. The left box stated: "*Your brain creates the subjective, conscious experience (or the sensation) of seeing a tree*.", followed by a picture of a tree with blurry edges. The right box stated: "*Your brain computationally processes and analyzes all the sensory information arriving from your retina",* followed by a picture of a computer circuit. We purposefully placed the two boxes next to one another, with a split arrow pointing at both of them simultaneously, in order not to suggest a certain temporal order of events. As people in Western cultures might still associate *left* with *earlier*, we decided to follow the empirically more conservative route and placed conscious experience—the process that we theorized would be considered by participants to occur later—on the left.

Participants were then told that the study was interested in how they thought these two concepts would relate to one another when it comes to when and where they take place in the brain, and asked to indicate their level of agreement with a set of 6 statements using a Likert-type scale ranging from 1 (*not at all*) to 7 *(very much*). Three of these items were intended to assess belief in spatial localization of consciousness (that is, consciousness happening at a specific location in the brain: "*Consciousness happens everywhere in the brain, not just in a specific area*" (reversed), "*Consciousness happens at a specific location in the brain*", and "*A certain area of the brain is responsible for our subjective conscious experience of things*"). The remaining three items were intended to assess belief in temporal localization/isolation (that is, consciousness happening only after processing of stimuli has finished: "*Our brain first analyzes all stimuli that we encounter, and only after that can we experience them*", "*Only after the brain is done processing and analyzing sensory information conscious experience takes place*", and "*Conscious experience of a stimulus is a phenomenon that occurs WHILE the brain is processing and analyzing that stimulus, not after*" (reversed).

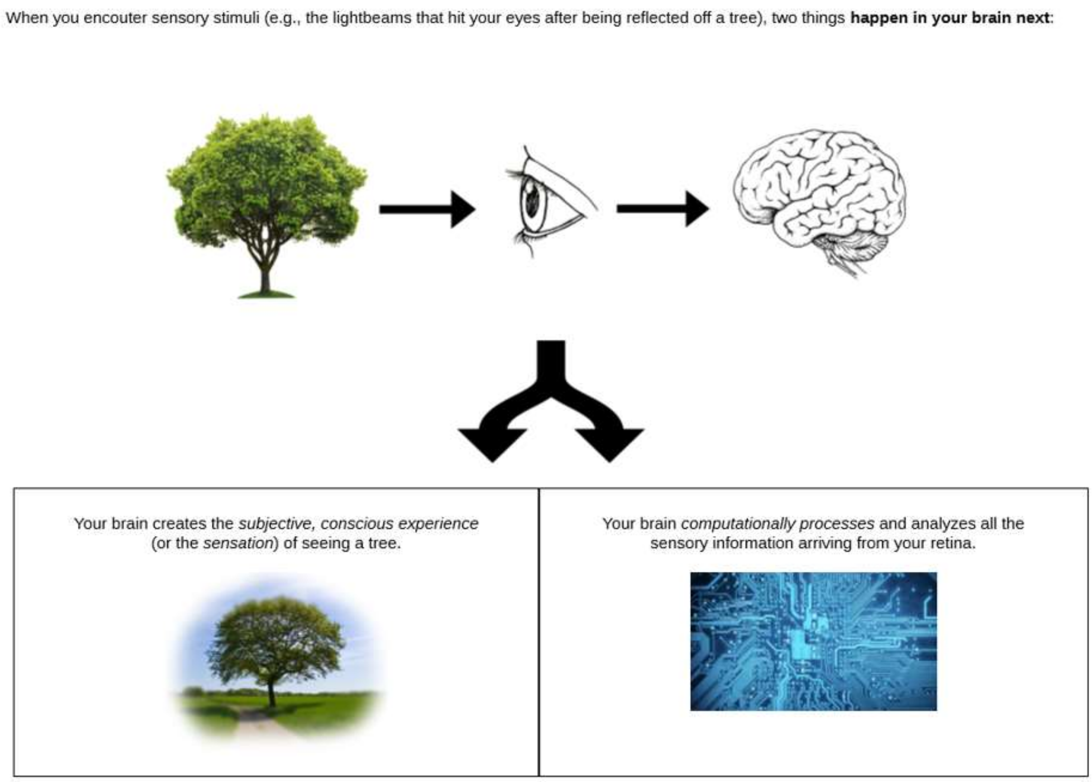


Figure 11. Introduction to conscious experience and processing of sensory information used in Studies 4 (fixed order, as displayed) and 5 (random order).

Participants also responded to a single attention check item. They were shown a simple math equation (4 + 2) and, in the instructions, were asked to ignore the equation but to simply enter the number 8 as their response. Finally, participants provided demographic information and responded to the exclusion item asking them about random or purposefully wrong responding.

Results

In order to test whether our items indeed captured two distinct beliefs, we entered all items into an exploratory principal component analysis with Varimax rotation and Kaiser normalization. As hypothesized, two factors with Eigenvalues greater than 1 emerged (1.59 and 2.44), cumulatively explaining 67.26% of the total variance. The three items comprising the *spatial localization* subscale loaded strongest on factor 1 (with factor loadings of .904, .850, and -.797), while none of the other items loaded on this factor (all factor loadings < .15). Conversely, the three items comprising the *temporal localization* subscale loaded strongest on factor 2 (with factor loadings of .879, .872, and -.519), while the remaining three items did not meaningfully load on this factor (all factor loadings < .12). We therefore created two mean scores out of the six items representing the two beliefs (spatial: $M = 4.43$, $SD = 1.48$; temporal: $M = 4.26$, $SD = 1.33$), with higher values indicating greater belief in the respective notion.

Importantly, as hypothesized, both beliefs were positively correlated, $r(258) = .18$, $p = .004$, 95% $CI_r = [0.03, 0.32]$. In addition, on average, people rather agreed than disagreed with the two beliefs. Both people's mean belief in spatial localization ($t(257) = 4.66$, $p < .001$, 95% $CI_\Delta = [0.25, 0.61]$, $d = 0.29$) and in temporal localization of consciousness ($t(257) = 3.10$, $p = .002$, 95% $CI_\Delta = [0.09, 0.42]$, $d = 0.19$) were significantly greater than the scale midpoint. Further, a paired samples *t*-test revealed that people's belief in spatial localization of consciousness was not significantly greater than their belief in temporal localization, $t(257) = 1.53$, $p = .127$, 95% $CI_\Delta = [-0.05, 0.39]$, $d_z = -0.10$.

Discussion

Conceptually replicating the previous results based on our drawing task and expanding them by including a temporal dimension, we found that a belief in consciousness happening at a specific location in the brain (spatial) and belief in consciousness happening *after* processing of all relevant information is done (temporal) constitute independent beliefs that are positively correlated, and that mostly people seem to explicitly endorse. This further supports the hypothesis that most people share a lay belief in a neurological Cartesian Theater. We designed Study 5 to verify the findings pertaining to belief in temporal confinement of consciousness using a more intuitive and elaborate measure.

Study 5: Temporal Localization of Processing vs. Experiencing

In our final study, our goal was to gain more insight into how precisely people perceive the temporal overlap between processing and consciously experiencing stimuli. In other words, we wanted to test, whether people perceive a temporal dynamic between the two dimensions that is either in line with the notion that conscious experience is a byproduct (i.e., that unfolds in parallel to) or a result (i.e., that unfolds subsequent to) of the processing of stimuli. Theoretically, it is possible for people to believe that consciousness begins at exactly the same moment that the processing of a stimulus begins (or earlier, or later), and that it ends at exactly the same moment this processing ends (or earlier, or later). We therefore set out to develop a task that is able to accurately assess these intuitions. Based on our previous findings, we hypothesized that people would on average consider consciousness to "happen" (that is, to start or to persist) after the processing and computational analysis of a stimulus has ended, that is, to conceptualize it as a "final destination" of signals.

Method

Participants and design. 223 participants were recruited from MTurk and participated in exchange for modest monetary compensation. 16 participants were excluded from data analysis, as they failed to correctly respond to an attention-check item. 9 further participants were excluded for not providing usable answers on the slider item[8], leaving a final sample of 198 participants (107 female, 90 male, 1 other, M_{Age} = 37.07, SD = 12.45). All participants were randomly assigned to one of two stimulus order conditions.

Materials and procedure. Participants were first introduced to the concepts of conscious experience and computational processing, as described in Study 4. We again told participants that we were interested in how they thought the two concepts related to one another, "*when it comes to WHEN they take place in the brain after the sensory stimulus (i.e., the real tree) was encountered*". They were then introduced to two sliders, one labeled "computation", the other "experience", placed on two horizontal lines below one another, representing the two concepts explained to them earlier (Figure 12).

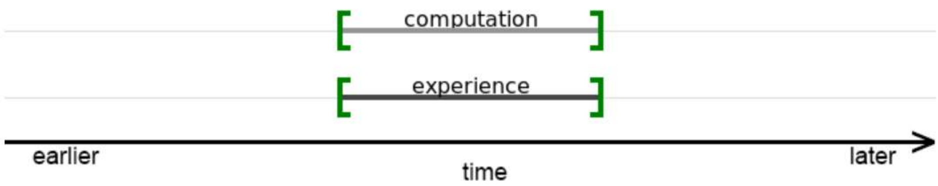


Figure 12. The slider task (starting position) used in Study 5 (vertical items presented in random order). Participants could move each of the four green endpoints to the left or right, affecting the onset, end, and duration of the two events.

[8] These participants moved all four slider endpoints to zero, indicating that neither processing nor experiencing a stimulus happened at all (as the width of both bars was zero). Including them does neither change the pattern nor the statistical significance of the effects reported here.

They were then told that "*each slider [had] two green endpoints, with the left endpoint indicating when the respective event begins and the right endpoint indicating when it is fully over.*" Participants could click on each of the four slider endpoints and individually move them to the left or to the right, thereby changing beginning, ending, and overall duration of the two events. They were informed that, in general, "*events that are positioned further to the left happen earlier, while events that are positioned further to the right happen later. Overlapping events happen at the same time".* To implement an unbiased test for our hypothesis, we set the default position of the two sliders to be identical (that is, perfectly aligned), representing the view that both processing and experience of a stimulus happen at exactly the same time.

To further circumvent potential confounds due to order of display, we assigned participants to one of two stimulus order conditions: In one condition, *experience* was explained in the left info-box and assessed on the lower of the two slider items, while *computation* was explained in the right info-box and assessed on the upper slider item. In the other condition, the orders were switched.

In addition to providing demographic information, prior to the main dependent variable, participants responded to a single attention check item, asking them to move a ten-point slider to a specific position, which served as an exclusion criterion for this study.

Results

The X-coordinates (that is, the distance in pixels from the leftmost point of the respective horizontal line, each of which was 800 pixels wide) of each of the four slider endpoints served as our dependent variables, with greater values indicating later points in time. In line with our hypothesis, we found that, on average, participants positioned the experience sliders (that is, the midpoint between the two endpoints) further to the right (*M* = 455.36, *SD* = 85.76) than the computation slider; *M* = 426.64, *SD* = 87.51, $t(197) = 2.80$, $p = .006$, 95% CI_{Δ} = [8.47, 48.95], d_z = 0.19. In other words, on average, participants considered conscious experience to happen later than computational processing of stimuli.

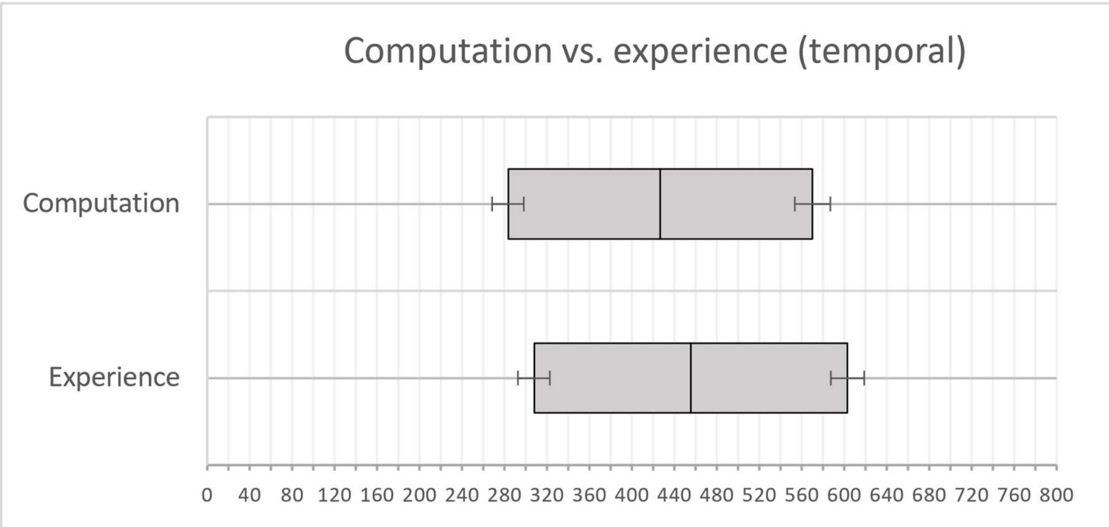


Figure 13. People's temporal location of neural computation and conscious experience (Study 5). Values on the x-axis represent pixels on the screen, with higher numbers corresponding to chronologically later events. Error bars indicate 95% confidence intervals (based on 5000 bias-corrected and accelerated bootstraps).

Looking at the individual slider endpoints, we found that participants on average believed that conscious experience (*M* = 307.94, *SD* = 102.59) would begin later than computational processing (*M* = 283.50, *SD* = 107.71), $t(197) = 2.34$, $p = .020$, 95% CI_{Δ} = [3.83, 45.05], d_z = 0.17. More important for our hypothesis, and in line with Dennett's (1991) concept of a Cartesian Theater, they considered conscious experience to persist (*M* = 602.78, *SD* =

115.85) even after computational processing fully ended (M = 569.79 SD = 119.15), $t(197)$ = 2.81, p = .006, 95% CI_{Δ} = [9.80, 56.17], d_z = 0.20 (Figure 13).

Discussion

Supporting the hypothesis that people, on average, believe conscious experience happens as a result of rather than as a byproduct of computational processing of stimuli, we found that people consider the conscious experience of a visual stimulus to persist even after the processing of that stimulus is completed. We did, however, not find that participants considered conscious experience to *begin* after computational processing has ended. Rather, there was substantial overlap between the two events. Still, participants considered consciousness to partly happen after computation has ended, and to therefore be the ultimate event in the process of perception. A reason for the substantial overlap between both bars could be the conservatively-chosen default position of the two bars (representing full overlap) that may have affected participants' responses. Notably, given that they are frequently used to explain the concept of a Cartesian Theater, we only compared conscious experience and computational analysis of *sensory perception* in this study. It is possible that, in some cases, people consider conscious thought to precede other mental processes, for example when initiating motor actions to pursue a goal. However, this may depend on whether they view these mental events as separate, consecutive events or as two aspects of the same mental event, which is how we introduced the two constructs in the present study.

General Discussion

Across six studies, using a combined sample of 2,057 US and UK-based participants (plus two additional studies in the SOM), we found that people have a spatio-temporally localized conception of consciousness that is in line with the notion of a (neurological) Cartesian Theater, as suggested by Damasio (1992) and Dennett and Kinsbourne (1992). They consistently considered a single, confined area of the brain to contribute to consciousness, and located conscious processes (but not unconscious thinking or motor control) in the prefrontal part of the brain. Locations of consciousness were primarily based on intuitions as opposed to, for example, naïve or scientific reasons, and were not affected by neuroscientific knowledge.

Testing Dennett's (1991) proposition of a lay belief in a Cartesian Theater more directly (i.e., the belief that information *arrive* at their neurological destination where consciousness happens), we distinguished between two components of sensory perception, computational analysis and conscious experience of sensory information, and found that participants considered conscious experience to be a more strongly spatially confined process in the brain, and to involve less brain activity, than computational processing.

When explicitly asked, we found that participants hold two distinct beliefs about consciousness, one pertaining to consciousness happening at a specific location in the brain (spatial localization), the other pertaining to consciousness happening *after* processing of sensory information is done (temporal localization). Both beliefs were positively correlated. Supporting this rationale, in a final study using a more intuitive measure, we found that participants considered conscious experience of sensory information to persist even after the processing of the corresponding stimuli ended, indicating that they considered consciousness a result (i.e. a simultaneously-occurring phenomenon), rather than a by-product (i.e., a subsequently-occurring downstream consequence) of computational analysis.

Interestingly, most participants revealed a tendency to consider all mental faculties they were presented with to take place in individual, confined brain areas, suggesting that lay people may have a view of the brain as an organ in which each individual part is responsible for a clearly defined task, rather than as a network of jointly operating systems. Yet, the present selection of mental faculties is likely not sufficient to confirm this claim. While we were exclusively interested in participants' conception of consciousness (and included the other processes to show that they discriminate between mental faculties and have distinct beliefs about the location of consciousness), these findings do not allow to conclude that participants consider consciousness to take place in a single area due to their subjective experience of a unified and continuous stream of consciousness. Further research would be necessary to determine if this is indeed the case.

Another noteworthy observation in Study 2 is that people considered less of the brain responsible for unconscious than conscious thinking. Typically, one would assume that—in line with modern psychological views—people would estimate most cognitive processes to happen unconsciously, with consciousness only being the metaphorical tip of the iceberg. Apparently, though, lay people seem to hold a different view. One possible explanation for people's overestimation of brain activity involved in conscious versus unconscious thinking could be that the extent of the latter is per definition not salient to them, whereas consciousness is experienced as complex, pervasive, and highly variable. Similarly, participants might entertain a general belief that more complex processes—such as conscious thinking—involve more neurological activity and space in the brain than less complex processes (e.g., motor control and unconscious thinking).

Theoretical contributions, limitations and future research

With the present research, we were able to gather empirical data suggesting the existence of neuropsychological lay beliefs regarding consciousness, which align with Damasio's (1992) hypothesis about a general (non-dualistic) belief in a neurological Cartesian Theater, both in terms of its spatial and temporal aspects. Over the course of this project, we expanded upon past research by developing new, easily administered paradigms to assess these abstract, metaphysical beliefs. This includes a flexible task for assessing lay beliefs about the location of brain areas responsible for certain mental faculties, a newly-developed 2-factor questionnaire assessing explicit belief in temporal and spatial localization of consciousness, as well as an intuitive, slider-based task to assess onset, end, and duration of mental events.

As outlined earlier, while there was no direct investigation into lay beliefs in a Cartesian Theater, a few studies have addressed the question of where people locate their selves. Yet, in many of those studies, participants were instructed to select a *single* location where they thought their self was located (suggesting the existence of a Cartesian Theater), and participants were not able to specifically select different brain areas. As such, our findings critically extend and help to conceptually clarify the literature on lay beliefs about consciousness and the location the self, introducing more precise and versatile measures, especially with regard to beliefs pertaining to the location of the self within the brain.

In general, future research may address some of the obvious limitations of the present work. For example, as we were interested in participants' localization of consciousness in the brain, we did not give them the opportunity to colorize areas in other parts of the human body. Past research suggests that people report feeling emotions throughout their entire bodies, despite them being mental events (Nummenmaa et al., 2014). Although emotions are certainly not the same as consciousness, and past research already established that most people locate the *self-as-perceiver* in the head of a human silhouette (Limanowski & Hecht, 2011), providing participants with a human outline might still yield some interesting results.

Another limitation of the present studies is the fact that we were only able to provide participants with a 2-dimensional, lateral outline of the brain to colorize—due to technical limitations. As such, we were not able to determine whether people were referring to areas in the neocortex or subcortical parts of the brain. While this aspect is not necessarily essential for determining whether people consider consciousness to take place in a single, confined area, it would make the descriptive assessment of *where* people locate it more accurate.

Likewise, while we found people to colorize a single area of the brain, one should be careful in interpreting the *absolute* size of this area. Given that the image of the brain was 2-dimensional, it is impossible to determine exactly how much of an “actual” brain people believed to be involved in consciousness. In addition, the brush sizes participants were provided with did not allow colorizing a single “point” inside the brain (pertaining to the terminology sometimes used when talking about the Cartesian Theater). As the image of the brain was comparably small (to allow for pixel-level analyses), a single click with the large brush, for example, already corresponds to 1.5% of the entire brain. A larger image would most likely have resulted in lesser colorization overall, given that small movements with the mouse pointer while colorizing would have colorized a comparatively smaller area of the brain.

Another avenue for future research programs revolves around the question which additional personality traits, beliefs, or attitudes predict belief in a Cartesian Theater in general, and belief in temporal and/or spatial confinement of consciousness in particular. For example, while reliance on intuition and reflection were not associated with people’s belief in our studies (Study 1b), it is conceivable that certain aspects of people’s personality that affect how they perceive the physical world outside of their minds—for example subclinical levels of derealization or depersonalization—are related to these beliefs. Further, in addition to a belief in mind-body dualism (Forstmann & Burgmer, 2015, 2017, see SOM), intrinsic religiosity—specifically religious belief that involves the concept of an afterlife or immortal souls—is likely to be associated with a belief in a Cartesian Theater (see SOM). Knowing which traits are associated with a belief in a Cartesian Theater also constitutes the first step in answering how one may be able to explain this belief in both scientists and lay people.

More practically speaking, whether people endorse the notion of a Cartesian Theater may also affect how they evaluate the consequences of certain brain injuries or diseases (e.g., those that specifically target the frontal part of the brain), and may affect whether they think patients suffering from these conditions are still “the same”. Likewise, the temporal component of the Cartesian Theater could have implications for how people judge behavior (e.g., when they assign blame for transgressive behaviors). Although we did not find that lay belief in free will predicted the spatial aspect of people’s localization of consciousness (see SOM for these results), it remains a possibility that a belief in consciousness happening comparably late in the chain of mental events is negatively associated with ascriptions of voluntariness or free choice to a target.

In sum, Damasio’s (1992) claim that a (neurological) Cartesian Theater “is certainly the common-sense concept of the nonscientist and nonphilosopher in the street.” (p. 208), seems to hold true, both intuitively and explicitly—at least for the population in which the present research was conducted. Our findings therefore support earlier theoretical reasoning on how lay people conceptualize consciousness, and critically extend previous research in this domain.

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