# A Brief Summary of the Sensorimotor Theory of Phenomenal Consciousness

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***ABSTRACT*** *This summary of the sensorimotor theory of phenomenal consciousness explains the purpose of the theory, emphasizes its metaphysical differences with most other current theories, gives links to overviews of supporting evidence, discusses frequent misunderstandings of the theory, and describes the future program of work.*

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## Phenomenal Consciousness as the main object of SMT

The sensorimotor theory (SMT) as initially proposed in O'Regan & Noë (2001) and significantly refined in O'Regan (2011), differs from other theories of consciousness because it provides a scientifically viable account not only for access consciousness but also for phenomenal consciousness, something that other theories cannot claim to do.

To achieve this aim, SMT takes a metaphysically different position as compared to other theories. Other theories search for an explanation of consciousness in terms of brain mechanisms that might generate consciousness. Instead, SMT considers that to explain consciousness, we must first define what we mean by having conscious experiences. SMT then shows that when this is done, each of the components that contribute to what we mean by having conscious experiences turns out to be amenable to science. In particular, a realization of SMT is that phenomenal experiences can be considered to involve active probing and verifying of (possibly counterfactual) sensorimotor laws. In this sensorimotor approach a lot of what can be said about phenomenal qualities can be expressed in the everyday language of sensorimotor laws. As a result, the "explanatory

gap" between the language of experience and the language of the brain disappears. There is no more "hard problem" for phenomenal consciousness.

## The hierarchy of ingredients for the sensorimotor approach to phenomenal consciousness

As an example of the sensorimotor approach, consider what it means for you to be consciously feeling the softness of a sponge.


*The self cognitively accessing (the fact that it is cognitively accessing (the fact that it is currently exercising (the sensorimotor know-how of the softness-probing-skill)))*

A first thing that it means is that the experience is happening to you -- else who would be having the experience? SMT therefore restricts its account of consciousness to cases where there is an agent who possesses sufficient cognitive capacities to have the notion of self. Note that by requiring a self, SMT is not surreptitiously including a notion of consciousness in order to explain consciousness. This is because even self-referring, recursive types of selfhood involving meta-knowledge of your own knowledge are today considered tractable for science (cf. discussion in O'Regan, 2011, Ch 6).

A second ingredient for what it means for you to be consciously experiencing the softness of a sponge is that your self must be cognitively accessing the fact that it is engaged in exploring the sponge and cognitively accessing the fact that the sponge is soft. The notion of "cognitive access" is used here in a hierarchical manner detailed in O'Regan (2011, Ch 7; 2012), and is again not a magical notion since it is implementable computationally and so tractable for science.

Finally a third ingredient for what it means to be consciously experiencing the softness is that you must be currently engaged in probing the sponge and determining that it is soft. What does that mean? It means that a particular "sensorimotor contingency" can

be verified, namely the fact that when you press the sponge, it squishes. Notice that at the cognitive, personal level, you are not aware of the exact movements you are making, the exact muscles that you are using to do the pressing, nor the nerve activations that are involved in detecting the changes in pressure. It is your brain that is dealing with the execution and verification of the necessary "softness-probing-skill". At the cognitive, personal level however, you have cognitive access to the fact you are currently engaged in exercising that skill, as a form of practical "knowledge-how". Notice also that exercising the "softness-probing-skill" does not require acting all the time. It merely requires your brain to have registered the fact that counterfactually there are a variety of actions it could undertake at the present moment, and that the resulting changes in sensory input would be governed by the laws of softness. In a similar way, when you are experiencing the feel of bicycle riding, you can momentarily lift your hands off the handlebars and stop pedalling. Even without acting right now, so long as you are properly cognitively accessing the fact that you are currently exercising the practical know-how that constitutes what it is to ride a bicycle, you are still experiencing the bicycle riding feel.

## Solving the "hard problem"

It is at this third sensorimotor level that the originality of SMT appears, allowing the "hard problem" to be dealt with. Under other theories of consciousness, explaining the difference in phenomenal qualities of soft and hard requires explaining why certain neural circuits generate the soft feel and others generate the hard feel. This raises the "explanatory gap" problem of finding a link between the language of brain science and the ineffable feels of soft and hard. SMT on the other hand considers that explaining the difference in phenomenal qualities of soft and hard requires explaining what you mean by being engaged in experiencing soft and hard. For this, the brain is not the right level of explanation. Instead, closer examination of what you mean by having an experience of softness reveals that what you mean by experiencing softness is (in addition to the appropriate cognitive accessing) to be poised to be able to squish, whereas what you mean by experiencing hardness is to be poised not to be able to squish. In a similar way the difference in what it feels like to ride a bicycle and to ride a motorcycle lies in the different things you do or potentially are poised to do. It is at this sensorimotor level that we find the appropriate explanation for the differences, not in the brain. Indeed, it would be very difficult to provide an intelligible explanation for differences in the feels of such sensorimotor activities in terms of the different brain activities involved, since these can be very different depending on the exact movements made, and the exact muscle and receptor combinations.

## Experiences with no action

Clearly the "trick" that allows SMT to overcome the explanatory gap lies in finding a strategy to rid experiences of their ineffability so that their qualities can be described in everyday language. Appealing to descriptions in terms of sensorimotor skills provides such a strategy. For tactile stimuli like softness and hardness and for physical skills like bicycle riding, where physical actions are inherently involved, the strategy seems convincing. And note that the SMT does not say that action must be involved at the moment when the experience is occurring. So long as perceivers have, from past experience, acquired counterfactual knowledge about a particular sensorimotor law, they may under some circumstances, even without moving, receive sufficient perceptual cues to confirm that they are currently exercising the know-how of the sensorimotor law. After having moved your eyes over many cats over many years, a single flash of a cat picture can usually give you the impression of exercising the know-how of seeing a cat.

But what about experiences like experiencing hot and cold, the redness of red, the sound of a 440 Hz sinusoid, the smell of a rose, the taste of sugar, where there is no obvious necessary action involved?

A first point is that these experiences all have modality-related qualities: they can be visual, auditory, tactile, gustatory or olfactory. These modality-related aspects are well accounted for in SMT by the fact that the laws describing the effects of body movement on changes in sensory influx are completely different in the different modalities, and constitute the specific what-it's like of each modality (O'Regan, 2010). But SMT further claims that even within any given modality, differences in experienced phenomenology must boil down to differences in sensorimotor laws. Within-modality quality spaces (Clark, 1993; Palmer, 1999) describe the structure of the comparisons people can make between experiences within a modality and as such constitute a description in everyday language of comparative aspects of phenomenal qualities. Such implicit knowledge that a person possesses of how a given sensation compares to others that might have been displayed in its place could contribute partly to the experienced quality of the sensation. But SMT hopes that a detailed study of the changes that different actions cause in sensory input may provide a more basic, non-comparative, absolute characterisation of within-modality experiences and their differences. Steps in that direction have for example been made by Philipona & O'Regan's (2006) for color, by Froese et al. (2020) for audition, Aytekin et al. (2008) for auditory localization, and Cooke & Myin (2011) and Millar (2021) for smell and flavor.

## SMT in a simple formula

In summary, SMT rejects attempts to solve the hard problem of phenomenal consciousness by finding a brain mechanism that generates phenomenal qualities. Instead, SMT starts by examining what exactly it means to consciously have an experience. SMT observes that a hierarchy of capacities is involved. This box describes what you are doing when you are having an experience with a particular quality:

> You are consciously experiencing a phenomenal quality when:
>
> You as a self are
> (cognitively accessing the fact that
> (you are cognitively accessing the fact that
> (you are exercising the know-how of the sensorimotor skill that constitutes verifying that quality)))

Each of the components of this hierarchy is describable in everyday language and thus is tractable by science. There is no mechanism involved that in any sense "generates" consciousness. Having a conscious experience just means deploying these capacities.

## Profound metaphysical difference with other theories

It is evident that, with its hierarchy of "cognitive access" and the "global access" to information that this implies, SMT has commonalities with "higher order thought" and "global workspace" theories of consciousness.

But, as mentioned above, compared to these and most other theories of consciousness, SMT is based on a fundamentally different metaphysical approach. Most theories of consciousness attempt to explain consciousness in terms of brain mechanisms. The mechanisms these theories postulate, like higher order thought, global access, or in the case of other theories, integrated information or recurrent processing, etc., are presumed in some sense to "generate" or give rise to the thing we call consciousness.

But for SMT, it is a Rylean "category mistake" to think that consciousness is any kind of "thing", and that it could be generated by anything, let alone by the brain. Instead, SMT "de-reifies" consciousness, and takes it to be nothing more than a word that describes a collection of capacities that humans (and some other animals perhaps) have to behave in certain ways or to say certain things about their experiences. As a consequence, instead of investigating brain mechanisms, SMT seeks to discover, describe and explain all the capacities people deploy when they consider themselves to be having conscious experiences. This investigation leads SMT to suggest that conscious experience involves, among other things, putting into action a hierarchy of cognitive access (and

thereby implicitly a kind of global access to information) that we also find in higher order thought and global workspace theories. But contrary to higher order thought and global workspace theories, this hierarchy of access does not in any sense "generate" consciousness. The hierarchy of access is just one component of what having a conscious experience consists in. It is part of what people mean when they use the word "conscious" -- it is part of the everyday definition of the term.

## The innovation of sensorimotor laws and the self

In addition to the metaphysical difference, another essential component that distinguishes SMT from higher order thought and global workspace theories is the inclusion of the notion of implicit, practical knowledge-how of sensorimotor contingencies. Including this in the ingredients that define what is meant by having a conscious experience provides SMT with a way to characterize sensory qualities in everyday language (soft = "it squishes when you press"; red = "it obeys the laws of redness when you change the illumination") and thereby to escape the explanatory gap that arises from trying to make the link between experienced qualities and brain mechanisms.

Another component that is not emphasized in higher order thought and global workspace theories is the self. Presumably theories like the higher order thought and global workspace theories neglect the self because they implicitly consider that higher order thought or global access mechanisms *in themselves* somehow "generate" consciousness or make consciousness "emerge". On the other hand SMT's investigation of what is meant by having a conscious experience notes that under everyday usage, having a conscious experience implicitly requires there to be a self "in the cockpit" to whom the experience can be attributed. Under SMT therefore the self must be included as part of the description of what it is to be conscious. Nevertheless under SMT, inclusion of the self is not what somehow generates the consciousness. The self is simply another capacity that is usually considered to be a necessary part of what people mean by being conscious.

## Empirical evidence

Various publications have shown how the SMT can be used to account for many kinds of sensory qualities (for an overview see O'Regan, 2010, 2011, 2012). For example, differences in experienced qualities of different sensory modalities can be naturally explained in terms of the different kinds of practical, sensorimotor knowledge you exercise when you see, hear, touch, taste and smell. The approach leads to interesting science concerning the possibility of sensory substitution. It can also explain the qualitative "presence" of visual perception, that is the impression of seeing a perfect,

detailed, stable, scenic expanse displayed in front of you, despite what seem like horrendous defects of the visual apparatus (O'Regan, 1992). This is the work that gave rise to the discovery of change blindness.

Even what would seem like the canonical case of a "quale", namely the redness of red, can be partially accounted for by noting that the experienced quality of red consists in the counterfactual knowledge that the light impinging on the eye can change in a particularly simple way when you orient the surface towards different illuminations (Philipona & O'Regan, 2006).

Other examples relating more to neuroscience are the suggestions of Froese et al. (2020) showing how SMT predicts activation of motor structures during audition, and Seth's (1994) and Curwen's (2022) sensorimotor accounts of synesthesia.

Finally, SMT can provide an account of the different degrees to which perceptual, bodily, emotional and mental experiences have something it's like at all, rather than nothing it's like, and the degree to which they seem to have a perceptual "displayed-before-us" kind of presence (O'Regan, 2022). The account makes use of two aspects of "control": control over our voluntary bodily movements, and control over the flow of sensorimotor information that can be exercised by voluntary bodily movements.

Despite SMT's advantages over other theories in dealing with phenomenal consciousness, several misunderstandings about SMT have in the past stood in the way of its being taken seriously.

## The misunderstood role of action in SMT

The most frequent misunderstanding concerns the role of action. For example, some critics ask how the theory can explain that one can perceive the redness of a flash of light without moving the eyes. The answer is that since childhood, over the course of development, our brains have accumulated knowledge about the sensorimotor laws that govern how surfaces of different colors change the reflected light. In adulthood, when we receive any particular retinal stimulation, the brain can, using additional contextual cues and a priori hypotheses, make an informed guess as to which of the multiple possible such laws is likely to be the one that is currently applicable. Moving the eyes or body to confirm which particular law currently applies may supply additional confirmation, but may not be necessary. Of course, the fact that contextual cues or prior knowledge may be misleading sometimes causes errors, as demonstrated in the well-known "the dress" phenomenon (Witzel et al., 2017). The important point is that the brain is using all possible information to determine which law is currently applicable, even when no actions are being performed. Once the determination is made, we as persons will cognitively access the fact that we are currently engaged in the experience

of red. This process of finding the best explanation of current sensorimotor laws has been formalized in predictive coding theory (Seth, 2014). Predictive coding also emphasizes the importance of counterfactual information in determining the quality of experience.

### Dreams and hallucinations

A related misunderstanding to the problem of actions concerns dreams and hallucinations. Since here there is no interaction with the world and so no practical know-how of sensorimotor contingencies being exercised, how could one have conscious perceptual experience during dreams and hallucinations? SMT says that there are two types of reason there could be such phenomena. In one possibility, the brain systems that usually signal the verification of knowledge-how of sensorimotor contingencies become activated without external stimulation and without motor action. The other possibility is that the brain systems that govern cognitive access incorrectly judge that they have received confirmation from the systems registering the knowledge-how. Under both possibilities the result is that the self believes itself to be having veridical experiences.

### The misunderstood role of the brain in SMT and more metaphysics

Another misunderstanding of the SMT concerns the role of the brain. Many people think that consciousness must be generated in the brain. They think this is convincingly demonstrated, among other things, by the fact that dreams and hallucinations involve no sensory input and no actions, and yet we are perfectly conscious of them. SMT is particularly sensitive about this issue, because it illustrates the profound metaphysical difference between classical approaches and the SMT. When people say “consciousness obviously is generated by the brain”, what they generally mean is that there must be neural mechanisms that have the special property of generating a thing that we all are familiar with, and that we call consciousness. Under this view, consciousness is the kind of thing that can be generated by some mechanism. But as explained above, SMT on the other hand adopts an entirely different metaphysics, in which consciousness is “de-reified” and instead considered to be a collection of capacities that humans have and that allows them to behave in certain ways and say certain things about their experiences. It is in this sense then that SMT claims that “consciousness is not generated in the brain”: because consciousness is not generated at all. The difference between the classic view and the SMT view is analogous to the difference between the vitalistic view of life and the modern view of life. Vitalists believed that life is a “thing” that must be generated by something, and so they went looking for a vital spirit that does the job. Modern biology has taught us that it is scientifically more productive to de-reify life, and to consider it as a collection of capacities to act, each of which can be

explained by today's scientific methods. SMT takes the same stance with regard to consciousness. It claims it is scientifically more productive to consider consciousness to be a collection of capacities to act. Examining each of these in detail reveals that they can all be explained in terms of today's scientific methods. This is even true of what is usually considered to pose the "hard problem", namely phenomenal consciousness. For this, SMT invokes sensorimotor laws to explain the quality of experiences and a hierarchy of cognitive access and a self to explain why people say they are conscious of the qualities.

## Can SMT be falsified?

The main claim of SMT is that the quality of experiences can be accounted for convincingly in terms of sensorimotor laws. To falsify the theory it would be necessary to show that people can have different experiences without there being any action that can either modulate the sensory input in systematic ways at the moment of experiencing, or else has modulated the sensory input in systematic ways in the past history of the person. The theory would also fail if the sensorimotor laws that objectively describe an experience could be shown not to be those that a person experiences. To caricature, the theory would fail if we could show instances where a person feels that a sponge is hard if nevertheless when they press the sponge it squishes easily. In demonstrating this however, it would have to be guaranteed that the person's hierarchy of cognitive access had not in some way been induced into incorrect beliefs in the way that may happen in hallucinations and dreams.

## The future program of SMT

Because of its metaphysical choice to consider consciousness to be a collection of multiple capacities, SMT's future program cannot be to try to uncover "the" mechanism that generates consciousness. Instead, its program must reside in the progressive cataloging of all the associated capacities, ranging from the self, through cognitive access, to the know-how of sensorimotor contingencies. Other theories, despite their different metaphysical motivation, are already at work with the self and cognitive access, seeking the brain regions and mechanisms that can instantiate these capacities. The task that is more unique to SMT would be to try to detail the sensorimotor laws, and thereby the objective underpinnings of all the things that people say about different kinds of experiences. There are amodal qualities like intensity, size and location; there are qualities that distinguish the different modalities (visual, auditory, tactile, gustatory, olfactory) and those that distinguish types of experiences (perceptual, bodily, emotional, mental) (for this see some first steps in O'Regan, 2022). And then within each class of experience there are individual qualities like the difference between rose and lilac smell or between red and green. All these differences should be, according to SMT, expressible

in terms of the everyday language of sensorimotor contingencies and together constitute “what it’s like” to have a conscious experience. An interesting additional consideration concerns social interactions. It may be, particularly in the case of pain and emotions, that social signalling and interactions play an important role in determining experienced qualities. It may be that the notion of sensorimotor contingency should be extended to include social interactions (Weichold, 2016; Lübbert et al., 2021; Engel et al., 2022).

Ethical considerations posed by the theory also deserve to be seriously researched. If SMT is right that there is no “thing” called consciousness, and that it is simply a matter of cultural convention what combination of capacities we define to be needed for an agent to be worthy of the word “conscious”, then consciousness should really not be considered an all-or-none thing. Using consciousness as a criterion to make ethical decisions becomes very tricky, and,like the concept of “soul” in the middle ages, runs the risk of becoming a culturally determined way to discriminate against agents that fail a particular culture’s arbitrary standards.

## References


Aytekin, M., Moss, C. F., & Simon, J. Z. (2008). A Sensorimotor Approach to Sound Localization. Neural Computation, 20(3), 603–635. doi:10.1162/neco.2007.12-05-094

Froese, T., & González-Grandón, X. (2020). How passive is passive listening? Toward a sensorimotor theory of auditory perception. Phenomenology and the Cognitive Sciences, 19(4), 619–651. doi:10.1007/s11097-019-09641-6

Clark, A. (1993). Sensory Qualities. Clarendon.

Cooke, E., & Myin, E. (2011). Is Trilled Smell Possible? How the Structure of Olfaction Determines the Phenomenology of Smell. Journal of Consciousness Studies, 18(11–12), 59–95.

Curwen, C. (2022). Music-Colour Synaesthesia: A Sensorimotor Account. Musicae Scientiae, 26(2), 388–407. SAGE Publications Ltd. doi:10.1177/1029864920956295

Engel, A. K., Verschure, P. F. M. J., Kragic, D., Polani, D., Effenberg, A. O., & König, P. (2022). Editorial: Sensorimotor Foundations of Social Cognition. Frontiers in Human Neuroscience, 16. Retrieved from https://www.frontiersin.org/articles/10.3389/fnhum.2022.971133

Lübbert, A., Göschl, F., Krause, H., Schneider, T. R., Maye, A., & Engel, A. K. (2021). Socializing Sensorimotor Contingencies. Frontiers in Human Neuroscience, 15. Retrieved from https://www.frontiersin.org/articles/10.3389/fnhum.2021.624610

Millar, B. (2021). Towards a sensorimotor approach to flavour and smell. Mind & Language, 36(2), 221–240. doi:10.1111/mila.12275

O'Regan, J. K. (1992). Solving the" real" mysteries of visual perception: the world as an outside memory. Canadian Journal of Psychology/Revue canadienne de psychologie, 46(3), 461.

O'Regan, J. K., & Noë, A. (2001). A sensorimotor account of vision and visual consciousness. Behavioral and brain sciences, 24(5), 939–973.

O'Regan, J. K. (2010). Explaining what people say about sensory qualia. In N. Gangopadhyay, M. Madary, & F. Spicer (Eds.), Perception, Action, and Consciousness: Sensorimotor Dynamics and Two Visual Systems (pp. 31–49). OUP Oxford.

O'Regan, J. K. (2011). Why red doesn't sound like a bell: Understanding the feel of consciousness. New York: Oxford University Press. Retrieved from http://www.oxfordscholarship.com/view/10.1093/acprof:oso/9780199775224.001.0001/acprof-9780199775224

O'Regan, J. K. (2012). How to build a robot that is conscious and feels. Minds and Machines, 22(2), 117–136. Springer Netherlands.

O'Regan, J. K. (2022). Differences in "what it's like" to have perceptual, bodily, emotional and mental experiences are related to voluntary control over information and body movements. PsyArXiv. doi:10.31234/osf.io/6xzde

Palmer, S. E. (1999). Color, consciousness, and the isomorphism constraint. Behavioral and Brain Sciences, 22(06), 923–943.

Philipona, D. L., & O'Regan, J. (2006). Color naming, unique hues, and hue cancellation predicted from singularities in reflection properties. Visual Neuroscience, 23(3–4), 331–339.

Seth, A. K. (2014). A predictive processing theory of sensorimotor contingencies: Explaining the puzzle of perceptual presence and its absence in synesthesia. Cognitive Neuroscience, 5(2), 97–118. Routledge. doi:10.1080/17588928.2013.877880

Weichold, M. (2016). Mastering Sociocultural Contingencies: On Extending the Sensorimotor Theory to the Domain of Culture. Journal of Consciousness Studies, 23(5–6), 203–227.

Witzel, C., O'Regan, J. K., & Hansmann-Roth, S. (2017). The dress and individual differences in the perception of surface properties. Vision Research, Individual differences as a window into the structure and function of the visual system, 141, 76–94. doi:10.1016/j.visres.2017.07.015