Abstract

The ancient mind/body problem continues to be one of deepest mysteries of science and of the human spirit. Despite major advances in many fields, there is still no plausible link between subjective experience (qualia) and its realization in the body. This paper outlines some of the elements of a rigorous science of mind (SoM) - key ideas include scientific realism of mind, agnostic mysterianism, careful attention to language, and a focus on concrete (touchstone) questions and results.

The Scientific Reality of Mind

The mystery of the mind is now often called “The Hard Problem”. The popular 2015 Tom Stoppard play by that name is available on the web as video with reviews, etc. A first step towards a SoM is to acknowledge that there is a problem. It is currently conventional, almost mandatory, to assert (without evidence) that there is no problem. This quote from the distinguished clinician and neuroscientist Michael Gazzaniga is typical.

“Instead of an immaterial mind floating around with each of us, modern science has moved the mind into the brain and made it very physical” (10, p.28).

If we do acknowledge the mystery, the question arises of how it could be addressed scientifically. Any science of mind is necessarily committed to scientific realism (1). As is often the case, Rebecca Goldstein puts it best:

“Scientific realism is the view that science expands upon—and sometimes radically confutes—the view of the world that we gain by means of our sense organs. Scientific theories, according to this view, extend our grasp of reality beyond what we can see and touch, pulling the curtain of our corporeal limitations aside to reveal the existence of whole orders of unobserved and perhaps unobservable things, hypothesized in order to explain observations and having their reference fixed by the laws governing their behavior. In order for theories to be true (or at any rate, approximations of the truth) these things must actually exist. Scientific theories are ontologically committed.”

Of course, scientific realism, like all of science, is approximate and subject to revision. This entails the fact that hypothesized scientific concepts will sometimes be revealed as mistakes. Famous cases include the ether, phlogiston, vitalism, empty space, etc.

The development of a SoM depends on the realization that the mind/body/world problem is currently a mystery. The perception literature already contains a wide range of touchstone challenge problems (2, 3) for any proposed reductionist explanation of the relation between the human mind, our bodies and brains, and the physical world, including Figure 1 below.
Technical Vocabulary for a SoM

But I've gotta use words when I talk to you." Sweeney in T.S. Eliot's Sweeney Agonistes.

Sweeney's lament here was that words could not express the full complexity of his feelings and thoughts. The contested usage of technical terms is also endemic in discussions of two of the most profound scientific mysteries: the mind/body problem and the ultimate nature of physical reality (27). There are many scientific mysteries, but few are as confounded by language issues as the classical mind/body problem. For one thing, language is itself a fundamental, possibly essential, feature of the human mind. The standard meaning of "mind" in the mind/body problem, which we will follow, is the personal subjective experience (SE) of people. The mind/body/world problem is also of continuing interest in Philosophy, where the meaning of technical terms is even more important. The classic book (25) by Hillary Putnam contains a detailed analysis of fundamental lexical difficulties in the philosophy of the mind.

Without a commitment to the scientific reality of "mind", as a subject of scientific inquiry there can be no science of the mind (SoM). The very idea of a SoM has been problematic. There are some profound reasons for this, but much of the difficulty arises from the lack of core technical vocabulary for the scientific study of the mind. The importance of technical language for science is expressed nicely in the introduction to the ambitious book (24) The Neuroscience of Emotion: A New Synthesis:

"A comprehensive science of emotion also needs to connect with all domains of science that are relevant to emotion: it needs to connect with psychology and with neurobiology. Doing this requires a consistent terminology that makes principled distinctions, and that allows clear operationalization of the different concepts that a science of emotion will use."

The study of emotion and its subjective partner feelings is an instance of the brain/mind problem and the need for a consistent terminology extends to the general case considered here.

There are many other disciplines and practices concerned with the human mind and the foundations for scientific study are not always clear. For example, a statement that a spider or a robot has a mind could be a scientific or a definitional assertion. Similarly, when philosophers postulate "the extended mind", https://en.wikipedia.org/wiki/Extended_mind_thesis, this could be a profound ontological claim or just the obvious fact human minds depend upon cultural artifacts and communities.

There is interesting and productive work in the SoM (2), but no coherent program. One requisite is a small core vocabulary (24) of technical terms for a unified SoM. Almost all of the terms proposed here are common words with standard meanings. To begin, Science is public exploration of phenomena, involving theory, modeling, experiment, and replication. As above, Mind canonically refers to the private mental activity of humans. These two definitions already highlight one of the challenges for any SoM – how can there be a public science of private experience. In addition, there are many
extended and metaphorical uses of terms like *mind* and often confusion about their intended meaning.

A *scientific problem or mystery* is a phenomenon for which there is currently no plausible explanation. A related source of mystery is an *inconsistency* between two or more theories of the same phenomena. A previous article (3) made the case that the mind/body/world problem is *inconsistent* with current neuroscience and computational theory. Such inconsistencies often lead to scientific revolutions. Much of the historical success of science can be traced to concerted effort on mysteries. One of the best-known cases is the fact that Rutherford’s planetary model of the atom entailed that electrons orbiting around the atomic nucleus would radiate energy and eventually crash into it. This was one of a number of deep inconsistencies leading to the development of quantum theory.

A recent important inconsistency in Cognitive Science is the “Word Superiority Effect” (23). A wide range of experiments established that people were faster and more accurate in recognizing the letter A in context, e.g., CAT, than the same letter alone. These results conflict with the naïve assumption that more input should require more processing. This was one of the inconsistencies resulting in the paradigm shift to massively parallel (connectionist) models of brain function. [https://en.wikipedia.org/wiki/Connectionism](https://en.wikipedia.org/wiki/Connectionism).

Historically, Democritus built a theory of perception explicitly based on his idea of atomic structure.

“Democritus’ theory of perception depends on the claim that eidôla or images, thin layers of atoms, are constantly sloughed off from the surfaces of macroscopic bodies and carried through the air ... It is the impact of these on our sense organs that enables us to perceive.” [https://plato.stanford.edu/entries/democritus/](https://plato.stanford.edu/entries/democritus/)

This was probably the first enunciation of the *mind/brain/world problem* that examines the relations between the physical world, our bodies (and brains), and the human mind of first person subjective experience. From a contemporary view, human bodies and minds evolved to be adaptive in the physical and social world, so the mysteries of the mind and of physical reality are entangled (27).

An additional terminological proposal here is that we use the terms *evolution* and *fitness* in the conventional manner as they apply to all living things. There is no way for an organism or a scientist to calculate present fitness since it depends on the future. We introduce a somewhat new term *actionability* (4) to label an organism’s internal estimate of the expected fitness of its potential actions in the current *situation*. In simple cases like the amoeba or human reflexes, actionability reduces to immediate *action*. Actionability is an extension of Gibson’s perceptual *affordances*, [https://en.wikipedia.org/wiki/Affordance](https://en.wikipedia.org/wiki/Affordance) that adds quantitative, active, situational, goal-directed perception and reasoning. One major function of a mind is to compare actionabilities, sometimes by mental *simulation* (4), before committing to an action.

The main additional requirement for a SoM is *scientific realism*, described above. As scientists, we must start with the assumption the mind, body, and the external world are all real in the sense that they are subjects of study. Many other practices and belief systems (including reductionist physicalism) deny the reality of one or more of these. Any such
denial is the most serious barrier to a SoM. Even without denying the reality of the mind, it is popular to assume that there is no mystery, that the mind is manifestly the activity of the brain, and that all will be revealed by routine science so there is no need for a SoM (9). Stanislas Dehaene, a leading experimentalist, says: “If you had any lingering doubts that your mental life arises entirely from the activity of the brain, these examples should lift them” (26, p.153).

There are many well-known scientific challenges to such faith-based reductionist theories of mind. The figure below is one of the simplest.

![Figure 1. A Perceptual Mystery](image)

Focus on the center of the image for about a minute and the grid will appear uniform. There is nothing in the brain, as we know it that could encode the large regular grid that we experience. Some other basic inconsistencies among neural computation theory, brain function and visual experience are shown in (3),

Several more or less equivalent terms are to describe the subjective experience (SE) associated with the mind. For the core vocabulary, we will consider the following as sharing meaning: Phenomenology, Qualia, Subjectivity, 1st person Experience. Since all of these (like mind) refer by default to the human mind, we need another term to denote mind-like behavior in (much) simpler animals. If the human mind evolved, there must be evolutionary precursors that also need to be studied (5, 6).

In addition, there is currently no good word to label any postulated mind-like capacity of robots and this leads to considerable difficulty. We will probably not be able to define the
robot equivalent of SE until we understand better animal SE and its precursors (7). Using the term “precursors” can replace the intense arguments on whether various animal abilities should be labeled “mind” or “Consciousness”, etc.

One useful distinction is the recent C0, C1, C2 definitions in Dehaene et al. (9). They define C0 as unconscious mental activity that is not experienced, C1 as activity that is accessible for computation and report, and C2 as self-monitoring of C1. A major advantage of this proposal is that it provides a label (C0) for the vast range of behavior in the absence of awareness. In this terminology, SE falls within C1. There is general agreement that subjective experience (SE) is an essential aspect of the mind and of any notion of consciousness - we will focus on SE unless specifically stated otherwise.

Words to avoid.

There are also terms that should be explicitly excluded from the SoM core vocabulary - such as consciousness, dualism, illusion, instinct, and technical terms from other domains like – AI, quantum, recursion, supervenience, God, etc.

The term “illusion” has two mutually inconsistent definitions and is often used without specifying which is intended. The word is sometimes used to describe a perception that is inconsistent with external reality and at other times to describe an experience that is instead inconsistent with the neural representation even when the subjective experience is more like external reality. To further confuse the issue, “illusion” is also used metaphorically, as in the postulated “illusion of Free Will”. Everyone agrees that we all act as if we had Free Will in everyday life, even determinists who deny that they have this capability. There does not seem to be an agreed upon definition of “illusion” that supports its use in a serious discussion of the mind.

The term “consciousness” has dozens of meanings, and there is currently no standard scientific definition. George Miller (8) suggested in 1962 that use of the term consciousness should be suspended.

“Consciousness is a word worn smooth by a million tongues. Depending on the figure of speech chosen it is a state of being, a substance, a process, a place, an epiphenomenon, an emergent aspect of matter, or the only true reality.”

I also suggest that the term instinct has no technical value in a SoM, especially when it is proposed as a scientific answer as in Gazzaniga’s “The Consciousness Instinct” (10). An instinct is a behavior that depends, at least in part, on specific genetic factors rather than only on learning. There is certainly such a substrate for the human mind and other aspects of Consciousness, but applying the label “instinct” does nothing to illuminate the mystery of how it works.

A major linguistic source of confusion is the dichotomy monism/dualism. This can lead to the assertion that either our current scientific knowledge is adequate or we must invoke some non-material ontological forces. The toxic term for a SoM is dualism. This word is invoked to suggest that any questioning of current reductionist materialism necessarily invokes some
immaterial spirit that is outside of science. The quote above from Michael Gazzaniga is typical and there are many others. Science does not work this restricted way. The history of science is replete with the discovery of novel theoretical concepts having the most profound scientific and practical consequences. The history of Medicine presents a paradigm example.

In summary, any effective SoM must honor the scientific reality of the mind, the body, and the physical world. It must also acknowledge that there are currently scientific mysteries, including the mind/body/world problem. Given the great historical success of scientific inquiry, we should assume that some, but not necessarily all, of these mysteries can and will be explained in this century. The stance that best summarizes these constraints is agnostic mysterianism (3, 11). Agnostic mysterianism is neutral with respect to hypothesizing one or more aspects of mind that are not currently materialist (dualism). However, we do require that any SoM proposal be tested on touchstone problems like Figure 1, the binding problem, and the stable visual world (3).

**Beyond Words**

Science is only one of many approaches to coping with the world and our place in it. Everyone needs to deal with the world and science does not (at least currently) provide all the answers. In fact, most people do not directly rely on science for any of their important beliefs and actions. Nevertheless, Science, and more generally intellectual activity, continues to have profound impacts on the world and our understanding of the world including our minds.

This article is my attempt to suggest a set of ideas and attitudes that could form a common basis for a scientific approach to some mysteries of the mind. Obviously, this requires a minimal shared understanding of various terms, as proposed above. Actually doing the science will entail making additional distinctions, as always. For concreteness, I will follow the literature and mainly discuss visual perception, but will also consider subjective aspects of other perception and actions.

**Clinical Findings and Concreteness**

Very few of the myriad theories of the mind, consciousness, etc. take into account the relevant rich clinical findings. Damasio (12) and Gazzaniga (10) are significant exceptions and should be required reading. One major clinical outcome is that some aspects of SE and mind depend entirely on primitive brainstem structures found in at least all mammals. Among other things, this moots the arguments about whether consciousness is based in the front or the back of the cerebral cortex. These results also challenge the position (9) that meta-cognition (C2) is required for subjective experience (C1). In addition, these clinical findings add to the importance of studying the precursors of mind and consciousness in other animals (6, 7).

Even the restricted notion of Mind defined above might be too broad for an initial integrated effort on a Science of Mind. There are several advantages to starting with concrete cases of mental activity, like perception and action, which have measurable correlations with the external world. This involves reduced emphasis on interesting questions like emotions, free will, the sense of self, etc. An obvious benefit of this
concrete approach is that we know that animals also depend on effective perception and action. In addition, the behavior and neural structure of some mammals is similar to that of humans and is much better understood.

Many of the historic mind/body issues, like the unity of perception, aka the binding problem (16), and the internal model of the physical world (5) are also present in animal behavior. Most of the intellectual effort has focused on vision, but there are also classic mind/body issues in speech, body awareness, motor action, etc. https://plato.stanford.edu/entries/qualia/. An important feature of concrete functions of mind is that they provide touchstone tests of theories and models of mental behavior. In fact, there are demonstrations that the standard model of neural computation (14) is inconsistent with subjective experience including the famous examples of the binding problem and of the stable visual world. A proof of this inconsistency was published as “Mysteries of Visual Experience” (3). That article starts with an experiential demonstration of the stable world “illusion”. It then proves that the basic facts about the structure and behavior of the visual system according to the standard neural theory of computation are inconsistent with the experience. It also shows that no known alternative theory of brain computation can explain such mysteries.

There are multiple active communities exploring a wide range of alternative brain implementations of the mysteries of the mind, but none that solve the touchstone problems above. The core technical constraint is that all known fast, non-local communication in the brain (and body) is mediated by neural spike signaling (3). Therefore, any proposed sub-neural computational mechanisms (glia, synapses, microtubules, quantum effects, etc.) are restricted to a single neuron and can only transmit simple signals. There is no plausible computational alternative to the standard model (14).

This focus on concrete mind/body experience has yet another advantage – we can study precursors of these mental activities in simpler animals. If we assume that the human mind is a natural trait, we should study how it might have evolved (5, 6, 7). This will be discussed in detail in a companion paper (TBD). Looking ahead, many animals have the subconscious (C0) functional equivalent of concrete experiences such as sensory integration and spatial awareness. Moreover, even current robots exhibit these abilities. However, the core mystery of SE (qualia, etc.) remains unexplained.

Science as Demystification

‘The most beautiful and profound experience is the feeling of mystery. It underlies religion as well as all deeper aspirations in art and science.’ Einstein

In some sense, the core mission of science is attempting to explain the mysteries of nature. The history of science is largely a saga of increasingly sound theories of the physical and social world. There is broad agreement that the nature of the mind is one of the deepest current mysteries and one might hope that science will help demystify it. In fact, several ancient mysteries of the mind have been largely reduced to routine science within our lifetime.
One interesting case is synesthesia (15), a perceptual experience in which stimuli presented through one modality spontaneously evoke sensations in an unrelated modality. The most common form, seeing/hearing numbers or letters as having specific colors, was well known to the Greeks. Many eminent scientists have studied the phenomenon including Goethe, Locke, and Newton.

The father of psychophysics, Gustav Fechner reported on a first empirical survey of colored letter experience among 73 synesthetes in 1871. There followed several decades of empirical work, interrupted by the dominance of behaviorist strictures against subjective experience for a period around 1920-1965. The results included the fact that synesthesia had a genetic component, but not much more. Active research resumed the 1980s as a consequence of the general cognitive revolution and this effort established the reality of synesthesia, but the mechanisms were still unknown.

The scientific understanding of synesthesia has advanced through a wide range of theoretical and experimental efforts. The empirical genetic link has given rise to a rich collection of detailed studies of the individual genes involved in various instances of the dozens of known synesthesias. An early theoretical hypothesis was that some extraneous neural connections survived pruning in early development; there is now considerable support for this and it has led to discussion of why this “error” has evolutionary value (13). The full panoply of modern imaging methodologies is also being applied and these supply strong support for the subjective reports. Looking ahead, the combination of neural measurements with individual subjective reports can provide us with a solid foundation for a SoM.

By now, the science of synesthesia is fully developed, with its own structure of journals, conferences, web presence, etc. and is recognized as a fruitful domain for the study of the genetics, development, neuroscience, behavior, and subjective experience in general (15). This is a paradigm example of demystification in the science of mind. Interestingly, the more exotic synesthesia phenomenon is now much better understood than the more basic (and ancient) problem of how the brain binds multiple features (16).

However, the mind also entails spiritual and other beliefs where science has not been notably effective. One currently popular reaction to this fact is the movement to defer any direct science of mind and focus on measurable “correlates” of mental experience. This is most developed in the large Consciousness community as NCC, the Neural Correlates of Consciousness –

“Discovering and characterizing neural correlates does not offer a theory of consciousness that can explain how particular systems experience anything at all, or how and why they are associated with consciousness, the so-called hard problem of consciousness but understanding the NCC may be a step toward such a theory. Most neurobiologists assume that the variables giving rise to consciousness are to be found at the neuronal level, governed by classical physics, though a few scholars have proposed theories of quantum consciousness based on quantum mechanics”  
https://en.wikipedia.org/wiki/Neural_correlates_of_consciousness

This NCC effort is perfectly compatible with the more focused SoM suggested here and might well produce useful insights. However, it is also compatible with the belief that the
mind is an epiphenomenon and of no direct scientific interest. The standard mantra is “the mind is what the brain does.” No details are ever provided. There is no general acknowledgement of the inconsistency (3) of the standard model of neural computation (14) with our subjective experience.

Rather than seeking an overarching Science of Mind, I suggest that the field focus instead on systematically demystifying specific mysteries, as in the case of synesthesia. Some promising opportunities are discussed next.

**Some opportunities and experiments**

Many disciplines are potentially relevant to a SoM, but direct comparison of the mind and brain seems to be the most promising approach. As mentioned above, there are several researchers focused on experimental SoM research. In the fall of 2017, Stan Klein and I ran an interdisciplinary UC Berkeley seminar course that explored “Science and Subjectivity”. The lectures and background material from that course is available as [http://rctn.org/wiki/VS298:_Subjectivity](http://rctn.org/wiki/VS298:_Subjectivity) and much of the material below follows this. A particularly focused book is (2).

The findings described earlier in this paper could yield concrete touchstone problems for proposed theories of representation, computation, and communication in the brain. The broken grid example of Figure 1 is one simple case. Both the binding problem and the illusion of a detailed stable visual scene (3) are omnipresent in daily experience, are functionally necessary, and have clear informational requirements. We could ask proponents of speculative brain models how their theory could account for these two concrete phenomena. That is, assume your theory is true and show how it helps explains these (or other) touchstone tasks. I have done this informally with several leading proponents of various models and have never heard even a vague claim of adequacy.

Community acceptance of some such touchstone tasks could sharpen the discussion of information processing in the brain. Of course, the deep mind-brain problem remains a mystery, but we could require that proposed models of brain function address some of the concrete touchstone problems.

One institutional problem is an almost complete separation of research goals into careful experimental work on tractable problems and unfettered speculation on the deep mysteries of the mind. We need research on the omnipresent, but currently unexplained, everyday visual experiences. As mentioned above, there is a large range of experiments that explore various aspects of the binding problem (16) and the stable world illusion (17). None of these has yet helped with the core mysteries. However, there is some recent work that has illuminated the boundary between the known and the unknown in related areas. Such examples might suggest ways of approaching the problems raised in this paper.

The general mind-brain problem is the deepest and most famous mystery involving the neural substrate of subjective experience. No one has proposed a general solution, but there are some recent experiments that constrain the possibilities. For simplicity, we will focus on
visual perception; other modalities are discussed in a companion paper on precursors and the evolution of subjective experience (TBD).

Cohen et al (18) explore the relation between awareness (consciousness) and attention. The mechanisms of (visual) attention are extensively studied and relatively well understood. An important aspect of attention is saccades, which are often triggered without awareness. On the other hand, these unnoticed saccades show that there is no evidence of awareness in the absence of attention. This all suggests that attention and awareness are neither inherently linked nor doubly dissociable.

Another visual mystery that has been somewhat demystified is postdiction, where a subsequent stimulus seems to causally affect the percept of an earlier input. For example, a flashed letter can be masked by a somewhat (~100-200 ms) later image in a nearby position. Apparent motion is also postdiction since the trajectory can not be computed until after the second flash. Shinsuke Shimojo has done extensive work on postdiction, recently summarized in (19). In one experiment, an artificial scotoma induced by TMS (Transcortical Magnetic Simulation) was filled in with the color shown later. The paper describes four compatible plausible neural substrates for rapid postdiction and considers memory effects like “hindsight bias” that makes events seem more predictable after the fact. This analysis is then extended to address the well-known controversy concerning action before awareness and its relation to the mystery of free will. The article suggests that the “sense of agency” is another instance of postdiction, resulting in an illusion of action before awareness. This does not solve the mystery of free will versus determinism (20), but does greatly sharpen the question.

Perhaps the most directly relevant research is that of the von der Heydt lab (21) on ambiguous figure-ground scenes like the duck/rabbit and face/vase images and the Necker cube. Employing a wide range of behavioral, neural, and computational findings they have established that border ownership is the basis for these and a number of related phenomena, including object identification. They also describe in detail a plausible neural substrate. Convincing evidence was found for the requirement of top-down input in early visual brain areas V1 and V2. Border ownership was also shown to be central to filling-in, as with the blind spot. The effects of border ownership were also shown to extend across saccades and to affect attention. Their finding of increased spike synchrony between neurons whose border ownership preferences are consistent with the stimulating object, even when the neurons are widely separated in the cortex, is strong evidence for feedback grouping circuits and is relevant to aspects of the binding problem.

More generally, Simons and Rensink (22) have a deep and thoughtful discussion of the prospects and perils of scientific research on problems at the boundary of subjective experience. Their story on the developments around the phenomenon of “change blindness” suggests guidelines for the kinds of work suggested here.

Conclusions

There are many active efforts to find a general solution to the mind/body/world problem, consciousness, etc. or to promote one’s favorite existing solution. My suggestion for a Science of Mind is more modest.
It begins with acknowledging that subjective experience is central to mental life and that the scientific relation of this (mind) to its embodiment is currently a mystery. The next step is to follow the tradition of “scientific realism” and to establish “mind” as a first class research subject. This entails a technical vocabulary and eschewing the scientific use of undefined terms.

The adoption of an “agnostic mysterianism” stance recognizes current mysteries, but also that Science has progressively demystified many deep questions, often leading to major advances in knowledge and the quality of life.

More specifically, recent research has helped explain some mental phenomena that had been viewed as mysterious. These include synesthesia, hyper-acuity, subjective contour, word superiority, etc. There is every reason to believe that similar results will be forthcoming in this century, but no way to predict when, if ever, to expect a complete physicalist science of the mind.

What we do know is that the traditional practice of science, taking all phenomena seriously and augmented by ever improving knowledge and techniques, is the only known way forward. It has been especially productive to focus effort on issues at the boundary of the known and unknown. Institutional reward systems have not been supportive of ambitious research on the mind, but this seems to be changing.

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