The Quantum Nature of Consciousness



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2026

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A Popular Science Book

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Preface

Every description of a person has an external aspect. We can measure body temperature, record the brain's electrical activity, and track eye movements. Yet no such record, by itself, conveys how pain feels, why a familiar voice brings warmth, or what it means to be present in one's own life. Consciousness makes this gap immediate: we know the world through experience, while the nature of experience itself still requires explanation.

The Quantum Nature of Consciousness explores the possibility that the brain participates in a broader physical organization of experience. An organism may be a selective interface through which more fundamental processes take the form of an individual human presence. The word "may" matters here. This book develops a hypothesis and asks how it could be tested; it does not begin from an established fact that consciousness exists outside the body.

The image of the body as an avatar is appealing in its clarity. It lets us imagine a relationship between a person and reality that differs from the relationship between a device and the output it produces. Yet this image contains a difficulty. An avatar presupposes an owner who already knows what they want, remembers their past, and retains their individuality. Explaining consciousness only begins when we ask where that owner came from. The joint formation of personhood will therefore be a central theme: a possible fundamental basis of experience and a particular human self will not be declared identical in advance.

The path begins with simple distinctions. Experience, the ability to respond, memory of an event, and a representation of oneself are connected, but they are investigated in different ways. Quantum physics then enters as a language of states, probabilities, interactions, and constraints. Later, that language meets biology: proteins, spins, anesthesia, and nervous system activity. Only then can we construct a model of our own and ask what observation might change its prospects.

The text assumes no prior training in physics. Equations come with explanations, while the details of calculations are placed in the mathematical appendix. Their purpose is to connect ideas with quantities that could, in principle, be determined. A formula becomes useful when it reveals a relationship or exposes a contradiction. Mathematical notation alone does not turn an assumption into a fact.

Findings from particular studies are identified by references in square brackets. The bibliography gives the publications and the addresses where they can be found. Theoretical proposals are distinguished from observations; preprints are identified as preprints. Imagined situations help clarify consequences and are not presented as experiments that have been performed. The authors' hypotheses receive working names, without any claim that similar ideas had no predecessors.

Philosophy and theology remain significant where they ask about the primacy of experience, the unity of the world, and the continuation of personhood. Moving into scientific inquiry requires adding a proposed mechanism and conditions for testing it. Failure is therefore also considered here: an external bearer may not be found, the proposed quantum process may prove biologically insignificant, and a successful physical model may still fail to explain why experience exists at all.

This openness does not abandon the project. It makes the project definite. If the human body really participates in a connection with a more fundamental basis of consciousness, that connection must have properties. If individuality emerges at the boundary between the organism and that basis, there must be conditions under which it emerges. The scientific content of the idea begins with an attempt to specify those properties and conditions precisely enough to investigate them.

Prologue

Where Presence Comes From

A room at the end of the day. A cup stands on the table; a car passes outside. There is a sound, and light catches the edge of the table. Amid these familiar sensations, a question unexpectedly arises: who is noticing all this?

Usually, the question dissolves into the next action. A message needs an answer, a window needs closing, a task needs finishing. This time, let us pause.

Some events are accessible to an outside observer: moving air, light, changes in living tissue. And there is how those events feel from within experience. The sound of the car may irritate us, silence may bring relief, and the light may recall an evening in childhood. Physical description and experience concern the same unfolding events, but they are presented to us differently.

The question of consciousness arises within this distinction. We want to understand how the world becomes experienced and why experience has a particular point of view. Why is what happens given to this person, with this person's memory and sense of being present?

The most familiar research strategy starts with the brain. There are strong grounds for it: changes in brain function are associated with changes in wakefulness, behavior, and perceptual content. Researchers can also intervene in brain processes and observe the consequences. We will examine these studies in detail. [2, 3, 15]

Yet a separate step remains between describing these dependencies and explaining subjective experience. Some researchers expect a sufficiently complete theory of neural organization to provide it. Others seek a deeper level of description. This book considers the possibility that an unaccounted-for link exists in the relationship between the brain and experience.

Imagine a radio receiver. Changing its construction can alter the volume, sound quality, and available stations. Destroying the device stops the sound in the room. The source of the broadcast may nevertheless continue operating elsewhere.

The analogy is appealing because it distinguishes the source from the means of access. It reminds us that an output's dependence on a device does not, by itself, reveal where the transmitted content originated. But radio communication has something our hypothesis does not yet have. The transmitter can be located. The signal can be measured independently of the receiver. Its frequency, delay, and encoding can be determined.

This is precisely the work that separates comparing the brain to a receiver from developing a physical theory. We would need to identify the counterpart of a signal, describe the coupling, and formulate testable

predictions that distinguish the new model from existing neurophysiological explanations.

The comparison itself may prove too crude. A receiver presupposes a ready-made broadcast. What if a person does not receive a complete stream of consciousness from the outside world? What if a particular self arises only through the interaction of a more fundamental process with memory, the body, and the brain?

The body would then have a different role. It establishes the location from which the world is accessible, distinguishes one's own actions from external events, and preserves a history of encounters. Even within a hypothesis of a broader basis of consciousness, these functions cannot be treated as an inessential shell. They help determine the specific form of experience.

One line of inquiry involves quantum physics. Existing hypotheses about the brain consider specific physical carriers, including nuclear spins and states of protein structures. We will ask whether their properties could supply the testable mechanism of interaction that the receiver image still lacks. [4, 7]

Quantum physics describes properties of matter that cannot always be pictured as the motion of small, familiar objects. Its language includes superpositions, probabilistic measurement outcomes, and correlations among the parts of a composite system. These concepts provide powerful tools for describing nature. None of them, by itself, denotes a soul or a person. [14]

We cannot solve the problem of consciousness simply by renaming the unknown "quantum." If a special quantum mechanism is proposed, its physical states, lifetimes, and influence on brain function must be specified. A claim that consciousness exists outside the organism requires another step: explaining why the mechanism found concerns experience and why its source should be sought beyond the body.

Several distinct questions arise. Can the brain use particular quantum processes? Do they play a causal role in states associated with consciousness? Is there a more fundamental basis for experience itself? Can anything related to personhood exist independently of this organism?

Each successive question requires additional justification. Success at one stage does not automatically answer the others.

This does not make the search fruitless. Instead, it creates problems that can be addressed separately. We can test a physical mechanism. We can clarify the limits of a neural model. We can show that a proposed coupling is too weak to produce the expected effect. Such a constraint also changes what we know.

A good hypothesis allows the world to disagree with it. If it is compatible with every possible outcome from the outset, research will bring us no closer to an answer. We will therefore seek observations that would make us reconsider our own idea.

Let us return to the room. The car has passed. The cup is still on the table. No new instrument has appeared, but the question has become more precise. We want to know what relationships among physical processes make this particular presence possible.

We will begin with the nearest accessible participant in those relationships. The brain.

Part one

Experience and its boundaries

Chapter 1

The Brain and the Observer's Boundary

When we say “consciousness,” several different things often come into play at once. The man is awake. He distinguishes objects. He feels pain. He knows his name. He notices his own mistake. These abilities are related, but the differences between them are important for any study.

In this book, by subjective experience we will understand the presence of an experience: for the system, what is happening is somehow felt. Qualia is the word for the qualitative aspect of such an experience, such as the experience of color or taste. Self-awareness will be the form of representing oneself as a participant in what is happening. Reflection is an appeal to one’s own thoughts, decisions and reasons for action.

These are working definitions that are used below. They help us not to demand from each conscious state a developed story about ourselves and not to accept any story about ourselves as direct evidence of experience.

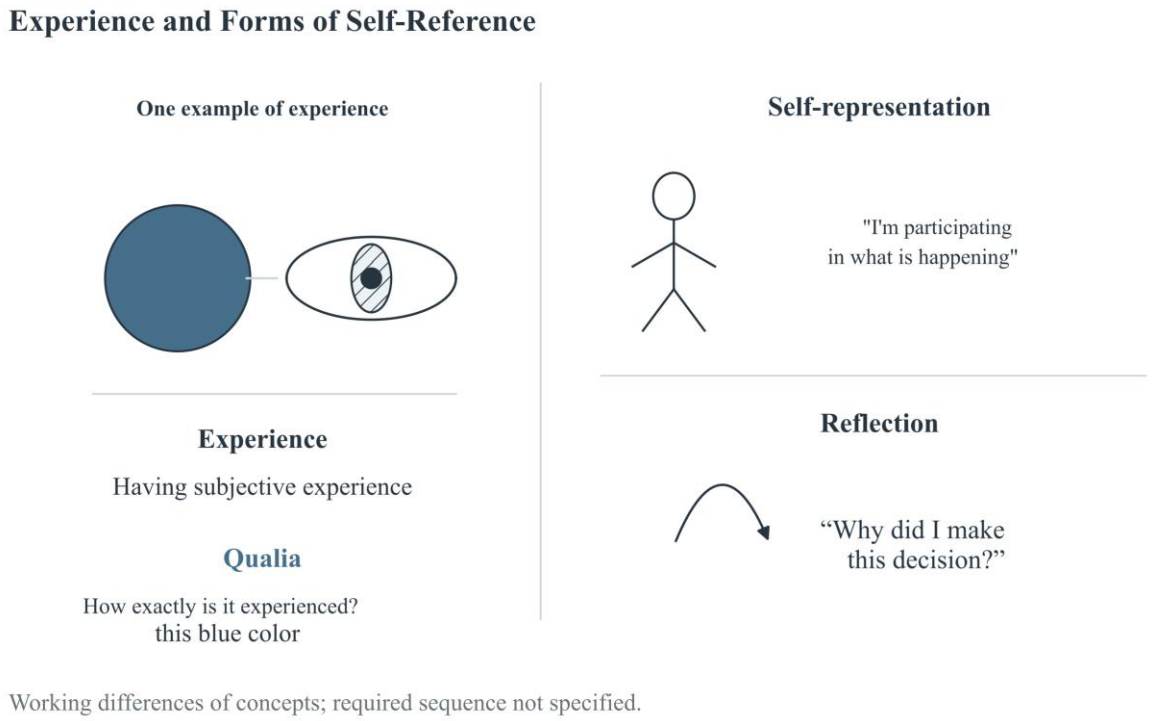


Figure 1. Working differences book. Qualia denote the qualitative side of experience; self-representation and reflection refer to different ways of addressing the system to itself. The diagram does not set a ladder for the development of consciousness.

The same principle is needed when studying artificial systems. The program can describe its states, correct errors and maintain a detailed autobiography. These possibilities are observable. The question of whether she has an experience requires a separate justification. The Mira Project will be discussed throughout the book as a research context for models of memory, self-representation, and reflection. The name of a project or the complexity of its behavior does not resolve the issue of qualia.

Experience and its traces

The researcher does not have an instrument that would show someone else's experience in the same sense as a thermometer shows temperature. There are stories, actions, physiological indicators and ways to compare them with each other. However, each method can fail.

A lack of response during an experiment may indicate a lack of experience. But the person may also fail to hear the instruction, fail to understand the task, or be unable to move. An absence of reports after wakefulness returns allows another explanation: the experience may not have been retained in memory. These possibilities impose different requirements on the experiment.

In a study by Simone Sarasso and colleagues, the brain's response to magnetic stimulation under the influence of different anesthetics was studied in eighteen volunteers. After ketamine, participants reported vivid

dream experiences, although they did not outwardly respond during the study. With ketamine, induced brain activity maintained a complex, wake-like structure; with propofol and xenon its complexity was lower. [2]

This result is important for our topic: the absence of a behavioral response is not sufficient to confidently conclude that there is no experience. Moreover, the story after waking up does not provide a continuous record of what happened at every second. The researcher must take into account simultaneously the state of the brain, the possibility of response and memory.

The interface hypothesis also has to explain these differences. It needs to predict which properties of the proposed mechanism change under the influence of different substances, and indicate an independent indicator against which the prediction can be checked.

What the brain is already forcing us to admit

It is possible to imagine consciousness as separate from the organism and still recognize that human experience is highly dependent on the brain. There is no logical contradiction here. But the scientific question concerns the accuracy of this relationship.

In the experiments of Andre Bastos and colleagues, stimulation of the central thalamus in two macaques against the background of continued administration of propofol restored signs of wakefulness and changed some of the neural dynamics. This is a causal intervention: researchers manipulated a particular system and recorded the effects. It does not provide direct access to the animal's subjective experience, but it does limit possible explanations for the condition. [3]

If the brain is the interface, why does this kind of intervention change how it works? What happens to the connection? How does this relate to changes in neural activity? Saying “antenna turned on” is not enough unless the mechanism and measurement are specified.

Data on the content of perception are even more demanding. In a clinical study by Joseph Parvizi and colleagues, electrical stimulation of specific areas of the fusiform gyrus in one patient distorted the perceived appearance of real faces. Comparable changes did not occur with sham stimulation or stimulation through adjacent non-specialized electrodes. [15]

This result shows how specific the model requirement can be. It is necessary to explain the connection between the place of intervention and a certain aspect of the experience.

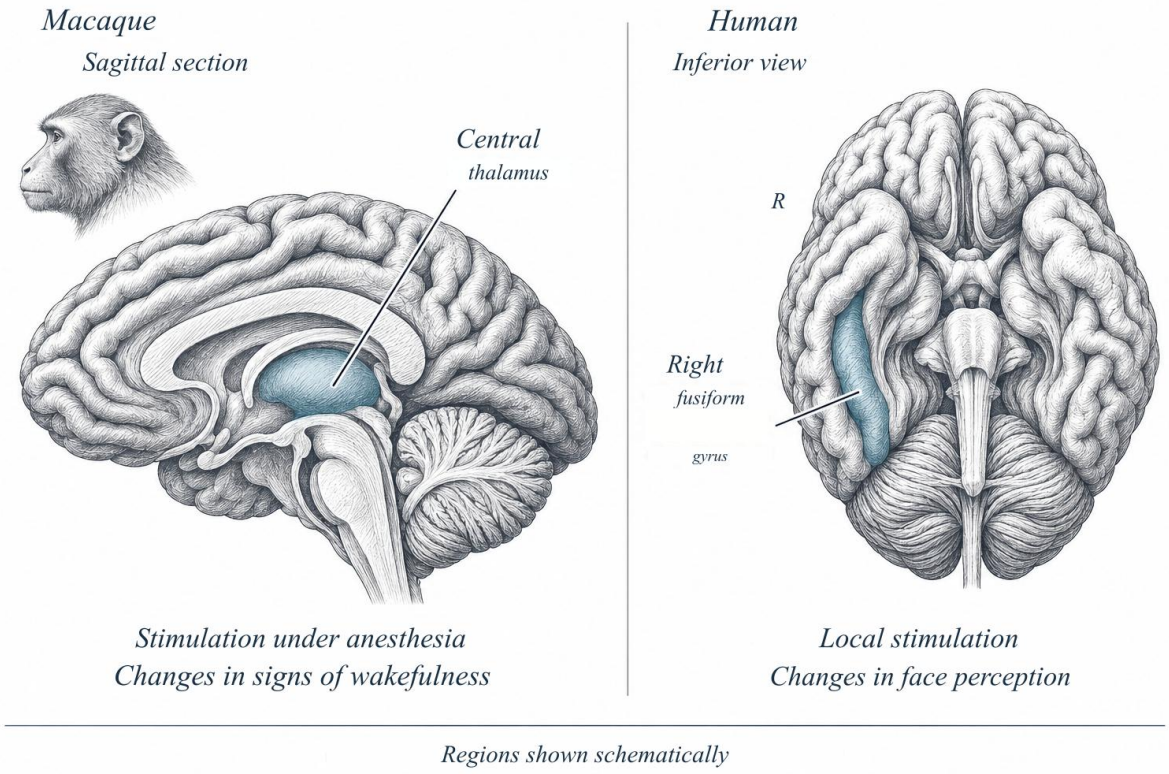


Figure 2. Different interventions affect different observable functions. On the left is an anatomical landmark of the central region of the macaque thalamus: stimulation during anesthesia changed behavioral signs of wakefulness [3]. On the right is a landmark of the human right fusiform gyrus: local stimulation changed the perception of faces [15]. The areas are shown schematically; the drawing is not a map of stimulation points and does not indicate a single center of consciousness.

The interface hypothesis allows that brain damage or stimulation alters the transformation of a more fundamental process. However, such an explanation is not enough without its own forecast. If any outcome is retroactively attributed to interface reconfiguration, the model no longer distinguishes between the expected and the unexpected.

Therefore, neurophysiology must enter into our hypothesis as a set of commitments. It will be necessary to explain why different interventions have different consequences, why certain contents emerge, and why changes in the organism do not appear to be arbitrary switching between countless alien personalities.

Nor should we weaken the alternative. You need to compare your hypothesis with a meaningful neural model that can learn, retain memory, change state and interact with the environment. Defeating the caricature of such a model will not say anything about the nature of consciousness.

What does the word "outside" mean?

The sentence “consciousness is outside the brain” allows for several significantly different readings.

In the first case we are talking about ordinary physical space. There is supposed to be a carrier somewhere outside the body that interacts with it. The hypothesis then faces questions about the spread of the impact, its intensity, delays, and how it can be independently detected. A new field or a new interaction channel cannot be introduced by name alone.

In the second case, we are talking about a quantum description of a composite system. Its general state may contain correlations that cannot be reduced to an independent description of the parts. However, the mathematical division into subsystems does not yet tell where the subject is located. The presence of entanglement also does not provide controlled superluminal communication. A physically valid channel is required to transmit a message. [14]

In the third case, “outside” means ontological primacy. It is assumed that experience or the possibility of experience refers to the fundamental properties of reality. This statement may not at all imply a separate place where a ready-made observer is located.

Such versions cannot be quietly replaced by one another. A spatially external carrier, nonclassical correlations, and the primacy of consciousness make different demands on explanation. If an experiment tests an optical process in a protein, its result cannot be transferred without additional arguments to the existence of a person outside the organism.

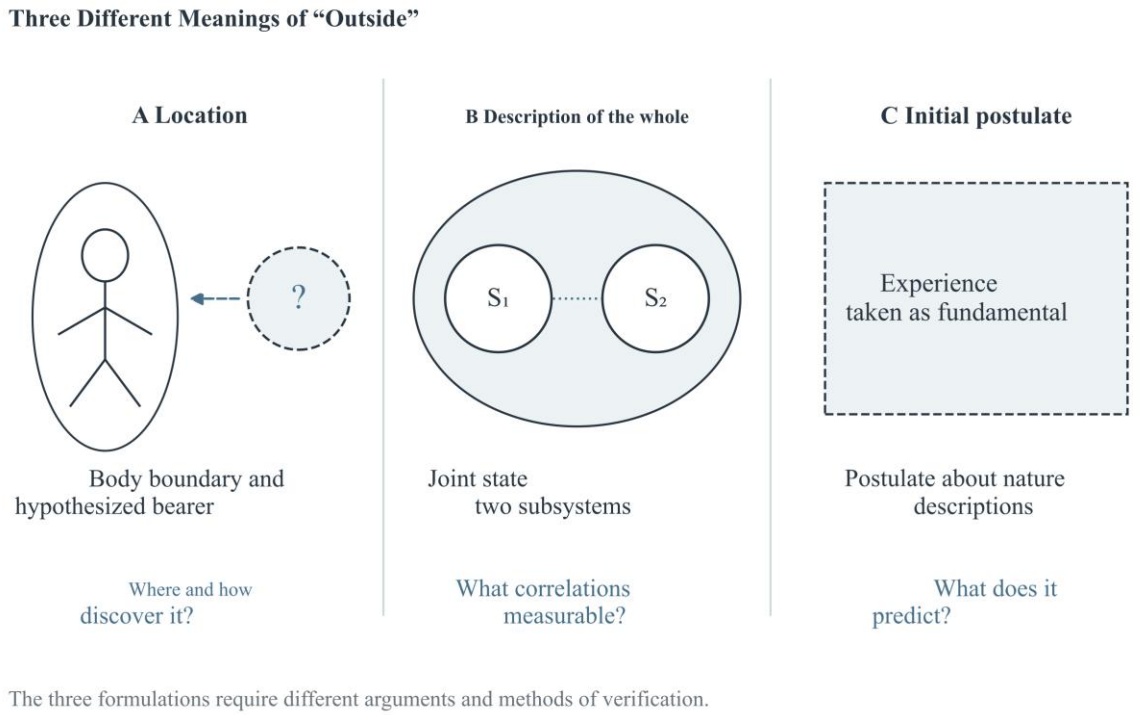


Figure 3. Three different meanings of "out". Spatial arrangement, description of a composite system, and ontological primacy require different arguments and do not automatically confirm each other.

For the book we will choose the most specific route. First, let's look at the physical mechanisms and their connection with brain function. Then we ask whether the data requires a broader system. Only then will we return to the question of the fundamental status of experience.

Why does the word “avatar” require clarification?

The image of an avatar seems clear: there is a user, and there is his representation in another environment. But when applied to a person, this image imperceptibly presupposes the presence of a ready user. He should already have memory, intentions and his own point of view.

This is exactly what we have yet to explain.

If the primary consciousness, even before connecting with the body, has memory and personal history, the hypothesis must explain their origin and method of storage. If it does not have human memory and character, the body participates in the formation of personality much more deeply than the usual image of a controlled figure suggests.

We suggest starting with the second option. Let us assume that there is a more fundamental basis for the experience. A specific subject can arise through its connection with a system that distinguishes between its own state and the world, holds history and directs actions. Then individuality is determined by the organization of interaction.

This is our working hypothesis for the joint formation of personality. It is compatible with the central idea of the book, but it introduces a significant limitation: the existence of a common ground does not necessarily imply the preservation of the individual after the destruction of the organism.

To discuss the preservation of identity, additional conditions will be needed. There must be preserved the differences by which this person is different from the other, the order of his memories and the way in which the experience continues. General information that an organism once existed does not provide these conditions.

In the future we will compare two versions of the interface idea. In one, the personality is entirely defined outside the body, and the organism provides access. In the other, individuality is formed jointly and significantly depends on the organism. They cannot be declared equivalent because they answer questions about development, memory, and brain dysfunction differently.

Why is quantum physics here?

It is possible to formulate a model of an external source without quantum words at all. Therefore, the quantum part must receive independent justification.

It is necessary to determine the specific carrier: for example, certain electronic states or nuclear spins. Then explore the interactions, the retention time of the desired properties and the way of influencing

biochemistry. Finally, it is required to show that the phenomenon under consideration is not exhausted by a suitable classical model.

This kind of reasoning is found in existing research programs. Matthew Fisher proposed considering nuclear phosphorus spins and putative calcium phosphate structures as possible elements of quantum processing in the brain. The value of this idea lies, in particular, in the set of specific physical and chemical questions. The sentence itself does not demonstrate a working quantum brain memory. [7, 8]

Stuart Hameroff and Roger Penrose have a different mechanism: the Orch OR theory connects putative quantum processes in microtubules with an objective state reduction. This is a separate program with its own physical postulates. It cannot be considered an established theory of consciousness or a ready confirmation of the brain as a receiver. [4, 5, 6]

In our book, these ideas will be interlocutors. We will look at what they suggest and what results could change their assessment. After this, we will determine which elements can be included in our own model and which conclusions do not follow from them.

Research must have the potential to fail.

Suppose we chose a physical medium and calculated that its connection with the brain should give a certain effect. The experiment found no effect in the range where the method was sufficiently sensitive.

This is a reason to limit or reject the chosen version. If you change the medium, the strength of the connection, and the conditions of manifestation each time after familiarizing yourself with the result, you will never get a negative answer.

Scientific work with consciousness today involves attempts to reconcile such differences in advance. In a Cogitate Consortium study published in 2025, proponents of Integrated Information Theory (IIT) and Global Neural Workspace Theory (GNWT) were involved in formulating predictions prior to testing. The results for 256 participants supported some of the expectations and called into question important predictions of both theories. [1]

This is a useful example of exploratory courage for our book. You can defend your hypothesis while simultaneously defining in advance the circumstances under which you will have to deviate from it.

The first boundary is already clear. We have compelling reasons to study the brain as a causally significant part of human consciousness. The possibility of a more fundamental basis remains a question. To move between them, one will need to discover an additional mechanism and explain its relation to experience.

The next chapter will begin with what is often hidden behind the word “quantum”: what exactly distinguishes a quantum state from the usual description, how it interacts with its environment, and why these differences might matter to a living system.

Chapter 2

What changes with a quantum description

In an ordinary room, things seem to have predetermined properties. The cup is on the table, the lamp is turned off, the book is open to one page. Ignorance of the observer does not prevent objects from being in some state. If you hide a coin under your palm, the uncertainty concerns which side it is facing. The coin itself does not have to wait for a glance to get its side.

This image is so familiar that it imperceptibly becomes a universal model of reality. I would also like to translate quantum theory into this language: a particle is supposedly a small object about which not enough is known yet. However, in a quantum description, not only the amount of information changes. The rules relating the preparation of the system, possible interventions and the distribution of results are changing. It is these rules that must be understood before looking for an explanation of consciousness in them.

State as a set of possibilities

A physical state can be understood by asking which differences it allows us to detect. If two preparation procedures yield identical outcome distributions for every admissible measurement, they are indistinguishable within the chosen description. If a measurement distinguishes their statistics, the states differ. This makes "state" a working concept rather than a promise to reveal an object's hidden essence.

For the simplest quantum system, we select two states that a suitable measurement can accurately distinguish and denote them with the symbols 0 and 1. They form a basis—a set of reference states through which any pure state of this system can be expressed. They can be selected states of spin or polarization of light. The pure state is written as a superposition:

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle, |\alpha|^2 + |\beta|^2 = 1.$$

Here ψ denotes the state, and α and β are complex amplitudes. Vertical bars and angle brackets are included in the accepted notation for state vectors. When measured in the chosen basis, the probabilities of the outcomes 0 and 1 are equal to the squared modules of the corresponding amplitudes. This is a special case of the Born rule. [14]

Amplitude differs from ordinary probability by the presence of a phase. For probability, what matters is how often the result occurs. What is also important for amplitude is how it combines with other amplitudes. Therefore, two systems with the same probabilities in one measurement may behave differently in another measurement. The quantum state cannot be completely described by one table of answers to one question.

There is no consciousness in this recording yet. It applies to systems that are not assigned the ability to feel. The content of the formula is determined by physical training and measurement, and not by how mysterious the subject of study seems.

Why superposition does not equal ignorance

Let's imagine two methods of preparation. In the first case, the device randomly selects the 0 state or the 1 state, with each occurring in half of the runs. In the second, it prepares the same state each time with equal amplitudes of the two options. A measurement that differentiates only between 0 and 1 will produce the same statistics in both cases. But this does not mean that the same physical states are prepared.

The second method has a certain phase relationship. An appropriate transformation before measurement allows this ratio to be converted into a probability difference. For a random mixture there is no such certainty. The difference is revealed by the results of the sequence of physical operations. [14]

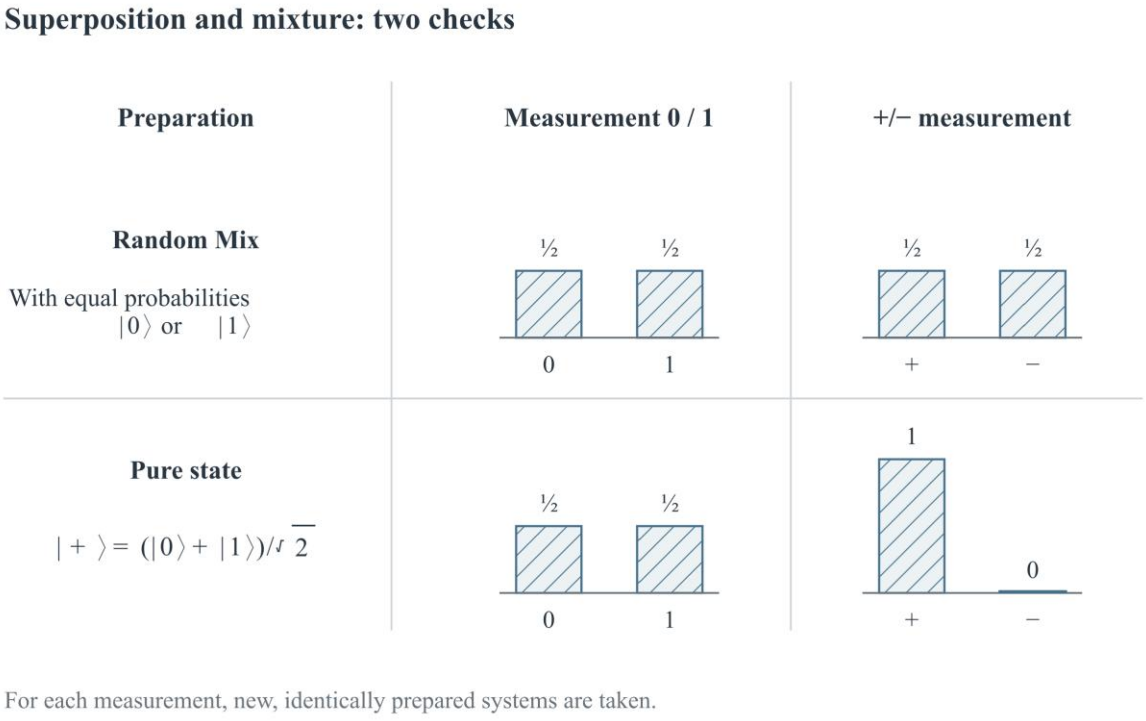


Figure 4. Case Study: Two preparations produce the same probabilities on one measurement but differ on the other. The numbers are calculated for selected ideal states and are not experimental brain data.

It is helpful to imagine two waves on the surface of the water. At one point their rises coincide, at another rise meets with a decline. The resulting picture depends on the relative shift. This analogy conveys the role of the phase, but does not make the quantum object an ordinary water wave. It

only helps to understand why adding amplitudes in a quantum calculation is different from simply adding probabilities.

This implies an important limitation of language. The phrase “the brain simultaneously processes several options” does not say anything about quantum superposition. A typical computing system can also support multiple competing solutions. For a quantum statement, it is necessary to specify physical states and an operation that will reveal precisely the phase relationships between them.

It is equally not enough to call a thought indefinite. Human uncertainty can be described by classical probabilities. The coincidence of the words “probability”, “choice” and “uncertainty” in psychology and physics does not establish the identity of the mechanisms.

Measurement leaves a physical trace

The measuring instrument must vary differently depending on the system being studied. Otherwise, its testimony will not reveal anything about it. Detecting light requires the interaction of light with matter; determination of magnetic properties requires appropriate coupling to a field or other sensing device. Observation begins with physical discrimination.

In the quantum description, such an interaction can link the system to the device and then to the environment. Different alternatives leave different traces. If these traces become virtually inaccessible to joint control, the observed interference may disappear. No one is required to read the screen to do this. What is important is the structure of the interaction, and not the subsequent awareness of the result by the person. [14]

But it would be just as hasty to declare that this has already solved all questions of measurement. The theory allows one to calculate observed probabilities and the evolution of composite states. The question of how to understand the single reported outcome and the status of the remaining alternatives allows for different interpretive approaches. Their difference cannot be subtly replaced by the assertion that experiment has already established the decisive role of human consciousness.

For a book, this boundary is useful. It frees the study of consciousness from the need to rely on the ambiguity of the word “observer.” A physical observer may mean a recording system. The subject of experience means the one for whom something is experienced. These are different roles, even if in a particular laboratory a person performs both.

How to describe part of a general system

Any study distinguishes the system from its environment. In one case, the system is an electron; in the other, a molecule, a cell, or a network of neurons. The choice depends on the question. It does not mean that the selected part has actually stopped interacting with the rest of nature.

If two parts are in an entangled state, describing each separately does not contain all the information about their joint correlations. To describe one part, a reduced state is obtained from the general state: it allows one to predict the results of measurements only in this part, without a separate description of the other. The mathematical operation of such a transition is called a partial trace. The local state may be mixed, although the state of the whole is pure. [14]

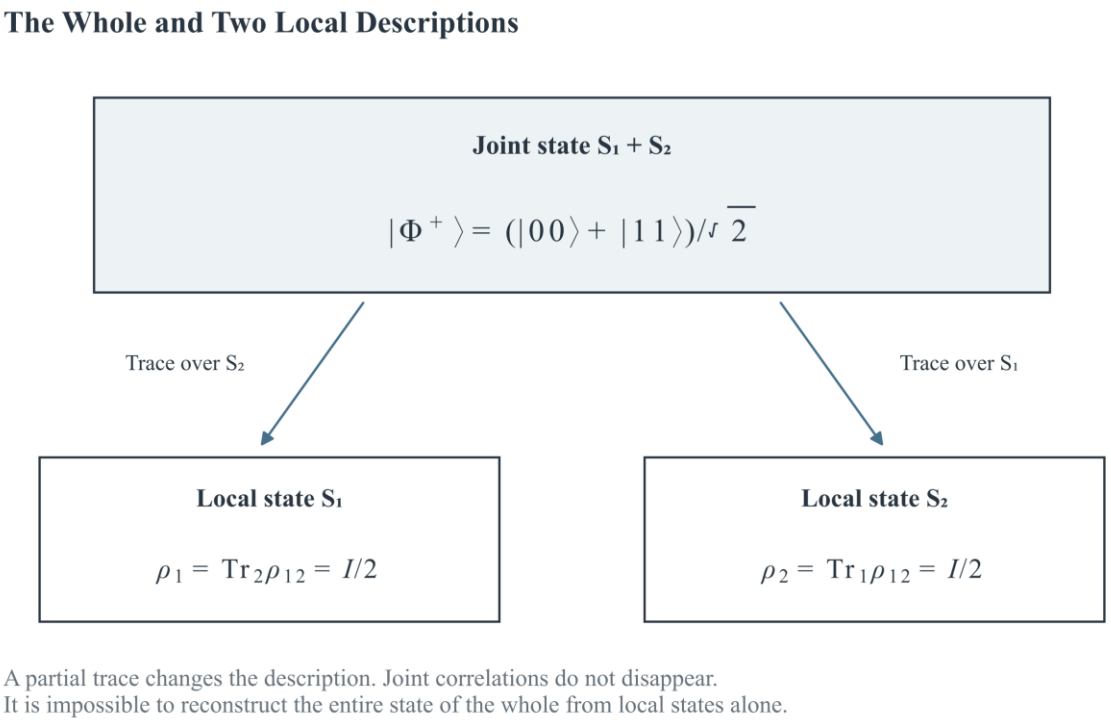


Figure 5. The state of the subsystem is obtained from the state of the whole as a partial trace. Local descriptions generally do not contain all joint correlations. The diagram explains the physical description; the unity of experience requires a separate explanation.

Here the temptation arises to immediately place consciousness in the “whole.” It seems as if the irreducibility of joint correlations automatically explains the unity of experience. However, these are two different questions. Correlations show how measurement statistics are related. Unity of experience concerns why certain events are given to one subject. A meaningful correspondence between them is still required.

If it is argued that consciousness belongs to a broad composite system, its boundary must be determined. Which interactions involve the process in the subject, and which simply connect it with the environment? Why does experience not extend without distinction to all objects causally connected with the body? How should a change in connection change the observable properties of experience? Without answers, the word “whole” only transfers uncertainty to a larger scale.

Such questions do not prohibit expanding the boundaries of the system. They make expansion meaningful. If one does need to take into account a

previously overlooked subsystem to explain the data, it will be a physical result. But the belonging of this subsystem to the subject will require one more argument.

From physical information to its meaning

In conversations about consciousness, the word “information” often refers to everything at once: a physical difference, a written sign, a message, and the meaning of the message. Meanwhile, the same sequence of signs can be understandable to one person and not communicate anything to another. The physical media remains the same. The meaning depends on the rules of use and on the history of the system that receives the record.

Quantum information theory considers, in particular, the distinguishability of states and the possibilities of transferring, transforming and storing these states. This analysis allows us to determine what is available to the recipient through a given channel. It does not by itself attribute understanding or experience to the recipient. Therefore, the expression “consciousness is quantum information” requires an addition: what state is meant, what process uses its differences, and why should this use be accompanied by a subjective quality?

There is one more border. An unknown state cannot simply be read in its entirety from a single instance of the system, like a ready-made line on the screen. Restoring a description from measurements requires certain assumptions and a set of data. The result of a particular measurement is not a snapshot of all potential properties. [14]

This is especially significant when trying to talk about human memory as a quantum record. It is necessary to distinguish between the preservation of a physical state, the ability to extract information from it, and the restoration of a meaningful history. Even perfectly stored media does not guarantee that an arbitrary recipient will be able to access its contents. And an accessible record of biography does not yet establish the continuity of experience of the person whose biography it describes.

Thus, the word “information” helps build a model only after the relationships have been clarified. What's different? For which system? Through what kind of interaction? What are the consequences of discernment? These questions do not require in advance to abandon fundamental consciousness, but do not allow us to replace its explanation with a single physical term.

The quantum mechanism must have time to change something

Let a state be discovered that preserves the required phase relationships. Its existence in itself does not explain the function. The mechanism must have time to influence a process that is related to behavior, memory or the content of perception. For this, not only the lifetime of the state is important,

but also the strength of the connection, the speed of transfer of influence and the stability of the result.

You can imagine a device with excellent internal memory, to which it is impossible to write anything and from which it is impossible to extract anything. It may be suitable for storing a predetermined state, but not for processing external information. The opposite extreme is also understandable: a very sensitive system easily accepts influence, but just as easily loses its differences under the influence of random disturbances.

A possible biological quantum mechanism falls between these extremes. It needs selective openness: to interact with the necessary processes and retain the properties on which the result depends for a sufficiently long time. In a physical description, such properties are associated with degrees of freedom - for example, with the position of a particle or its spin. This task has physical content even before the construction of a theory of consciousness.

Therefore, the question “is the brain quantum” is too broad. The substance of the brain is described by quantum physics already at the level of chemical bonds. The more meaningful question is: Does a particular brain function use a particular quantum property in such a way that, without it, the observed outcome changes? The answer will require a model that can be compared with a suitable classical approximation.

What questions can you ask now?

After the introduction of the quantum description, the original idea takes on several independent directions. You can explore which states are generally available to the selected medium. It is possible to find out how long the difference between superposition and mixture lasts. It is possible to test how this difference affects the molecular response or function of nerve tissue. One can separately ask what relation the found process has to experience.

None of these transitions are accomplished by mathematical notation alone. The state vector does not contain a ready subject. The interaction operator does not explain the meaning of sensations. The probability of an outcome does not equal the freedom of decision. But precise language allows you to see the location of each gap and set a specific research task for it.

For the brain-as-interface hypothesis, this means the possibility of a more rigorous formulation. The intended external contribution must change the physical state of the observable system. If this contribution is quantum, it is necessary to indicate how its action differs from an ordinary random signal. If contribution is associated with subjectivity, it is necessary to explain why a change in the physical connection should be accompanied by a change in a certain aspect of the experience.

The possibility of a meaningful negative result also appears. Measurements may show that the proposed states lose the necessary

properties too quickly. Or that a difference predicted for an additional mechanism is absent where the method would detect it. Such a result will limit the specific construction, preserving the very question of the nature of consciousness.

Quantum theory makes the search more demanding. Instead of indeterminate depth, it offers distinguishable states, operations, and constraints. The next question arises on a human scale: what exactly must be preserved and changed in order for what happens to be felt to belong to one being?

Chapter 3

Where to Look for the One Who Experiences

A person reaches out to a cup and almost never decides separately who owns the moving hand. Belonging is already present in action. The cup is on the outside, the hand serves as a means of movement, the effort is felt as one's own. This little episode seems simpler than the question of the origin of consciousness. However, it already combines the perception of the world, the representation of the body, the expectation of the result and the feeling of one’s own participation.

If you only look for the subject as a hidden point inside the head, this whole device is easy to miss. In such a search, consciousness is presented in advance as a small spectator: the senses provide him with pictures, memory shows him the past, the will allows him to press internal buttons. But then the same question arises for the viewer himself. How does he see pictures and feel pressure? Moving the observer inside the system does not solve the problem.

Body Ownership Does Not Always Follow Anatomy

In an experiment by Matthew Botvinick and Jonathan Cohen, the participant's real hand was hidden from view, and an artificial one was placed in front of him. Simultaneous touching of both hands could cause the feeling that the visible artificial hand belonged to the participant himself. The authors also compared matched and mismatched touch conditions and assessed changes in the perceived position of one's own hand. The work showed the connection of bodily identity with the coordination of visual, tactile and proprioceptive information. She did not show the transfer of consciousness into the object. [16]

The difference is fundamental. The physical hand has not moved, but the way the body is represented has changed. Therefore, the experienced boundary of the body is not a simple photograph of an anatomical boundary. There is a work of coordination between the body and the sensation of the body. Its results are usually so familiar that they are taken for granted.

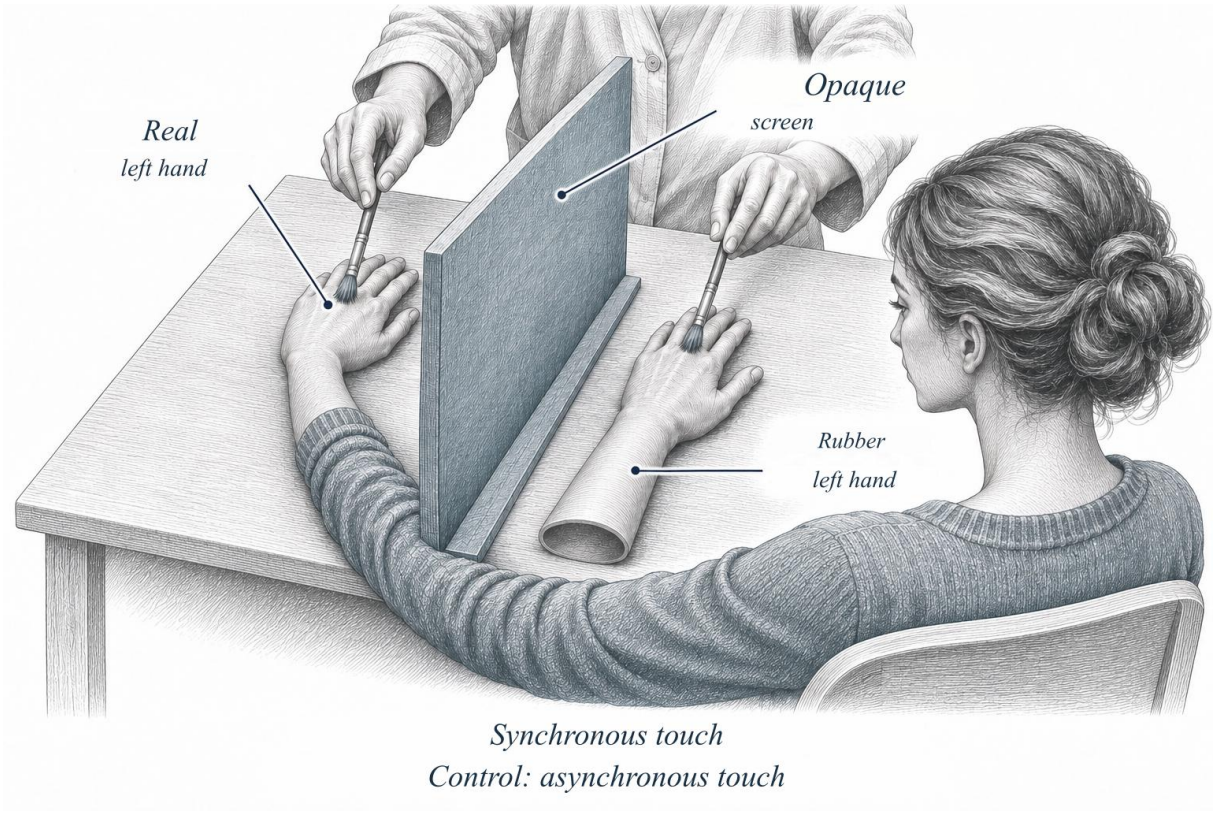


Figure 6. Principle of experiment with rubber hand [16]. The participant sees an artificial hand, while the real hand is hidden from him by an opaque screen; it is shown to the reader from a different angle. Touching the two hands coordinates or diverges in time. The juxtaposition of visual, tactile, and proprioceptive information can alter the sense of bodily belonging. The transfer of consciousness into an object is not assumed here.

Such coordination of signals does not have to be reasoning in words. Belonging may be felt before an explanation emerges. This is why observation of the bodily self should not be confused with an account of character or biography. It is possible to examine a particular component of self-representation without assuming that it exhausts the personality.

A meaningful possibility arises for the idea of an interface: the boundary of an individual's experience may depend on how the system relates events to its own body. However, this possibility is not yet chosen by the physical carrier of the experience. It first of all indicates what kind of organization any theory that places the basis of consciousness within the organism or outside it must explain.

The body communicates itself from within

Some information about the body comes through vision and touch. The other is related to internal processes: breathing, heartbeat, state of organs. A person does not see these processes the way he sees a cup, but they can participate in the well-being and emotional coloring of what is happening. The concept of interoception is used to perceive internal states.

Hugo Critchley and colleagues examined brain activity during a task to estimate the timing of one's own heartbeats. They found associations

between task performance and activity in a number of areas, including the right anterior insular and adjacent opercular cortex. The study also found correlations between interoceptive discrimination accuracy and several subjective measures. This is evidence for the involvement of specific neural systems in accessing bodily signals, rather than the detection of a single location where the subject is located. [17]

You can mentally compare two organisms that receive the same image of the external world, but are in different internal states. For one, the path to water is of urgent importance, for another it remains a neutral opportunity. The difference here isn't just about the image. It concerns what the body requires and what activities become valuable.

Therefore, the metaphor of the body as a screen is insufficient. The screen has no needs of its own, whereas the body must maintain its existence. In a research model, this allows us to connect self-representation with regulation: the system distinguishes events not only by form, but also by how they influence the conditions of its further existence.

Such a functional explanation does not yet reveal the qualitative side of hunger or anxiety. It describes why internal signals may have a special place in the organization of behavior. For the hypothesis of a more fundamental consciousness, this organization represents a possible mode of individuation: the general physical process, if it exists, must receive a certain perspective through the specific needs and limitations of the body.

Several meanings of one “I”

The word “I” brings together various faculties. You can recognize your own reflection, remember your past, distinguish your own movement from an external push, report an experience and doubt the correctness of your decision. Having one ability does not automatically mean having the others. It is useful to distinguish them even when they work together.

Bodily self-representation refers to what one's body perceives and where the perspective of action is located. The sense of authorship refers to participation in an event: the movement was due to one's own action or was imposed from the outside. Autobiographical representation connects the present state with history. Reflection allows you to make your own ways of perceiving and deciding the subject of further consideration.

These distinctions provide a working framework for analysis. They do not mean that several independent people exist inside the head. Rather, the word "I" describes different relations between one system and its own states. This distinction helps us avoid demanding the full complexity of a human biography from a brief sensation.

The working differences between experience, self-representation and reflection are summarized in Figure 1.

Suppose a device has been created that accurately distinguishes between its own commands and external disturbances. It demonstrates a certain form

of action control. If the device additionally stores history, it becomes possible to connect the present with the past. But even the combined presence of these functions does not allow us to simply write the word “experience” into the technical description. The question of subjectivity remains separate.

The opposite mistake is to consider subjective experience impossible without a developed story about oneself. In such a definition, consciousness would be identified in advance with one of the complex forms of human self-consciousness. Then the study of other creatures would be limited to formulating the question before obtaining the data.

Perspective of action without an internal spectator

In everyday life, events are usually presented in relation to the body. Closer or further, reachable or unattainable, dangerous or safe - these differences acquire meaning from a certain position. A behavior model requires a center of reference. However, the center of reference does not have to be a separate object.

Geographic coordinates do not require that the small owner be inside the map. The observer's position can be determined by the relationships between objects and the possibilities of movement. Likewise, a system's functional perspective can be determined by the way it links perception, memory, and action. This analogy does not explain the subjectivity of a card or a machine; it shows only the logical possibility of organization without an internal spectator.

In the brain one can look for processes necessary for a certain aspect of experience without expecting to find an organ in which a ready-made “I” sits. The research by Parvizi and colleagues discussed in the first chapter shows how local interventions change the specific content of perception. It helps distinguish features, but does not turn the face recognition area into a storage area for the whole observer. [15]

The absence of a single center found is also not an argument in favor of its external location. This would be a conclusion based on the principle: if the item you are looking for is not here, then it is somewhere else. Perhaps the original expectation of an individual item was incorrect. And perhaps a broader theory is indeed needed. The result of the research must choose between these options, not the usual image.

The present needs to continue

The perspective of action has not only a position in space, but also an extension in time. For a movement to be part of one action, the system must somehow connect its beginning, continuation and expected result. Otherwise, the sequence of states would remain a set of independent episodes. This is a functional requirement that can be formulated even before solving the issue of subjective time.

Let's imagine a device whose state is completely erased after each step. It receives a new image and produces a response, but does not retain a trace of the previous event. Another device uses the previous step to interpret the current one. The difference between them can be found in tasks where the same signal has different meaning depending on the context. However, the presence of such a difference does not mean that the second device survives the passage of time.

This example allows you to separate the two statements. Certain forms of self-representation require the accessibility of history. But the availability of history is not sufficient evidence of subjective continuity. Both statements must remain in the model, otherwise it will either lose functional certainty or too quickly declare any memory to be consciousness.

In the hypothesis of joint personality formation, the history of connection takes on special significance. If individuality arises in interaction, it is necessary to explain how the current properties of the system were formed and what consequences they have. A list of instant characteristics alone is not enough for this. Two systems may look similar now and yet have different histories of relationships with the world.

Therefore, the expression “same subject” requires a selected criterion. We can talk about preserving memory, continuing a causal chain, or a feeling of self-recognition. These criteria may coincide in ordinary life, but their coincidence cannot be considered in advance as a law for all conceivable physical implementations.

Where is the boundary of the subject?

The bodily boundary seems a natural candidate for the boundary of consciousness. However, even at the level of functions, the body is constantly dependent on the external environment. Writing aids memory, a tool enhances movement, and language connects personal decisions to the experiences of others. This dependence forces us to clarify what exactly it means to include something in the system.

To complete a task, you can consider a person together with a notepad. For a neurophysiological experiment, it is possible to limit the analysis to the brain and a specific set of input signals. To study metabolism, a different boundary will be needed. All of these descriptions are acceptable if the choice of boundary is appropriate to the question.

But functional inclusion does not equate to belonging to subjective experience. The fact that a notebook supports memory does not mean that it feels together with the owner. From the fact that without external oxygen the body stops working, it does not follow that all the air becomes part of one subject. Causal dependence is too widespread to define the limit of experience on its own.

The author's interface hypothesis will require a narrower criterion. It can be assumed that individuality is associated with a stable mutual influence

between certain internal processes, the memory system and the putative additional carrier. Then the boundary should be determined not simply by the presence of a connection, but by its structure and consequences. This is an exploratory assumption from which measurable differences have yet to be derived.

For example, breaking a connection must change something specific, rather than explain every possible change. Reduced agreement may impair information fusion, access to history, or the stability of self-representation. If the proposed mechanism is specifically related to experience, it will be necessary to show why its action cannot be fully explained by disturbances in response, attention, or memory.

What remains of the avatar image

An avatar in a virtual environment usually already has an external user. The avatar itself does not create its biography, needs or ability to distinguish between itself and the world. Therefore, transferring this image to a person imperceptibly brings too many ready-made answers. It presupposes personality even before its origin is explained.

A more cautious version retains only the idea of mediation. The body sets a set of available influences and methods of action. The brain connects them in time and maintains the idea of their relationship to the body. The supposed fundamental basis of experience, if it exists, participates in this organization, but is not yet required to contain a complete human personality.

In such a model, the subject is considered as a stable process. His present states are dependent on history, bodily needs guide action, and the structure of interaction must explain how multiple events come together into one perspective. It is the device of this connection, and not the image of the hidden passenger, that becomes the subject of research.

This is not a ready-made theory, but already a direction for its construction. Instead of searching for the little observer, questions arise about belonging, access, continuity and boundaries. Each of them can be associated with different measurements and different possible errors.

The subject remains the central difficulty. However, it is now formulated more precisely: how is it that the physical organization that distinguishes between the world and itself is also the organization for which what happens is experienced? To move forward, it will be necessary to examine the old ideas about the soul and the primacy of consciousness so that they receive clear commitments to observation.

Chapter 4

Old questions in verifiable form

The question of whether man is exhausted by the visible body arises before any complex device. Death, sleep, memory and the feeling of one's own separateness force one to search for an explanation of what it means to be someone. Religious language can answer this question through the soul and its purpose. Philosophical - through the relationship between experience and the world. The scientific approach begins with a different requirement: what observation must change if the proposed explanation is true?

These ways of talking cannot simply be declared to be different names for the same theory. They can solve different problems. A statement about the meaning of life does not become a measurement when a formula appears next to it. But an image or a philosophical assumption can pose a question for which a physical model can subsequently be found. It is this transition that is of interest to this book.

What is saved during translation

There are different meanings of the word “soul”. It can denote personality, moral worth, a living presence, an immortal principle, or a bearer of memory. These values do not have to match. Therefore, scientific work accordingly begins with the choice of a specific statement, and not with the search for an instrument that should detect everything at once.

If soul is understood as the capacity to experience, the question arises about the conditions of subjective experience. If an independent bearer of biography is assumed, questions about recording, storing and retrieving information are necessary. If we are talking about the action of an immaterial cause on a body, it is necessary to understand what observable changes will distinguish this action from already known interactions.

During translation, some of the original meaning may be lost. Science is able to test a certain statement about memory without resolving the question of human purpose. It can limit the pattern of external influence without making a judgment about the religious picture of the world as a whole. The boundaries of the conclusion are determined by which specific statement was verified.

This book retains the original question but takes it into a testable form. Instead of the statement “the personality is larger than the body,” a problem appears: are there any observed dependencies that require an additional carrier to be included in the model to explain? Instead of saying “everything is connected,” the question is what connections are significant, how they are discovered, and what differences they create.

Primacy allows for different models

The assumption of primary consciousness may mean that experience refers to fundamental properties of reality. In this case, it does not have to be at a separate point in space. This situation concerns what is considered initial in an explanation. To relate it to physics, we need a rule of correspondence between a fundamental property and specific physical organizations.

Another version assumes an independent physical system outside the body. It interacts with the brain and contributes to the human condition. Here the usual research task already arises: to determine the medium, the method of communication, the magnitude of the effect and the conditions for its occurrence. The unknown nature of the medium does not negate these requirements.

The third version shifts the emphasis to relationships. Neither the organism nor the putative wider system alone constitutes a complete human person. The individual subject emerges from the sustained interaction between them. This version is closer to the hypothesis of joint formation of personality developed further, but for now it also requires its own physical content.

The difference between versions is important for assessing failure. If a particular external field is not detected, this may weaken the model of that field. It does not automatically refute any idea that experience is fundamental. Conversely, the philosophical appeal of fundamentality does not support the specific meaning of coupling strength in a physical experiment.

The idea becomes more precise when it stops moving between these values based on convenience. Each statement must retain its own subject. Otherwise, a positive result will be counted towards all versions at once, and a negative result will not apply to any one.

The cause must leave a discernible trace

Let's imagine two models of one experiment. In the first, a person’s state is determined by the functioning of the body and normal interactions with the environment. The second one adds an external carrier that acts on a certain brain process. If both models predict the same observations under all available conditions, the choice between them is not yet decided by this experiment.

For a difference to occur, the participation of an additional carrier must lead to a certain observable effect. For example, it can change the response to an independently measured stimulus or specify a dependence on distance, orientation, or time. These examples indicate the type of prediction that is possible, rather than reporting already discovered properties of consciousness.

However, any unusual coincidence does not indicate a new channel. Two systems can respond to a common external factor. The measuring instrument may introduce similar errors. The way episodes are selected can highlight matches and leave out discrepancies. Therefore, the model must include not only the desired cause, but also the real ways in which the observed result occurs.

Caution is also needed in the other direction. If the intended effect is realized through a change in brain activity, you cannot simply exclude all brain activity from the analysis and expect the effect to persist. Such a procedure may remove the action path itself. The question is one of comparing causal explanations, not of mechanically subtracting everything known.

This gives rise to the constructive meaning of the image of the receiver. Its scientific version begins where there is a certain connection between input, transformation and output. The receiver is interesting not by its name, but by the fact that it allows you to predict how the result will change after changing one of the links.

The formula does not replace the relationship between concepts

Mathematical notation can give precision to the model. But it can also hide emptiness if familiar symbols are assigned uncertain meanings. It is enough to designate consciousness with a letter, enter the coefficient of “spiritual energy” and write an equality to obtain an external resemblance to physics. As long as there are no definitions and measurement procedures, the similarity remains superficial.

An equation is useful when it relates quantities whose values can be specified, measured, or derived from other conditions. It is also necessary to check the dimensions. Energy, time and probability do not become interchangeable just because a complex subject is being discussed. If a new quantity is introduced, its meaning must be determined before it is used in the explanation.

Even a correct physical calculation does not automatically resolve the issue of experience. You can get the lifetime of a state or the probability of a reaction. To move from this value to consciousness, an additional assumption is required: why exactly does it matter to the subject and how to discover this meaning regardless of the original idea.

Therefore, the mathematical part of the book will serve two purposes. It must describe a possible mechanism and at the same time show its limits. The standard recording of the interaction of two subsystems will remain standard physics. The author's contribution will begin in the selection of testable connections between these dynamics and specific aspects of experience.

This order does not reduce the boldness of the hypothesis. It makes visible exactly where a new step is being proposed. Without this, it is impossible to understand what needs to be tested: a long-known equation, an unknown biological mechanism, or a new rule of correspondence between physical organization and experience.

When the question has not yet become an experiment

It is possible to formulate a statement about consciousness that by definition has no observable consequences. For example, assume an additional entity that does not affect the body, memory, actions and measurement results. Such a statement may have philosophical implications. But the experiment does not provide a way to distinguish between its presence and absence.

This does not give the right to call a statement false simply because it is currently unverifiable. However, it does not allow us to present it as a confirmed natural scientific result. There is a separate distance between logical possibility and data support.

There are also intermediate cases. The model may have observable consequences that are currently too small for available instruments. It also happens that the type of effect has already been determined, but the biological carrier has not yet been sufficiently studied. Future measurement sensitivity, range of acceptable parameters, and indirect limitations can then be discussed. It is important not to confuse the technical inaccessibility of a certain experience with the absence of any conceivable difference.

A negative result also depends on the conditions. If the method was only able to detect strong effects, the lack of signal limits the strong variations. It does not show that every weak effect is absent. But the possibility of an infinitely weak effect should not be turned into a way to save any explanation: such an effect must still be significant enough for the function that is attributed to it.

This is where physics and the explanation of consciousness come together especially closely. A carrier that cannot be detected due to its negligible effect is difficult to simultaneously claim as the cause of large and lasting differences in body performance without an additional amplification mechanism.

The same observation can support different stories

Let's imagine that after changing some physical parameter, a person distinguishes visual signals differently. A proponent of the interface model might attribute this to the setup of an additional channel. The neural model could explain the result by changes in cell sensitivity. Both stories may be compatible with one observation. So the important question is: what additional outcome do they expect differently?

The first model, for example, would have to relate the change to an independently determined property of the putative carrier. The second is with measurable cellular processes. The difference may be small, but it is what makes the comparison a study. If a new mechanism is introduced only after the result has been obtained and does not set its own expectations, its explanatory role remains unclear.

Nor can a theory be considered superior just because it uses more variables. Additional parameters allow you to adapt the description to already known data. A content check appears when moving to conditions that were not used to set up the model. The more accurately a new observation is predicted, the stronger the reason to continue working with the corresponding mechanism.

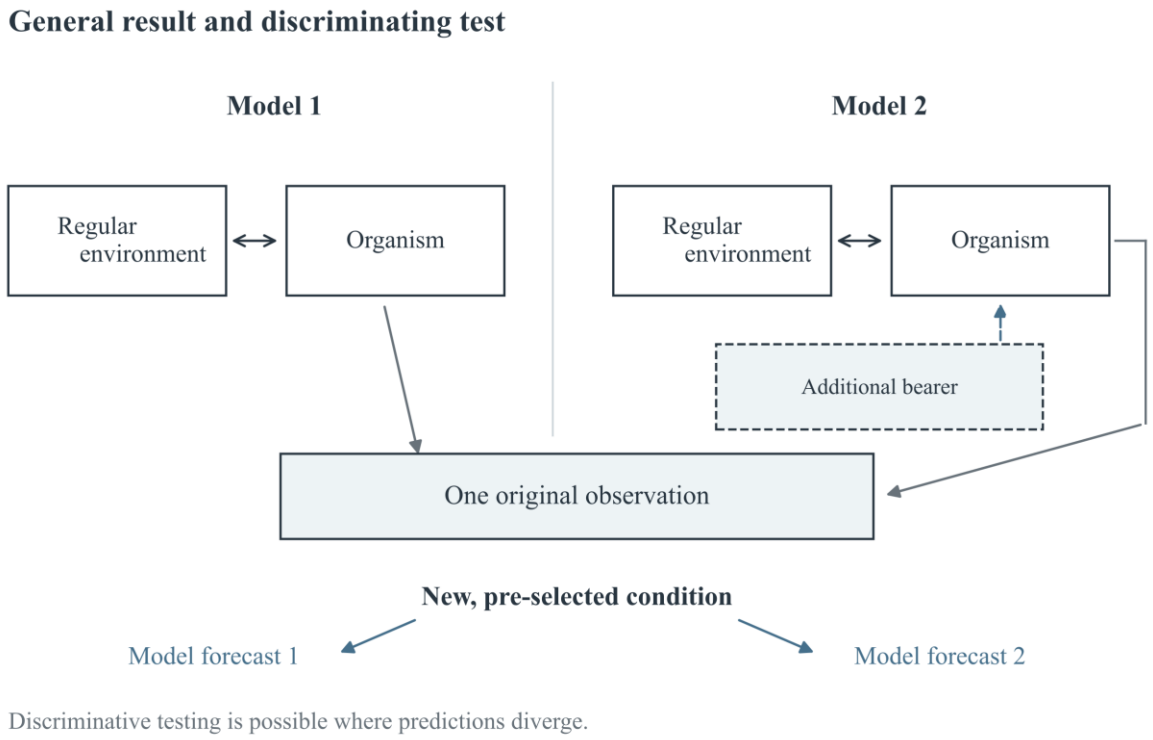


Figure 7. The same initial result can be compatible with different models. Discriminative testing requires a new condition and pre-formulated expectations.

For controversial issues, this rule is especially useful. It allows you not to decide in advance which image of a person should win. The study may reveal a broader physical system, or it may reveal the sufficiency of mechanisms that were previously underestimated. The scientific value of a work is determined by how much it reduces uncertainty, not by whether the result matches the original expectation.

Therefore, a scientific basis must also include data that resists the hypothesis. The external medium, if it exists, does not exempt the model from explaining the subtle dependence of experience on the brain. And the success of a neural explanation of a particular function does not

automatically turn all questions about experience into solved ones. Each approach must clarify what exactly it managed to explain.

The hypothesis becomes stronger through restrictions

Suppose that external input is needed only for the occurrence of the experience, and all information used in behavior is completely formed by the brain. This version differs from the assumption that an external system stores memories and transmits them to the body. In the first case, it is necessary to find an indicator that is sensitive to the expected condition of the experience itself. In the second, additional requirements for the information channel and memory appear.

If these options are separated in advance, the data may change their assessment differently. Detection of external physical influence does not yet show the presence of an external biography. Discovering the ability of a system to store information does not yet show that this information is being experienced. Each transition requires its own foundation.

Existing scientific programs already have examples of such refinement. The Orch OR theory links consciousness to specific assumptions about microtubules and objective reduction. Fisher's hypothesis highlights other media and processes. They can be discussed precisely because they name the physical links to which certain questions arise. The joint use of quantum concepts does not make these programs one theory. [4, 7]

The authors' interface hypothesis must also acquire its own set of constraints. It cannot serve as a general name for everything that remains unexplained. It must specify what is connected, why the connection is selective, how individuality arises, and how this construction differs from a neural explanation of the same observations.

Old questions retain their depth. The method of promotion is changing. Instead of seeking definitive confirmation of a pre-selected picture, it becomes possible to gradually eliminate inappropriate mechanisms and strengthen those that stand up to comparison. The next part of the book begins with an area where such an approach already has a specific subject: with physical processes in living matter.

Part two

Physics of a living system

Chapter 5

Quantum processes in a warm world

A living cell is not like a carefully isolated physical device. Molecules move in it, reactions take place, energy is consumed, and the environment of individual structures changes. At first glance, such an environment seems an unsuitable place for subtle quantum effects. However, the formulation of the question itself needs clarification. Maintaining a certain state over a long time and using a short quantum process are different tasks.

A molecular reaction does not need to maintain the properties required by a large quantum computer. It can use a certain dependence only at one short stage, after which the result is fixed by ordinary chemical dynamics. Therefore, the study of quantum processes in living matter begins with the scale of the problem: what exactly needs to happen, what degrees of freedom are involved and how much time they require.

Not all quantum physics means quantum computing

The chemical bond, absorption spectrum of a molecule and the electronic structure of a substance require a quantum description. In this broad sense, the quantum nature of biology is not an unusual hypothesis. Another statement may turn out to be unusual: for a certain function, a specially preserved coherence, entanglement or spin dynamics is essential, which is not enough to be replaced by a suitable classical model.

This formulation does not require that the entire organism be simultaneously in one controllable quantum state. Different scales may be described in different ways. For one reaction, quantum probabilities of transitions are needed, for the next stage a distribution of concentrations may be sufficient, and the behavior of the organism will require another level of description.

It's like going from a single element to a working device. The physics of the element is important, but explaining the purpose of the device does not arise simply by zooming in on a photograph. It is necessary to show how local changes influence further processes. In biology, such an intermediary could be a chemical product, a change in the shape of a protein, or a change in the rate of a reaction.

Therefore, the expression “quantum effect discovered” leaves the functional question open. The effect can be a necessary link, a side effect of the structure of the molecule, or a phenomenon accessible only under

special measurement conditions. To choose between these options requires studying the relationship between the levels.

How spin can change a chemical result

One of the most specific examples is the radical pair mechanism. A radical is a particle with an unpaired electron. If the overall process produces a pair of radicals, the spin states of the two electrons can influence the available pathways for further transformation. The spin here is a quantum property, not the literal spin of a small ball.

In a simplified description, singlet and triplet states of the pair are distinguished. A singlet has a total spin of zero; a triplet combines three states with non-zero total spin. These are the properties of the common quantum state of two electrons. Interactions with surrounding nuclei and the magnetic field can change the ratio of these states over time. If chemical channels differ in their spin dependence, the change in dynamics is reflected in the product yield. This way the magnetic influence gets the path to the chemical result.

Klaus Schulten, Charles Swenberg and Albert Weller back in 1978 proposed a chemical compass mechanism in which sensitivity to the direction of the field is associated with the peculiarities of the spin dynamics of radical pairs. Their work was a physical proposal for a possible mechanism for magnetic sensitivity in living systems. [19]

The significance of this idea lies in the structure of the explanation. The external field does not have to provide all the energy of the subsequent reaction. It can change the relative probability of paths, and the energy comes from another source, such as a previous light excitation. This makes it possible to understand why comparing the energy of a weak effect with the total energy of the system does not always resolve the issue of sensitivity.

However, sensitivity does not arise without conditions. Reaction times, types of interactions, spatial structure of the molecule, and competing processes are important. If the differences disappear before the yield changes, the proposed mechanism does not perform the desired function. Therefore, the word “quantum” should be followed by a description of specific chemical reactions and their rates.

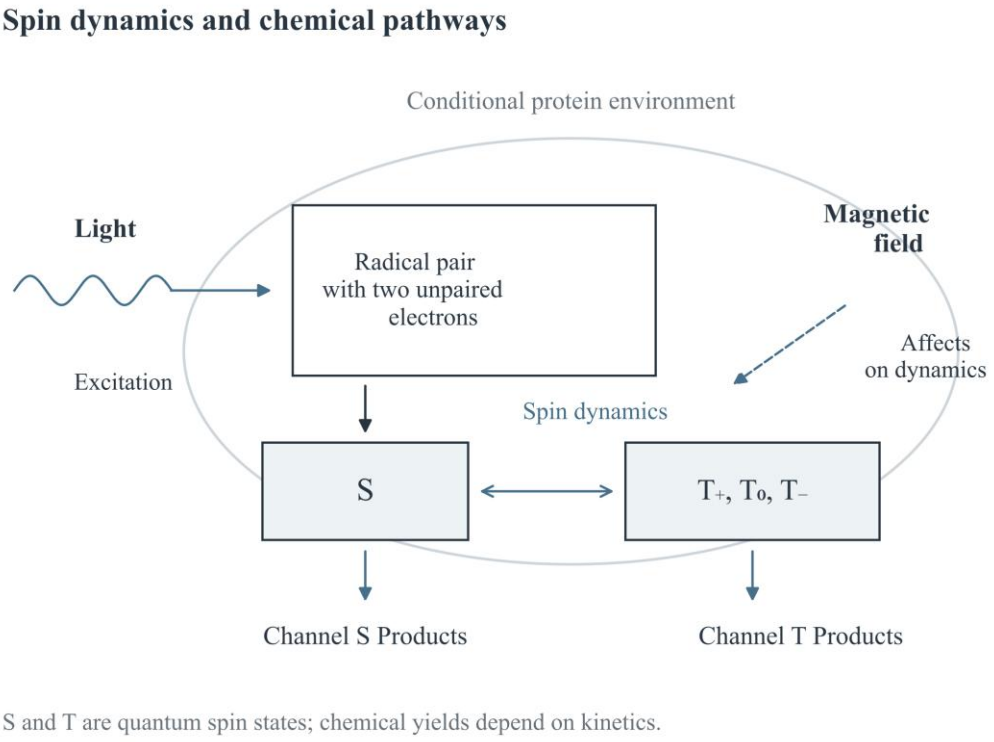


Figure 8. Simplified diagram of the radical-pair mechanism. Changing spin dynamics can change the probabilities of chemical pathways given the right times and interactions.

What has been measured in cryptochrome

A study by Jingjing Xu and colleagues, published in 2021, examined the photochemistry of cryptochrome 4 from the European robin. Experiments with the isolated protein revealed sensitivity to a magnetic field; this sensitivity differed from that of proteins from the other bird species examined. Changes to individual regions of the protein helped investigate the role of successive radical pairs. These results support research into a specific molecular mechanism. They concern measurements outside the whole organism and do not directly record how a bird experiences direction. [9]

The nature of the question is especially important in this story. The researchers isolated the substance, selected the exposure, and measured the dependence of photochemistry on conditions. This allows the proposed mechanism to be compared with other physical explanations for the result.

For a theory of consciousness, such an experiment represents an example of concreteness. If a specific carrier in the brain is suspected, it is useful to ask whether it can be studied independently of the complex behavior first. What quantity is changing? Which influence acts selectively? What chemical explanation options remain? These questions allow us to strengthen the physical link even before discussing subjective experience.

That being said, independent study has a price. By highlighting a structure, the researcher changes its environment. Therefore, laboratory

confirmation of a certain property and confirmation of its natural function form different stages. The first is capable of making the second plausible and verifiable, but does not replace it.

The environment both hinders and helps

The environment is often represented only as a source of destruction. For some quantum problems this is a useful first approximation: interactions with the environment result in a loss of available phase relationships. However, the biological mechanism cannot be completely separated from the environment. It receives energy and substances, interacts with neighboring structures and must transmit the result further.

Therefore, for a living system the question is the nature of the connection. Interactions alone destroy the distinction needed by the function. Others create the conditions for a reaction or reinforce its outcome. The same environmental change can be beneficial at one stage and harmful at another. There is no universal conclusion from the word “noise”.

The imaginary molecular machine illustrates this duality well. If you make it completely insensitive to the outside world, the possibility of registering a signal will disappear. If made sensitive to everything, useful distinctions may be lost among random changes. A working design requires selectivity, which is determined by state energy, geometry and modes of interaction.

This reasoning does not guarantee that the necessary selectivity is implemented in the brain. It explains what type of device might be worth checking. Instead of a vague "all noise" defense, one needs to determine which disturbances are significant and why some degrees of freedom may be less sensitive to them than others.

Disequilibrium is also not a ready-made answer. A constant influx of energy can support certain processes, but in itself does not prove the preservation of the necessary coherence. We will have to show where the energy goes, how the state is restored, and whether restoration introduces additional uncertainty.

Let's assume that cooling the sample enhanced the observed effect. This result is compatible with a decrease in some disturbances, but temperature simultaneously changes the rates of chemical reactions and the properties of the medium. Therefore, a temperature comparison alone does not highlight the desired mechanism. For explanation, the set of dependencies expected in advance from the model is important.

A similar difficulty arises when the composition of a substance changes. Replacing an isotope can change not only the spin properties, but also other characteristics of the system. A change in a protein can affect both the putative pathway of excitation transmission and the usual stability of the structure. Therefore, the accuracy of an intervention is determined by its physical consequences, and not by the name of the chosen method.

This makes the investigation slower than simply looking for an unusual signal, but allows explanations to be differentiated. A consistent picture becomes a strong argument: a certain effect changes a certain parameter, the change is reflected in the expected part of the dynamics, and comparable control conditions do not give the same result. This picture still allows for revision, but it connects the hypothesis with the structure of the system much more closely than a single coincidence.

From molecular effect to function

Let the molecular effect exist and reproduce. The next task is to find out whether the body gains access to its result. This requires a path from a small difference in response to a more sustainable change. Without such a pathway, the effect may remain physically interesting and biologically insignificant.

You can mentally trace the chain: the probability of the reaction differs, the amount of the product changes, the state of the sensitive structure changes, then a difference in the cellular response arises. Each transition comes with its own uncertainty. A small effect can increase, average out, or disappear among parallel processes.

Amplification does not mean information appearing out of thin air. It can make a small difference convenient for further use by consuming system energy. But along with the beneficial effect, extraneous disturbances may also increase. Therefore, not only the magnitude of the final answer is important, but also its specificity: does it depend on the property for which the model is proposed?

For consciousness, the chain becomes even longer. After the physical and cellular stages, it is necessary to clarify the relationship of the process to the state or content of experience. Influence on movement, for example, is not the same as influence on experience. Effects on memory can change the story of the past without necessarily changing the experience itself at the time of the event.

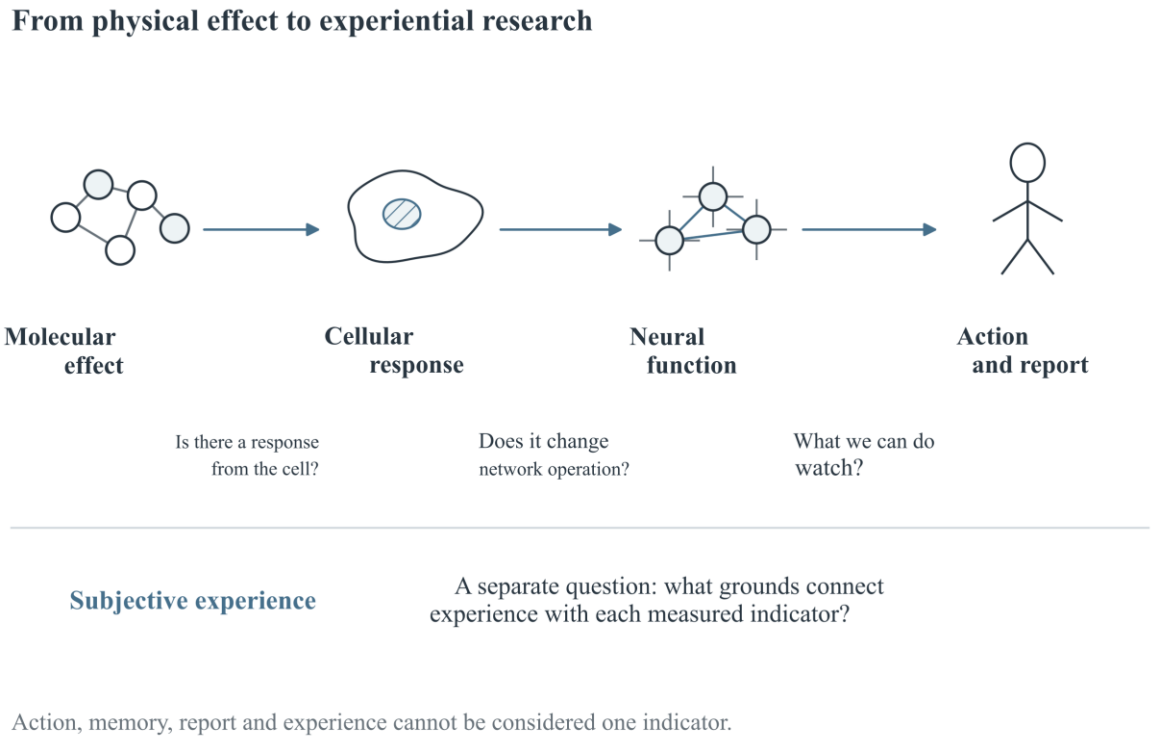


Figure 9. Levels of verification of a possible mechanism. The presence of a molecular effect, its cellular function, and its relation to experience require separate reasons.

This division makes partial success possible. Research may identify a new cellular mechanism, even if its specific connection to consciousness is not confirmed. This will remain a result about living matter. The requirement to immediately explain the origin of subjectivity in its entirety would rather prevent one from noticing its significance.

What quantum resource is really needed?

Different mechanisms have different requirements. For one, the phase in a certain basis is essential. For another - the spin dependence of the reaction. For the third - certain correlations between subsystems. The requirement for the conservation time of one property cannot be transferred to all other quantum mechanisms in living systems.

A short quantum stage can leave a long-term classical trace. In this case, storing the result does not require maintaining the original quantum state throughout the subsequent behavior. And vice versa, if the model assumes direct long-term storage of quantum information, a short initial effect is not enough for it.

This distinction helps to evaluate models of consciousness without extremes. Neither the proof of any molecular quantum effect nor the assessment of the rapid destruction of one selected superposition provides an answer for all possible architectures at once. It is necessary to find out exactly what operation is needed for a given architecture and at what stage it is performed.

It may also be assumed that a useful process involves a sequence of local events, each of which occurs anew. Then the stability of a function is determined by the reproducibility of the process, and not by the eternal preservation of one state. But if the author's model requires the unification of such events into a single subject, this unification must be described additionally. The repetition of a molecular reaction itself does not create an obvious criterion of subjective unity.

What Quantum Biology Gives to the Interface Hypothesis

Quantum biology shows how a seemingly unusual mechanism can be turned into a question about matter, reaction and measurement. It also teaches caution when moving between scales. A property of a molecule, a function of a cell, an animal's behavior, and an experience are not interchangeable results.

In the hypothesis being developed, the proposed interface must have precisely this physical certainty. It is necessary to understand what it receives, what it transforms and what it passes on. If the carrier is spin or electronic states, it will be necessary to study them under real conditions, and not limit ourselves to the name of a class of phenomena.

The receiver metaphor then becomes more meaningful. A possible mechanism may not receive a ready-made stream of consciousness, but may selectively connect certain states of the body with a broader physical system. However, the usefulness of this connection depends on its speed, stability and ability to create discernible consequences.

So the next question concerns time. Even if the desired states are physically permissible, they must retain their essential properties long enough for the intended effect. To appreciate this condition, it is necessary to distinguish between several processes, which in conversation are often combined with the same word “decoherence”.

Chapter 6

How long does the connection last?

Suppose a state has been found that could participate in the operation of the proposed quantum interface. The next question seems simple: how long does it live? But different processes can be hidden under the same time. The system can conserve energy and lose phase relationships. It may retain individual correlations but stop performing the desired operation. It can produce a stable averaged signal, although the state of each instance changes quickly.

Therefore, the discussion of time begins with defining what must be preserved. Memory, transfer of excitation and reaction require different properties. A number without specifying the state, environment and task does not allow assessing the suitability of the mechanism.

Energy and phase are lost in different ways

Consider a simple system with two energy levels. It can exchange energy with the environment, approaching the equilibrium distribution of populations - the probabilities of detecting it at each level. The characteristic time of such a process is often denoted T_1. Another quantity, T_2, describes the decay of certain phase relationships between levels. For a specific two-level model, these processes are related, but do not coincide.

To describe the state, it is convenient to use the density matrix ρ - a table of quantities from which the probabilities of measurement results are calculated. The element ρ_{01}, located outside its main diagonal, describes the coherence between the selected levels. In the exponential approximation, its modulus can change as follows:

$$|\rho_{01}(t)|=|\rho_{01}(0)|e^{-t/T_2}.$$

The indices 0 and 1 refer to the selected levels, and t denotes time. The formula shows how quickly the specific coherence in this basis decreases. It is applicable within the specified approximation and does not measure the duration of human thought.

Let us now consider a simple Markov model: further changes in the system in it are determined by its current state, without separately taking into account the history of the environment. If energetic relaxation is combined with independent pure dephasing, the relation holds:

$$\frac{1}{T_2}=\frac{1}{2T_1}+\frac{1}{T_\varphi}.$$

Time Tφ characterizes pure dephasing, which does not require changes in level populations. This ratio was obtained for the selected model; it cannot be automatically transferred to other ways of describing coherence. The

general mathematical language of Markovian open quantum dynamics was formulated, in particular, in the work of Göran Lindblad. [18]

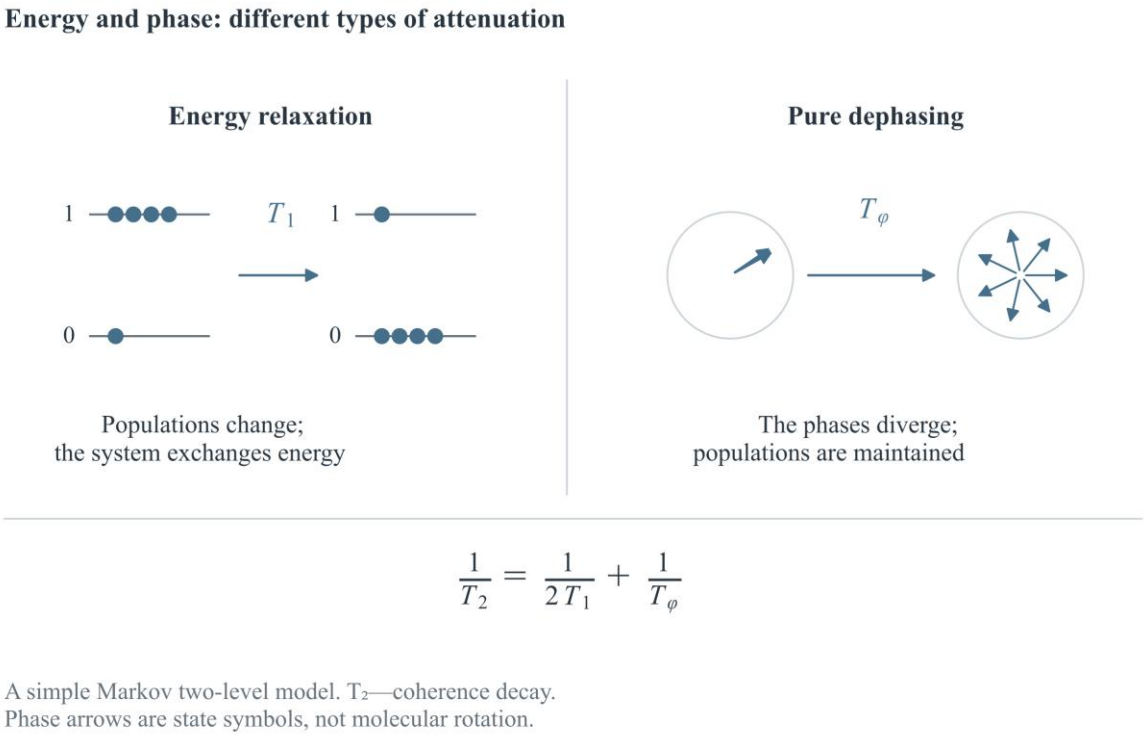


Figure 10. Different processes in a simple two-level model. T_1 describes energetic relaxation, T_2 is the decay of the selected coherence; pure dephasing can occur without population redistribution.

This separation immediately prevents an error. Long conservation of spin polarization or energy does not prove equally long conservation of all phase relationships. Conversely, observing the rapid decay of one signal does not yet establish the lifetime of each possible information property of the system.

Decoherence depends on the question to the system

Coherence is determined relative to the chosen method of state decomposition. If a superposition of two spatial positions is discussed, the interactions that can distinguish between these positions are essential. If certain spin states are considered, other connections are important. The same material can protect different degrees of freedom in different ways.

Therefore, it is impossible to assign a single “quantum time” to the brain in advance. It is necessary to name the system, basis, state and measured quantity. Even then, the result will depend on temperature, medium composition, disturbance frequencies, distances and preparation methods. This dependence is part of the physics of the mechanism.

The difference between an individual system and an ensemble is also important. Many similar specimens may have slightly different frequencies. The averaged signal is then attenuated due to the phase divergence between the instances, although some of this attenuation is not due to the irreversible

loss of information by each of them. Under suitable conditions, some contributions can be separated by a special sequence of actions.

This is why the word “time” in the graph requires explanation. Is it determined from the spectral linewidth, from the attenuation of the response after excitation, or from a special phase recovery procedure? Are the same states compared? Without these clarifications, similar designations can hide different physical quantities.

For the book, this means having to read numerical promises carefully. A statement about a long-lived state only becomes meaningful when accompanied by a description of how it was prepared, what was observed, and what process limits its useful life.

The Markov approximation often simplifies the calculation, but its applicability must be justified. It does not express a universal property of any environment: whether it is enough to know only the current state of the system depends on which interactions and time scales are essential for the chosen task.

If the environment retains significant memory of the interaction, some information may later influence the system again. Then the attenuation does not have to be described by a single exponential. More complex time dependencies are possible, and one T_2 number may only convey part of the picture. A more complete model will be needed to explain these dynamics; simply replacing one characteristic time with another may not be enough.

However, the memory of the environment is not equal to the memory of the individual. In the physical description we are talking about the dependence of current changes on previous interactions. This dependence can exist in a system to which no one ascribes an autobiography or experience. Therefore, the word “memory” here must be associated with what differences are preserved and how they manifest themselves.

For the external carrier hypothesis this is a particularly useful distinction. The environment can retain a physical trace of an event without maintaining an organism-accessible record of its contents. Returning part of the correlations may change the response without restoring the previous experience. Between such effects and the continuation of subjective history there remain separate links of explanation. Considering an open system allows us to pose these questions precisely without answering them in advance.

Temperature does not replace interaction calculations

In a warm environment, many degrees of freedom are actively excited. This may amplify certain disturbances. However, temperature itself does not determine the rate of decoherence. It is important how strongly the selected state is associated with these disturbances and what frequencies of the medium are important for it.

Comparing transition energies to thermal scales is useful when discussing populations and equilibrium. But it does not automatically solve the problem of the time of conservation of the phase relationship in any nonequilibrium system. It is necessary to describe how the state changes over time. The system can quickly lose the desired properties under weak thermal excitation or retain certain properties longer due to the peculiarities of the interaction.

This does not imply that the biological environment provides ready-made protection. A protective mechanism must be specified and shown to be compatible with the function. If a degree of freedom hardly interacts with its environment, it is difficult both to disrupt it and to use it to transmit a signal.

A familiar compromise emerges. The carrier must retain differences well enough and at the same time connect them with other processes quickly enough. For the interface hypothesis, this trade-off is especially important: the connection to the external contribution cannot be strengthened without assessing what additional perturbations come through the same physical path.

What does the debate about brain decoherence show?

Max Tegmark estimated very short decoherence times for the models of brain processes it examined and compared them with slower neural dynamics. Its conclusion was an argument against certain variants of quantum computing in the brain. This is a theoretical calculation depending on the selected states and interactions. [5]

Scott Hagan, Stuart Hameroff, and Jacek Tuszynski challenged some of the assumptions of this calculation in relation to their proposed microtubule states and obtained longer-term estimates. They also discussed possible terms for additional protection. Their work represents a theoretical answer rather than a direct measurement of coherence time in the conscious brain. [6]

The scientific meaning of the dispute does not boil down to choosing a more pleasant number. Different calculations must be brought to comparable physical conditions. If different superpositions, different distances between alternatives, or different connections to the environment are being evaluated, the difference in time may reflect a difference in the models. It is not in itself a contradiction of arithmetic.

The next step should reduce the uncertainty of these very premises. What states are actually available? What are the properties of their environment? How much of the purported protection persists in living tissue? How to relate the selected state to the measured response? Without such work, a dispute can remain for a long time an exchange of incompatible assessments.

This is a useful lesson for the author's hypothesis. It is impossible to select the largest estimate of time from the literature and declare it to be the

lifetime of the desired carrier. The value applies to a specific model and specific conditions. Its transfer to another structure must be justified anew.

Life time makes sense along with action time

Let us assume that coherence persists for a long time by the standards of a single molecular reaction. For a slow operation, the same period may be completely insufficient. Therefore, not only the absolute value is important, but also the ratio of the time the property is preserved to the time of its intended use.

Let us denote the time of the required action by τ. If an action requires maintaining the chosen coherence throughout its entire duration, the value of T_2 must be evaluated relative to τ. This is just the initial condition. Even a favorable timing ratio does not guarantee the accuracy of the operation, the presence of the desired connection, or the ability of the system to extract the result.

It is convenient to see the scale using a conditional example. Microsecond (μs) is a millionth of a second. Let the action take 1 μs. At $T_2 = 10$ μs, by its completion about 90.5% of the original modulus ρ_{01} is preserved; at $T_2 = 0.1$ μs - about 0.0045%. These are the values of the reduced exponential model with specially selected parameters, and not brain measurements. We are interested in the ratio of times: the same duration of action can be short or long compared to the decay time.

The opposite situation also does not always mean that the effect is useless. A short process can change the probability of a reaction, after which the result is held in another, more stable way. Then it would be incorrect to compare the coherence time with the entire duration of behavior. A comparison is required with the stage at which the quantum property is actually used.

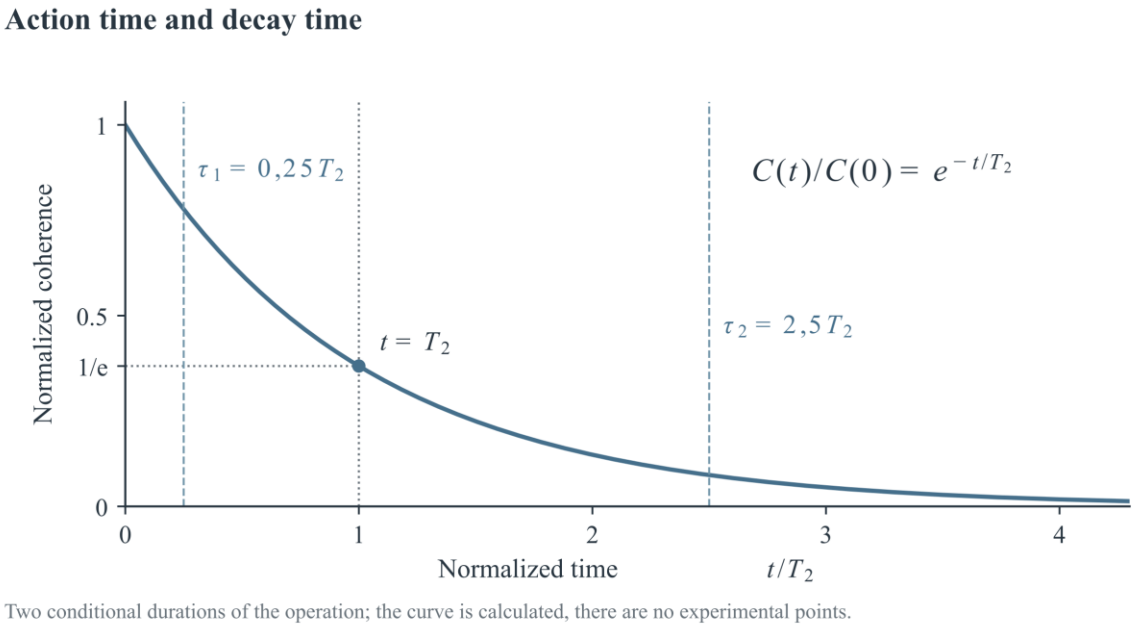


Figure 11. Training exponential model. The operation time is compared with the attenuation of the desired coherence. T_2 is a characteristic time, and not the moment of instantaneous disappearance of the property.

This opens up several possibilities when building a brain model. A quantum process can be a local seed, a repeatable transformation, or a long-lasting information carrier. Each version has its own timing requirements. Therefore, the claim that the time is too short or long enough should only be assessed after the architecture has been selected.

However, architecture should not appear solely to save a failed calculation. If a long memory is replaced by a chain of short events, it is necessary to re-describe how information is transferred between them and why the function is retained. The name "continuous updating" does not do the job on its own.

How to distinguish between state persistence and function persistence

A normal bodily function may be stable, although its molecular constituents are constantly changing. At the model level, this means that the organization of the process is preserved, and not necessarily each physical element. Likewise, a possible quantum mechanism could replicate itself many times without maintaining a single immutable quantum entity.

But the stability of the function does not automatically allow us to conclude that quantum coherence is continuously preserved inside. The function can be carried out through a sequence of stages, between which the classic result is transmitted. To distinguish between such variants, measurements are needed that are sensitive to the expected quantum resource at the desired stage.

There is one more level: the stability of the subject. Even if a certain function is reproduced without error, the question remains why its successive realizations refer to a single experiencing being. Physical coherence time cannot replace the criterion of personal continuity. Otherwise, the duration of the chosen molecular process, without proof, would turn into the duration of the existence of the “I”.

Separating these levels helps avoid false choices. Sustainable behavior does not require that every element be constant for it to exist. But for a model that directly links the unity of consciousness with a certain quantum state, the destruction of this particular state becomes a significant event that cannot simply be declared unimportant.

When lifetime allows testing a hypothesis

A useful study would relate time to function and specific condition. If a certain state is stated to be necessary for a certain effect, the model must predetermine the range over which the loss of the state changes that effect. The measurement is then able to constrain the hypothesis.

To do this, it is not necessary to start with a whole conscious organism. The physical link can be studied in a simpler system, where it is easier to distinguish the causes. Then it will be necessary to check whether the desired conditions are maintained when moving to the cellular environment and tissue. Each transition increases realism while adding competing processes.

Failure early on can be very meaningful. If the carrier does not retain the desired property even under conditions more favorable than those expected biologically, the chosen implementation loses support. If the property is discovered, there is a reason to explore the next stage, but not yet a ready explanation of subjectivity.

Time becomes part of the causal description: it determines what the system manages to accomplish and what differences it preserves. Now let's look at microtubules, one of the candidates for a physical carrier, and check what measurements of their optical properties suggest.

Chapter 7

Microtubules under light

In an optical laboratory, a protein solution can be illuminated in a way that it is never illuminated inside a living brain. This does not make the experiment meaningless. Controlled excitation allows you to ask a material a certain physical question: where does the absorbed energy go, how quickly does it dissipate, does the result depend on the arrangement of the molecules? The answer characterizes the capabilities of the substance. To know its role in the body, you will then need to find out whether the body uses this ability.

It is at this boundary that research into the optical properties of microtubules lies. They are interesting for quantum biology because they connect ordered protein architecture with molecular states that can absorb and emit light. For a book about consciousness, a specific subject of study appears here: the physical structure, its states and measurable transitions. Now the expression “quantum processes in the brain” can be replaced by questions about a very specific medium.

Protein architecture

The microtubule is composed of repeating protein units called tubulin. For cell biology, it is part of the internal organization of the cell, related in particular to transport and mechanical properties. For optics, the same structure represents an ordered arrangement of molecular groups. Different descriptions refer to the same object, but highlight different properties. Therefore, the discovery of interesting photochemistry does not negate known cellular functions, nor does it in itself confirm a new function. [10]

Tryptophan attracts particular attention. Its electronic states allow absorption of ultraviolet light and subsequent emission. In a protein, the properties of such a group depend on the environment: neighboring groups, solvent, geometry and possible ways of energy loss. When protein units are combined into a larger structure, not only their number changes. Distances and orientations between groups change, and along with them, possible interactions. [10, 11]

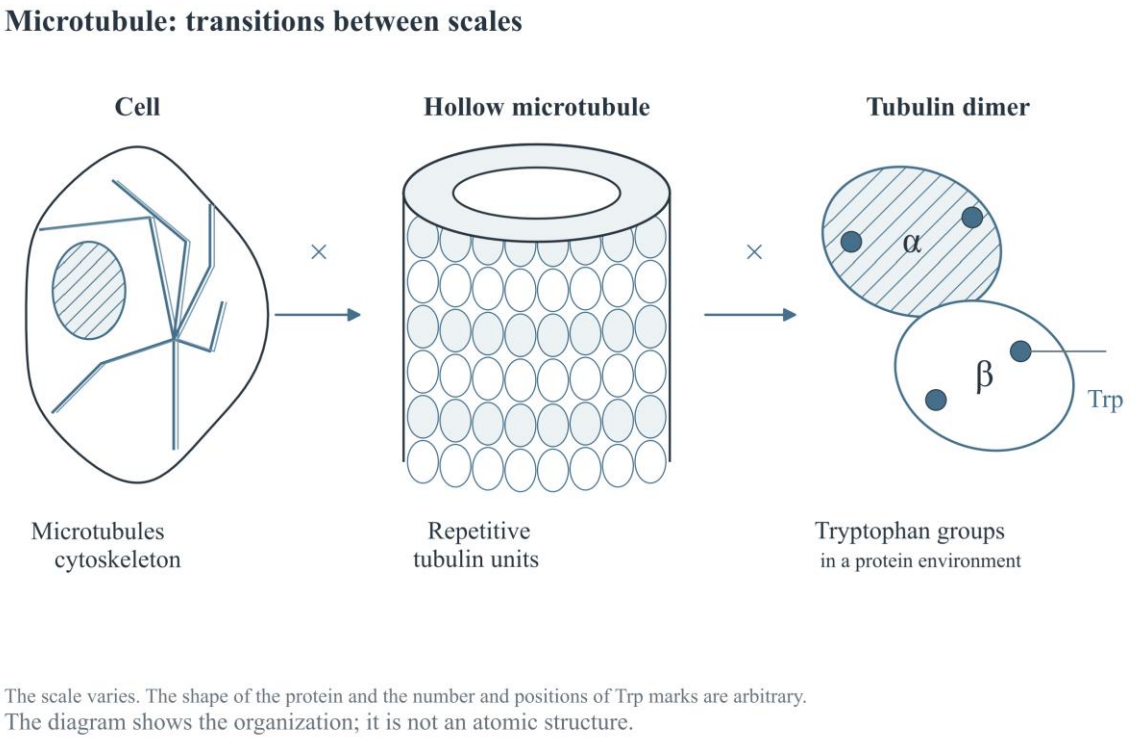


Figure 12. Schematic levels of microtubule organization: cellular cytoskeleton, hollow polymer, and α/β-tubulin dimer. Tryptophan groups and their surroundings are involved in optical properties. Fragments are shown at different scales; protein shape and Trp marks are arbitrary. [10, 11]

It's helpful to mentally separate the two questions. First: can excitation move from one area of the structure to another? Second: do multiple regions form a collective state that interacts with light differently than the sum of independent elements? The answers may be related, but they are different physical properties. Energy transfer does not equal long-term storage of arbitrary quantum information, and collective radiation does not equal the presence of a subject.

The study of energy transfer has independent value, even if its connection with consciousness is not established. If the geometry of the protein structure controls the excitation pathways, the cellular architecture becomes part of the physical circuitry for energy processing. The next question concerns whether there is a source of the necessary excitations in the body and whether they have time to influence other processes. In this sequence, interest in microtubules receives measurable content.

How to trace invisible transfer

The work of Aarat Kalra and colleagues studied the autofluorescence times of tryptophan and the influence of excitation-quenching molecules. From changes in luminescence, the authors assessed the transfer of electron energy in tubulin and microtubules. Under the conditions studied, the characteristic excitation diffusion length in microtubules was about 6.6 nanometer. Etomidate and isoflurane reduced this transfer. The authors also

reported that the conventional Förster transport description they used did not fully reproduce the observations. [10]

It is not the route of each individual excitation that is measured here. Optical signals are recorded and then the transport is inferred using the model. Such a transition is common in physics: the device shows the quantity from which the researcher reconstructs the properties of the process. The reliability of the inference depends on calibration, control of alternatives, and how uniquely the observed signal identifies the desired mechanism.

A mental example helps to see the meaning of extinction. An additional possibility of loss of excitation is introduced into the structure. If the excitation remains near the place of origin, the result will be the same. If it manages to explore a wider area, the probability of encountering a damper changes. Depending on the amount of absorber, the mobility of energy can be estimated, but for this it is necessary to take into account other reasons for the change in glow.

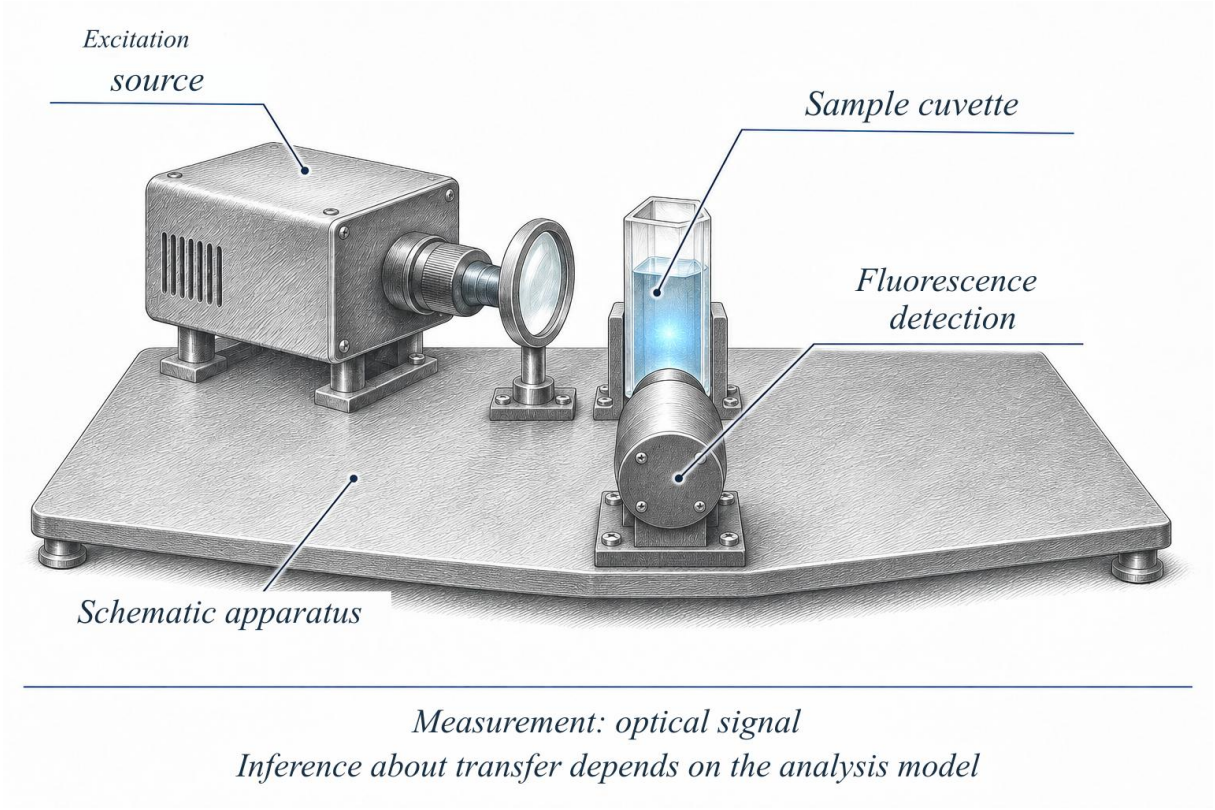


Figure 13. Principle of measurement and model inference. The device registers fluorescence; the properties of excitation transfer are assessed by the change in the signal, including the addition of a damper, and the selected description of the process [10]. A notional setup with side fluorescence collection is shown, rather than a reconstruction of the job-specific equipment. The trajectory of an individual excitation is not directly depicted.

A nanometer seems like a tiny distance on the scale of the brain. At the molecular scale, it may involve several interacting elements. Therefore, physical significance must be assessed relative to the design of the proposed mechanism. However, from a transfer of a few nanometers, whole-brain matching cannot be obtained by simply multiplying the distances. Moving to

a larger scale will require additional connections, time, and ways to maintain meaningful state.

What does collective radiation mean?

When interacting emitters form a collective state, their emission rate may differ from that of an individual emitter. Some states are bright: their contribution to the overall optical response is enhanced. Others couple weakly to light. These possibilities arise from the system's interactions and geometry; describing them as a shared intention of the molecules would needlessly attribute agency to them. [11]

Nathan Babcock and colleagues examined a model of large tryptophan networks and correlated it with fluorescence measurements of tubulin structures. The model predicted collective emissive states, and experiments showed changes in quantum yield when moving between levels of organization. The authors interpreted the agreement as evidence of the consequences of superradiant behavior. [11]

Fluorescence quantum yield is the fraction of absorbed excitations that result in the emission of light. This is a characteristic of the way energy is spent. In the simplest model with competing channels, it can be expressed as follows:

$$\eta = \frac{k_r}{k_r + k_{nr}}.$$

Here η is the quantum yield, k_r is the radiative decay rate constant, and k_{nr} is the total nonradiative loss rate constant. Both constants have the dimension of reciprocal time. In this simplified kinetic scheme, the yield increases both as the radiative decay is accelerated and as the competing losses are weakened. Therefore, the value of η alone is not sufficient to distinguish between these causes. [11]

Therefore, increased brightness by itself does not indicate which of the mechanisms has changed. Additional characteristics such as excitation lifetimes and independent absorption estimates will be needed. If collective radiation acceleration is assumed, the test must distinguish between it and the more usual reduction of non-radiative losses. It is this distinction that transforms the effect from an attractive picture into an established mechanism.

In this simple scheme, the two causes can be distinguished by measuring the excitation lifetime τ_f together with the quantum yield. For a single exponential decay, $\tau_f = 1/(k_r + k_{nr})$, so $k_r = \eta/\tau_f$ and $k_{nr} = (1-\eta)/\tau_f$. For example, illustrative values of $\eta = 0.30$ and $\tau_f = 3$ ns give 0.10 and approximately 0.233 ns^{-1}, respectively. This additional measurement turns an ambiguous brightness into estimates of two rates. For an inhomogeneous sample, multiple decay times, or reabsorption of light, these equations require an extended model; measuring τ_f alone does not eliminate the need for scattering corrections.

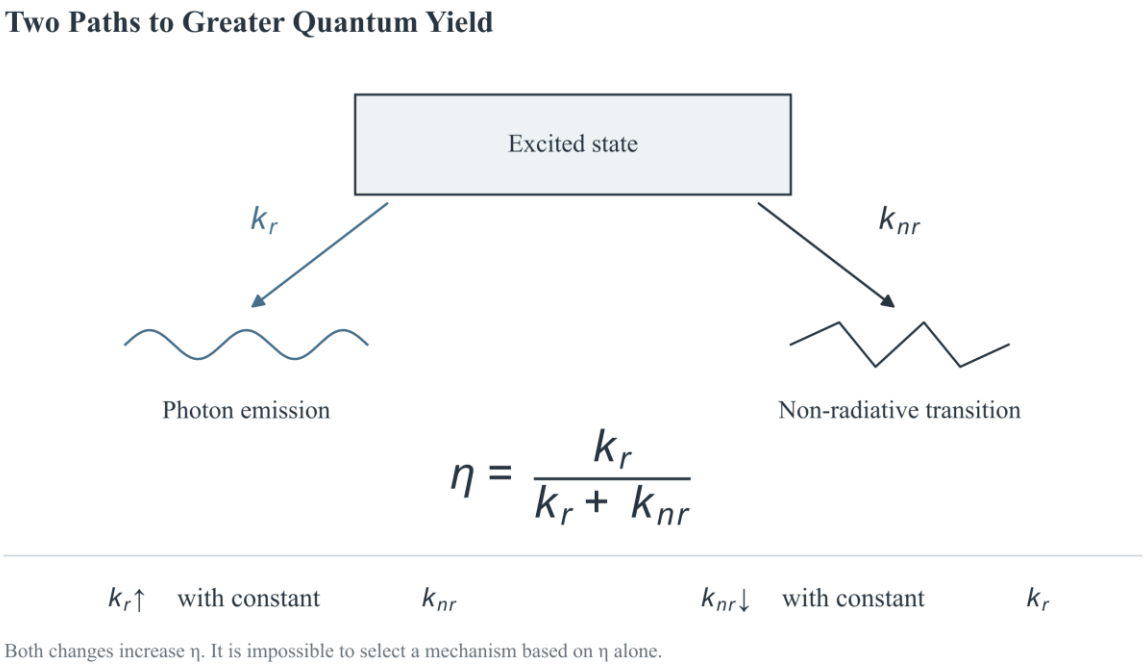


Figure 14. Two ways to increase quantum yield in a simplified kinetic model. A higher fraction of emitted photons by itself does not differentiate between the enhancement of the radiative channel and the attenuation of non-radiative losses.

Light can deceive the device

A biological sample not only absorbs and emits. It scatters light. Some of the radiation changes direction, and the instrument can mistake this effect for a change in absorption or the number of photons emitted. The geometry of the measurement also matters: where the detector is located, how thick the sample layer is, how the protein structures are distributed. These are not minor technical details if the conclusion concerns a small difference between two states of matter.

Leah Gassab and Travis Craddock's preprint 2026 compares modeling of tubulin structures with ultraviolet spectroscopy. The authors consider changes in fluorescence yield, the effect of added tryptophan, and limitations associated with scattering. They separately discuss the need for further measurements to separate possible mechanisms. The work shows how the initial interpretation can be made more specific while maintaining attention to measurement uncertainty. [13]

Let's imagine two identical light sources behind different glasses. If one glass sends more light into the detector, the instrument will register an increase, even though the sources themselves have not changed. The protein solution is more complex, but the logical problem is the same: the path from the source to the detector is included in the explanation of the result. It cannot be considered transparent just because the researcher's interest is directed towards molecules.

Therefore, a successful test of the proposed effect must be able to withstand changes in measurement geometry and method of analysis. If a finding holds true for only one background correction method or wavelength range, its applicability is limited. If different measurement methods converge, the physical explanation becomes stronger. Demanding optics here helps the hypothesis itself, since it removes false directions for further search.

The path from test tube to cell

Several transitions separate a molecular effect from conscious brain function. First, it is necessary to show that the carrier retains the required properties in the cellular environment. Next, a suitable excitation must arise. Then, changes in that excitation must affect a process involved in neuronal function. Only after these steps can one investigate whether this pathway relates to the state or content of experience.

These transitions cannot be replaced by correlation with anesthesia alone. A substance can affect multiple cellular targets, and a change in the optical signal can accompany a change in other properties of the protein. The question of causal mediation arises: is the observed photoprocess necessary for the further effect? The answer will require an intervention that alters this process selectively enough to allow the consequences to be observed.

For example, in the imaginary model, rearrangement of the molecular geometry simultaneously changes mechanical stability and optical interaction. If after it the neuron works differently, both reasons remain possible. The credibility will increase if it is possible to separate these changes: maintain the mechanics with changed optics or find another way to restore the intended optical path. This is the logic of future research, and not a description of an experiment already completed.

Communication with a wider physical medium will present another requirement. It will be necessary to establish that the corresponding states participate in the interaction with this carrier, and not only exchange energy within the protein. The mere presence of a structure inside a neuron does not make it a receiver of consciousness. A microtubule becomes a candidate for part of the interface only when the model has a defined input, transformation, and measurable output.

Even the word “sensitivity” here requires clarification. The structure may respond noticeably to strong laboratory stimulation and show little or no response to natural fluctuations in the intended field. Therefore, it is necessary to compare the quantities: how much energy the sample receives in the experiment, what is the expected intensity inside the cell, how large is the background. These comparisons do not invalidate the laboratory result. They determine how much of the natural process it actually models.

Suppose a narrow frequency range is discovered in which the response is particularly pronounced. It is tempting to call it the frequency of consciousness. But resonance characterizes the way the system interacts

with the influence. To link this resonance to an experience would require showing a consistent connection with an independently defined state or content of experience. Otherwise, the same effect could be observed in a protein solution, a cell, and a technical device, without any basis for attributing the same subjectivity to them.

In addition to the intensity and frequency of impact, it is necessary to compare the time scales of the processes. A brief molecular response can trigger a longer biochemical process if there is reinforcement or consolidation. But this does not allow us to consider the duration of the subsequent process as the lifetime of the initial coherence. The connection between the fast and slow links is itself part of the explanation. It is usually more difficult to indicate such a transition than to detect a beautiful spectral peak, but it is this transition that gives the physical phenomenon functional significance.

How a strong version can develop

A strong version of the microtubule hypothesis must make a specific claim that experiment can confirm or challenge. For example, a certain configuration of a protein creates a collective state; its lifetime and spectrum determine the sensitivity range; changing this configuration has predictable effects on cellular process. Such a chain allows each link to be verified and shows exactly where the model encountered the data.

Negative results are especially useful at this level. If a collective optical state exists but disappears in an environment close to the cellular one, the range of biological applications narrows. If it persists, but the state change does not affect the selected function, you should look for another function or recognize that there is no special role here. Once a function has been discovered, the next task is to determine its relationship to neural organization and experience.

A positive result is also possible, changing the entire formulation of the question. Protein optics may be essential for cellular regulation, but not for the external source of consciousness. Then the research will bring discovery, although the original philosophical expectation will not be justified. Science is not obliged to preserve the way in which the question arose; it is sufficient for it to maintain a verifiable connection between explanation and observation.

Microtubules show how meaningful the discussion becomes after choosing a physical medium. Instead of a general image, spectra, speeds, geometry and specific alternatives appear. However, even a precisely measured quantum effect does not yet answer the question of who the observer is. The next chapter examines the word “observation” itself: what role does physical interaction play in it and what role does the person reading the instrument readings play?

Chapter 8

An Observer without a Human

The detector can leave a recording at night when the laboratory is empty. In the morning, the researcher will read it, compare it with other records and draw a conclusion. In the standard quantum description, the moment of human familiarization is not introduced into the equation as a special influence. Measuring interaction occurs between physical systems, and a person learns about its result later. This difference alone is enough to make us use the expression “observer consciousness” more carefully.

For the study of consciousness, the question is especially tempting. If quantum theory uses the word "observation" and a person is able to observe, it would seem that the theory has already found a fundamental place for experience. However, the same word does not guarantee the same concept. Before connecting them, it is necessary to understand what exactly makes a measurement a physical process and what remains open after its mathematical description.

Recording occurs in interaction

In the simplest measurement model, the state of the system is associated with the state of the device. Different possible values of the measured quantity correspond to distinguishable states of the pointer. If the system was in a superposition, the joint quantum description generally contains correlations between its states and the states of the device. The device then interacts with its environment, and information about the result is propagated through other physical degrees of freedom. [14]

This description explains why measurement cannot be considered a weightless gaze. The device must physically interact with the object. The photon is absorbed, the charge is transferred, the molecule changes state. Even when the interaction is very weak, its role is determined by the ability to relate a difference in the system to a difference in the record. Without such a connection, no information about the selected value can be obtained.

Let's mentally replace the researcher with an automatic program that reads the detector and closes the shutter. Then we will replace the program with a simple electronic relay. The physical circuit continues to operate as long as the necessary interactions are maintained. To calculate the measured probabilities, you do not have to determine whether the relay is experiencing anything. Therefore, human self-awareness is not a necessary element of the standard quantum measurement procedure.

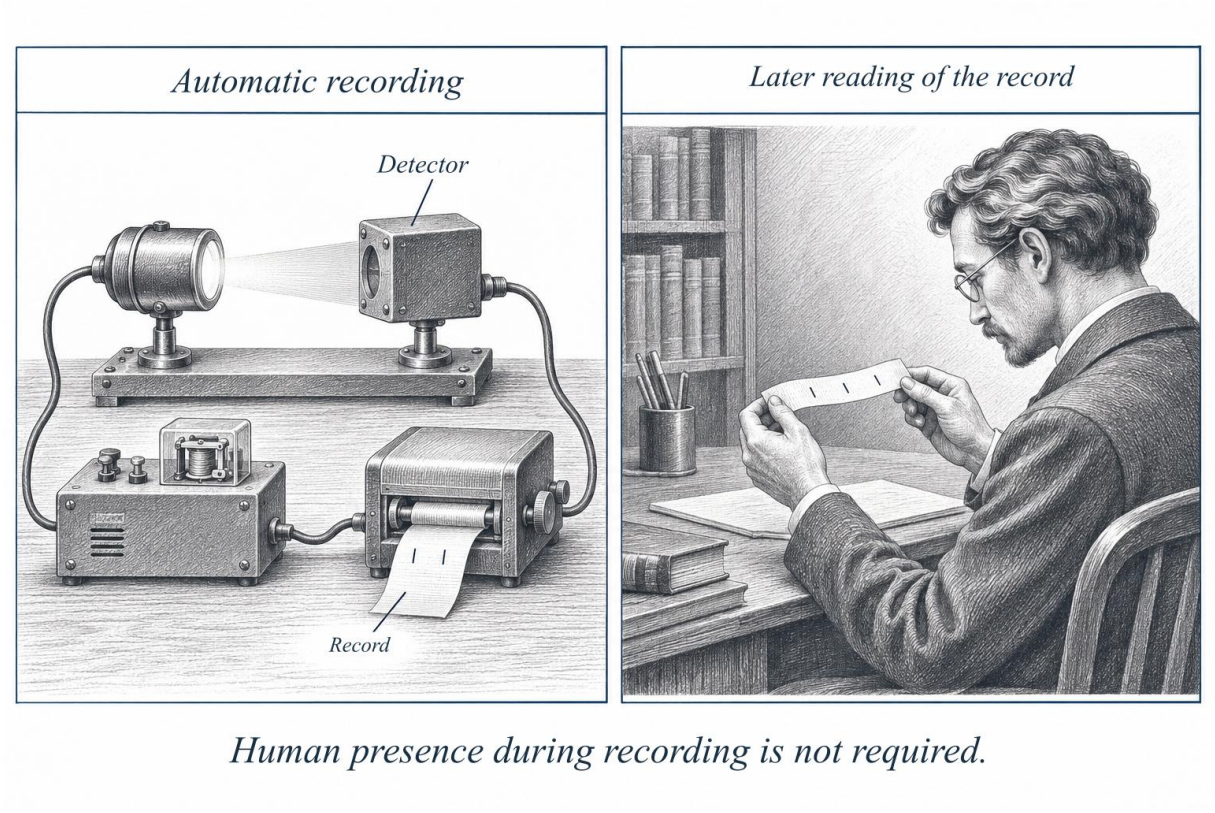


Figure 15. Physical registration and reading of the result are separated in time. In the standard measurement model, a record is created by the interaction of systems; the presence of a person at the device at this moment is not required [14]. The device and marks on paper are shown conditionally and do not reproduce the data of a specific experiment.

Here we were able to separate two questions: how a measurement record arises and why some processes are accompanied by experience. The first question allows for physical description without appeal to human self-consciousness. The second one remains open. A theory in which consciousness alters quantum dynamics must propose a concrete law and new testable consequences. The word “observer” alone is not enough for this.

Decoherence and outcome selection

Decoherence describes the loss of available interference relationships in a selected subsystem due to its interaction with its environment. As a result, certain alternatives begin to behave as a statistical mixture for local observation. The expression “for the selected subsystem” is essential here: the description of the entire composite object and the description of one of its parts solve different problems. [14]

This process helps to understand the sustainability of everyday records. To restore interference between macroscopically different records, it would be necessary to control a huge number of connections with the environment. Under normal conditions this is not possible. However, the explanation of the practical inaccessibility of interference does not yet exhaust the question of

why experience is given as one definite outcome. Interpretations of quantum theory describe this transition in different ways.

For further reasoning, restraint in both directions is useful. It cannot be declared that decoherence does not explain anything at all: it describes quite definite physical dynamics. But you cannot entrust its with the answer to any question about the experience. The success of one level of explanation does not eliminate the need for another. An interface theory must specify at what level it adds the mechanism.

One can imagine that the additional carrier affects the probability of outcomes. One then needs to explain how the observed probabilities are obtained when the carrier is not available to direct control, and under what conditions the deviation will occur. It can be assumed that physical probabilities do not change, but only the description of their relationship to experience changes. Then the experimental possibilities will be different. These two versions cannot be considered one theory simply because they both use the word “consciousness.”

Entanglement Is Different from Correlation

Two systems can produce similar results for the usual reason: they have a common source or have interacted before. If two envelopes contain pre-agreed numbers, opening one allows you to predict the contents of the second. But this analogy does not reproduce all quantum correlations for different measurement methods. It is the ability to change measurement settings that makes the test meaningful.

Bell's inequalities set restrictions on correlations for a certain class of local models under specified assumptions, including the independence of the choice of settings from the corresponding hidden variables. Quantum theory allows for the violation of these restrictions. Therefore, the experiment does not test the abstract “unity of everything,” but the specific structure of statistical dependencies between settings and results.

In 2015, Bas Hensen and colleagues performed a test with electron spins separated by a distance of 1.3 kilometers. The scheme simultaneously closed the main loopholes related to registration efficiency and locality of measurements. The resulting violation of Bell's inequality supported the quantum description of correlations against the class of local models tested. The experiment did not measure either people's thoughts or the connection of personalities across distances. [20]

This sets a high standard for the study of living systems. Synchronous oscillations of two neuronal populations are not evidence of entanglement. The similarity of the stories of two people is even more so. Each such result is subject to a variety of common causes, ranging from general effects to sampling patterns. A claimed quantum property must have its own criterion that truly distinguishes it from the alternatives being considered.

Why correlation doesn't convey the message

If two parts of the system are entangled and the measurement result of the first is known, this knowledge allows us to refine the prediction of the measurement result of the second. However, a person who has only the second part does not receive a controlled message in this way. It does not have access to the necessary sorting of data based on the results of remote measurements. To perform it, you need to transmit additional information via a regular physical channel. [14]

A simple thought experiment illustrates the difference. Two researchers agree in advance to label one outcome "A" and the other "B." After their systems are separated, the first researcher measures their part. If they cannot choose the outcome they obtain, the agreement does not become a way of sending the desired letter. The second researcher sees a sequence of results from which no message chosen by the first can be extracted.

Post-selection sometimes gives the opposite impression. After the experiment, one can select only those events in which a particular outcome was obtained on the first side. The conditional statistics on the second side will change. But the list of selected events itself must be communicated to the second side, so the procedure already uses an additional channel. The information is not obtained for free: it arrives together with the selection condition.

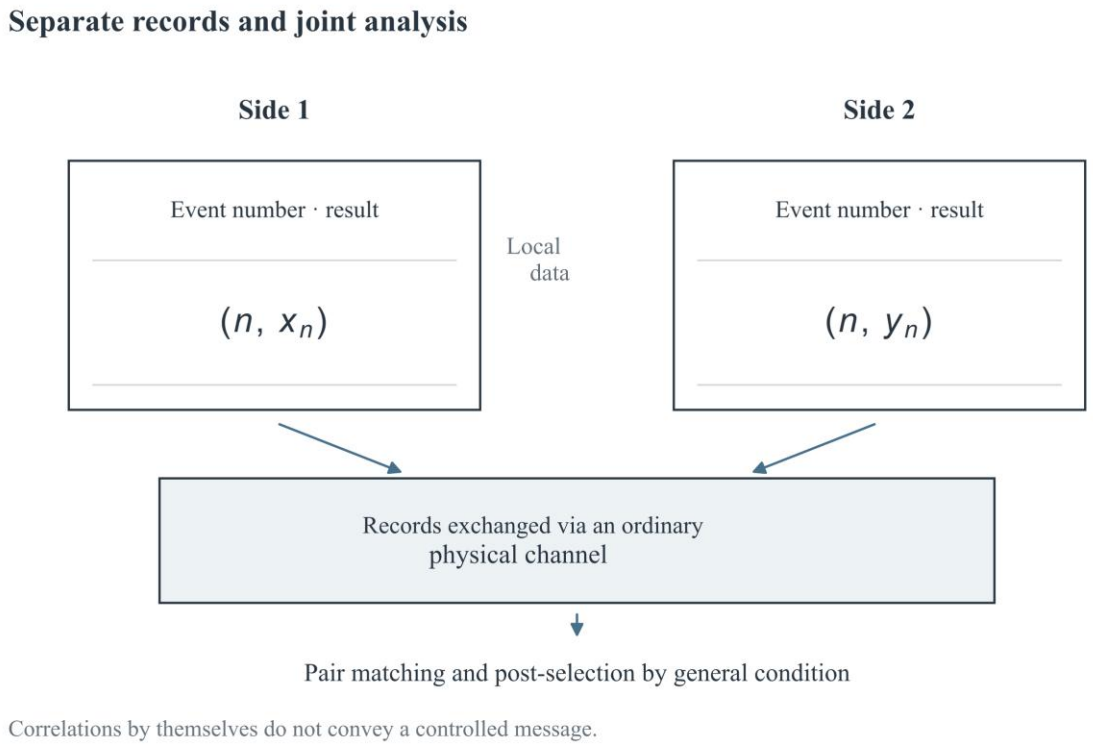


Figure 16. To compare remote results and perform post-selection, records need to be exchanged over a physical channel. Quantum correlations alone do not produce a controlled message on the other side.

This implies a specific limitation for external consciousness as a physical source. If it is to select the organism's actions, there must be a way in the system to convey the difference between the choices. Entanglement alone does not provide such a controlled channel. The model will need an ordinary interaction, a feasible quantum channel, or an explicit change to the standard dynamics. The latter option is especially demanding, since its consequences must not contradict already tested restrictions.

An important distinction arises between knowledge and influence. When the researcher learns the result on the remote side, his description of the available options changes. But a change in description is not yet a physical signal received by another system. In everyday life, these events often occur together: a message brings new knowledge and at the same time represents a physical signal. In discussing entanglement, they have to be separated especially strictly.

Let's imagine that the body must choose between two movements at the command of an external carrier. The observed probability of movement should depend on which command the carrier chose. If the local statistics of the organism are the same in both choices, no controlled difference has been generated. Subsequent detection of correlations may inform the joint structure of the data, but does not explain the choice of movement at the right moment.

This does not prohibit building a model of an interacting composite system. On the contrary, conventional channels allow the transfer of information, and quantum technologies use both correlations and real interactions. Constraint refers to the attempt to gain control only from the existence of entanglement. Refusal of such an attempt makes the hypothesis more specific: it is necessary to describe what exactly connects the subsystems and with what delay the influence spreads.

If a carrier outside the usual spatial description is assumed, the task does not disappear. It is necessary to determine the rules of connection between its states and observed events. While there are no such rules, the word “outside” does not explain why the body receives this particular information. It marks the location of the unfinished part of the model. Once the rules are in place, their compatibility with causality and experimental probabilities can be examined.

Common carrier and individual points of view

The assumption of a fundamental basis for experience may be broader than the hypothesis of message transmission. Perhaps consciousness is associated with a certain organization of the whole, and the body sets a local way of accessing its states. Such a thought is logically possible, but for it it is necessary to distinguish between physical correlation, functional accessibility of information and the subjective identity of experience.

Let's imagine a single physical object with two weakly connected subsystems. They may have a common past and some correlations. One

subsystem is able to use only a small part of the information about another. Even if there is entanglement in the general description, it does not follow from it that both parts form one point of view. Such a conclusion requires an additional principle about what physical relations correspond to the unity of experience.

This principle should define the boundary. Why are certain processes of the body included in one subject, but the processes of the room do not usually become part of the same experience? Why can changing the availability of information change behavior but not necessarily create a new subject? And why does a common source of physical states not mean a common human memory? Such questions cannot be resolved by merely pointing to the integrity of the quantum state.

Here the interface hypothesis has the opportunity to become more precise. It can connect individual experience not with any correlation, but with a certain form of stable interaction, memory and organization of feedback. Then the mathematical description of the state of the external carrier becomes only part of the model. The other part must explain how a particular center of discrimination arises and why its history is not arbitrarily confused with the history of the others.

What should the conscious observer add?

It is not enough for the theory of consciousness to reproduce the operation of the detector. It is necessary to explain why some processes correspond to experience, while others serve only as a condition for registration. One can try to deduce this from the organization of information, from the causal structure, or from an additional psychophysical law. But each path requires an argument connecting the physical description with the qualitative side of experience.

It is especially important to avoid a closed definition: the system causing the collapse is conscious, and the collapse is caused by the conscious system. This definition does not allow either party to be independently identified. To exit the circle, you will need either an independent physical criterion for reduction or an independent criterion for the state of the system, after which you can check their connection. Therefore, the objective reduction hypotheses and the idea of human attention as the cause of measurement must be considered separately.

Quantum theory really changes the usual ideas about state, probability and separability. Thanks to it, it is possible to formulate much more subtle models of the interaction of the organism with the environment. But the extension of physical language brings new responsibilities: respecting communication constraints, distinguishing between conditional and local statistics, specifying a testable property of the medium. It is these responsibilities that make the quantum hypothesis scientifically interesting.

The theory of Penrose and Hameroff assumes that the reduction of a quantum state is a real physical event associated with the fundamental

properties of space and time. Thus, the question of consciousness is connected with the hypothesis of a new physical mechanism. The next chapter examines these two links separately: if a mechanism exists, it can be sought regardless of which explanation of consciousness ultimately turns out to be correct.

Part three

Theories and resistance to facts

Chapter 9

Penrose and Hameroff's Proposal

Some theories of consciousness try to find the desired organization within an already accepted physical description. Others suggest that the description itself is still incomplete. Orch OR belongs to the second direction: it connects the question of experience with the question of why quantum alternatives give way to a certain outcome. This connection makes the hypothesis unusually bold and simultaneously creates several independent obligations.

To evaluate this program, it is useful to break it down into its parts. One concerns a fundamental law. The other is a biological carrier. The third links the supposed physical event to the moment of experience. The parts must agree, but none becomes confirmed just because the other can be expressed mathematically.

Three links of one hypothesis

As presented by Stuart Hameroff and Roger Penrose, the supposed quantum processes in microtubules are organized by the biological environment, and their completion is associated with an objective reduction of the quantum state. The word “objective” means that the reduction should occur as a physical event, and not depend on the presence of a person at the device. Biological organization is designed to make such events functionally significant for the neuron and conscious experience. [4]

This description itself does not yet define the necessary observations. Different links should have different characteristics. The composition and physical condition of the carrier are important. For reduction - the law of dynamics and consequences that distinguish it from ordinary interaction with the environment. To connect with consciousness, an explanation of why an event relates to a specific experience rather than simply changing a material system.

Let's imagine a device that contains the necessary protein structures, but does not have the organization of the brain. If the proposed physical process is found in it, this will support the physical part of the model. The question of experience will remain separate. Conversely, the detection of complex neural activity while consciousness is preserved does not automatically indicate what microscopic mechanism makes it possible.

This division is useful for both the supporter and the critic. It does not allow you to declare the entire program confirmed by one effect, but it also does not allow you to reject any research in protein physics due to doubts

about the theory of consciousness. The program may fall apart: some ideas will remain important, others will turn out to be superfluous. For a scientific hypothesis, this is a common method of clarification.

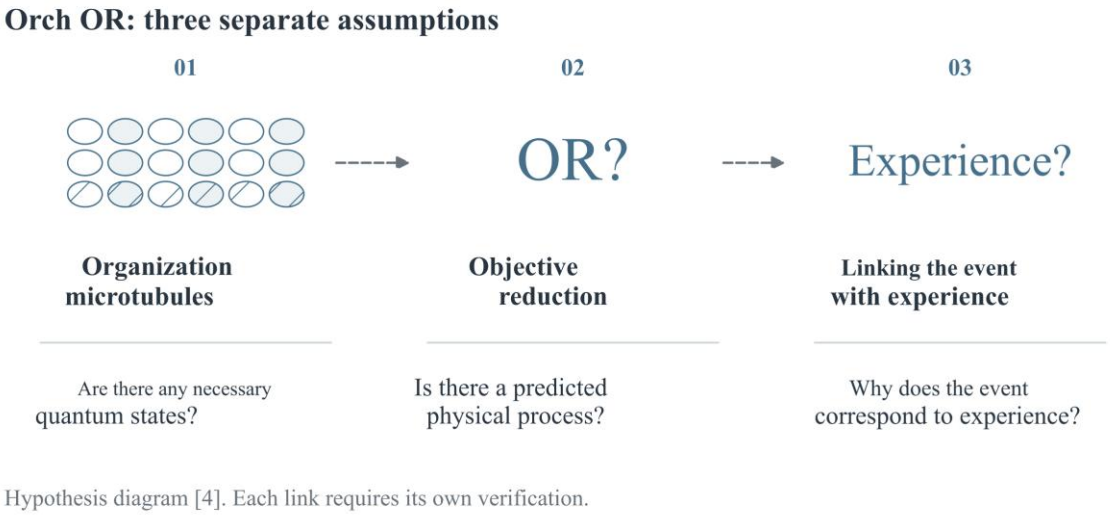


Figure 17. Orch OR connects the biological carrier, the objective reduction hypothesis, and the assumption of connection with experience. Support for one link does not automatically confirm the others.

Time before reduction

In a proposal for a gravitationally coupled objective reduction, the characteristic time is usually estimated by the relation:

$$\tau \sim \frac{\hbar}{E_G}.$$

Here τ is the expected characteristic reduction time, ħ is Planck's constant divided by 2π, and E_G is the gravitational energy associated with the difference in mass distributions in the alternatives under consideration. This is a heuristic relation within the framework of the corresponding hypothesis; it is not an established universal law of consciousness. [4, 23]

The main difficulty lies in the choice of alternatives. You cannot substitute the mass of the brain into the formula and get the time of thought. It is necessary to describe which mass distributions are involved in the superposition, how different they are, and which scales are significant. Changing these assumptions changes the energy estimate, and with it the expected time.

The dimension of the formula is correct: Planck's constant has the dimension of energy times time. But dimensional consistency is only necessary for physical meaning. Many incorrect models can also be written with correct units. Confidence occurs when independently determined parameters predict an observation that was not used to select them.

The reverse path is especially dangerous: take the desired duration of the experience and then select the mass distribution that gives this duration.

Such a calculation shows the possibility of coordination, but does not establish a mechanism. The check should at least partially go in the opposite direction - from the properties of the medium to the time and other consequences of the process.

Even the coincidence of time scales allows for several reasons. The network can set the rhythm that molecular dynamics obeys; a molecular process may limit the network; both processes may depend on a third condition. Therefore, similar periods do not determine the direction of causality. Clarifying this requires intervention or some other way to compare incompatible predictions.

A possible test should also take into account the distribution of times, not just the average. Two models are able to give the same average, differing in scatter, temperature dependence or change in media geometry. These additional characteristics are sometimes more useful in distinguishing patterns than matching the brain's habitual rhythm. They force a physical model to predict an entire pattern, rather than just one convenient number.

So the formula becomes the beginning of the calculation. It defines the relationship between quantities, but leaves the task of determining them independently. Only after this can one decide whether the hypothesized process explains the observed temporal organization or only allows it under specially selected conditions.

What should a biological organization do?

In the word “orchestrated” it is easy to hear the image of an internal conductor. However, the physical model requires other content: a certain organization of interactions, state support, control of transitions and connection with cellular function. Neither of these processes requires ascribing intention to the molecule. It is required to show what features of a living structure change the available dynamics.

A possible mechanism must solve the preparation problem. How does the system get to the desired state? Then the problem of conservation arises: which influences destroy it, and which are compatible with the necessary dynamics? After this, there is the output task: how does the result become significant for other processes of the cell? If the last link is missing, even interesting quantum dynamics can remain functionally isolated.

There is significant tension here. Strong interaction with the cellular environment is convenient for influencing biology, but it can also destroy the properties for which the quantum carrier was introduced. Weak interaction helps isolation, but makes preparation and readout more difficult. The model must find a physically feasible combination, rather than independently selecting the best properties of both limits.

Let's imagine two conditional configurations of the carrier. The first one retains the desired state for a long time, but has almost no effect on the cell. The second effectively triggers a biochemical response, but loses its state too

early. The presence of each configuration separately does not prove the existence of a duty cycle. We need a switching mechanism or some other way to link preparation, storage and exit in one system.

Why doesn't the decoherence debate end the question?

Max Tegmark and the authors of the subsequent response - Scott Hagan, Stuart Hameroff and Jacek Tuszynski - obtained different estimates of decoherence under different assumptions about the state and environment. This debate relates to specific physical models. It does not provide a single measured time that can be applied to all possible quantum processes in the brain. [5, 6]

To evaluate Orch OR it is therefore not enough to say “too warm” or, conversely, “the cell protects coherence.” It is necessary to compare exactly those states and times that the selected version uses. If the proposed operation takes significantly longer than the required relationships are maintained, the mechanism does not work in this form. If there is enough time, preparation, reading and functional communication remain.

The conservation of the quantum property makes the proposed mechanism possible, but does not yet confirm the entire theory. A similar distinction exists in engineering: a material can withstand the required temperature, but this does not mean that the engine assembled from it will work. A separate restriction has been lifted; other restrictions have not disappeared.

This approach keeps research from going to extremes. It does not rule out an unusual medium on an overly general assessment and does not declare it successful after one suitable number. For each version, one can create an internally consistent description and then determine which measurement will reduce uncertainty the most. Sometimes the decisive factor will not be a spectacular observation, but an accurate assessment of losses.

Reduction can be sought outside the brain

If objective reduction is a new physical process, its consequences need not manifest themselves only in conscious organisms. This is what makes it possible to test the physical part of the hypothesis, regardless of the difficulties of studying the experience. The altered dynamics may predict additional fluctuations, heating, or radiation, depending on the specific mathematical model.

Sandro Donadi and colleagues explored the implications of the Dieuchy-Penrose model in an underground experiment to search for weak radiation. The resulting restrictions excluded its natural version without a free parameter, considered by the authors. This result significantly limits the specific implementation of gravitational collapse, but does not amount to an experimental refutation of all possible Orch OR variants or any involvement of quantum processes in biology. [23]

The significance of this example is broader than one theory. A claim about the fundamental nature of consciousness may receive a testable part far removed from talk of consciousness. If the proposed law changes the behavior of matter, it must be compared with those experiments where there is no brain. Thus, the hypothesis ceases to use the complexity of a living system as a protection against verification.

The opposite result is also possible: a new reduction law will be established in physics, but the supposed biological mechanism will not be confirmed. Then new knowledge about matter will appear without a ready explanation of the experience. For scientific reasoning, this is a fundamentally acceptable outcome. The study of law and the study of its role in consciousness can move at different speeds.

The event has not yet become an experience

Even if all the physical links work, the issue of compliance remains. Why should a certain reduction event have an internal side? How are events related to the sensation of color and the sensation of pain different? How do multiple events form a coherent stream rather than a series of isolated bursts? The physical formula of time by itself does not answer these questions.

What is needed here is a principle that connects the structure of the process with the structure of experience. It can be proposed as an additional postulate, but then its content must be shown. If a postulate allows any physical result to be arbitrarily correlated with any experience, the predictive power is small. If it sets limits on possible differences in experience, prospects for verification arise.

For the selective interface hypothesis, Orch OR represents a possible interlocutor, but not a ready basis. Objective reduction in microtubules, even if established, does not in itself mean the transfer of personality from an external source. To obtain such a model, additional degrees of freedom, a communication method, and an individualization rule will be required. These elements are not automatically contained in the word “fundamental.”

A strong development of the idea could investigate how the properties of an external bearer constrain the permissible states of an internal mechanism. The external contribution would then need a distinguishable consequence. If the added entity never changes any probability and explains nothing about the structure of experience, its physical role remains undefined. If it does change something, the model must specify where to look for the change.

What remains after verification?

A theory can be useful even if it turns out to be wrong. It forces us to connect the properties of proteins, fundamental dynamics and the problem of subjectivity into one system of obligations. Where previously only the

word “secret” existed, specific questions appear. This is a merit of the research program, not evidence of its truth.

The most meaningful strategy is to clarify the links that allow independent verification. The properties of the carrier should be examined separately from the expectation of finding consciousness. The law of reduction is separate from the desire to preserve personality after death. Connection with experience - taking into account the results of neurophysiology, which any competing theory must explain.

This order preserves the boldness of the design. It allows us to assume a change in physics itself and at the same time demands the usual scientific responsibility from the assumption. The question is not whether the idea is unusual enough, but what observations become clearer and what new observations it allows us to expect.

The next proposal takes a different route. Instead of short-lived electronic processes, it focuses on nuclear spins, which may interact more weakly with their surroundings. This change of carrier changes the nature of the difficulties: preserving the state may become easier, but the question of how a protected state participates in the cell’s active chemistry becomes especially pressing.

Chapter 10

Nuclear spins and possible memory

A memory device faces conflicting demands. Its state must be preserved for a long time, but at the same time remain accessible for writing and reading. Complete isolation protects against interference while preventing use. In a biological system, the contradiction is especially noticeable: the cell continuously exchanges matter and energy, and its supposed quantum memory must be built into this exchange.

The idea of using nuclear spins takes the search to a different physical scale. Nuclear spins represent quantum degrees of freedom that, under certain conditions, can interact relatively weakly with their surroundings. Of interest is the possibility of linking their preservation with biochemical action. It is the combination of two possibilities that makes a hypothesis meaningful for research.

What stores the spin state?

Spin is a quantum property of a particle. The image of a spinning ball may help one remember the word, but it does not reproduce its mathematical meaning. For a spin-one-half system, measurement along a chosen direction gives two possible outcomes. This allows the corresponding state to be described as a qubit. Two measurement outcomes alone, however, do not mean that the system is already functioning as part of a computing device. [14]

Working memory must provide distinguishable states, their preparation, sufficiently stable storage and an accessible way of reading. Quantum memory additionally needs to store relationships that are essential for the chosen task. If only the ordinary probability of one of the outcomes remains, not all the information of the original quantum state remains available.

In a mental technical device, one can store one classical bit for a very long time and still completely lose the quantum phase. For the task “there was or was not an event” this is enough. For a problem that depends on interference, no longer. Therefore, the expression “long life” requires clarification: what exactly lives, in relation to what interference and for what subsequent operation?

Human memory introduces another distinction. A memory of an event contains relationships among many features and is embedded in the processes used to retrieve them. A stable quantum carrier does not automatically specify either this content or its belonging to a particular person. Even an ideal physical register remains a register until we describe how its stored state is organized and used.

This distinction can be expressed through language. Preserving a sequence of symbols and reconstructing the meaning of a story are different

tasks. The latter requires connections with other knowledge and with the current situation. Likewise, a physical state becomes part of personal memory only within a broader organization. Choosing an unusual carrier can change what can be stored, but does not relieve the model of the need to explain that organization.

Fisher's proposal

Matthew Fisher proposed considering phosphorus nuclear spins as possible elements of quantum processing in the brain. In this model, protection of the states is associated with hypothesized calcium-phosphate structures called Posner molecules. The proposed chain includes the formation and transfer of spin correlations, and the effect of certain chemical events on calcium availability and, in turn, neuronal activity. This is a theoretical research program connecting several testable physical and chemical assumptions. [7]

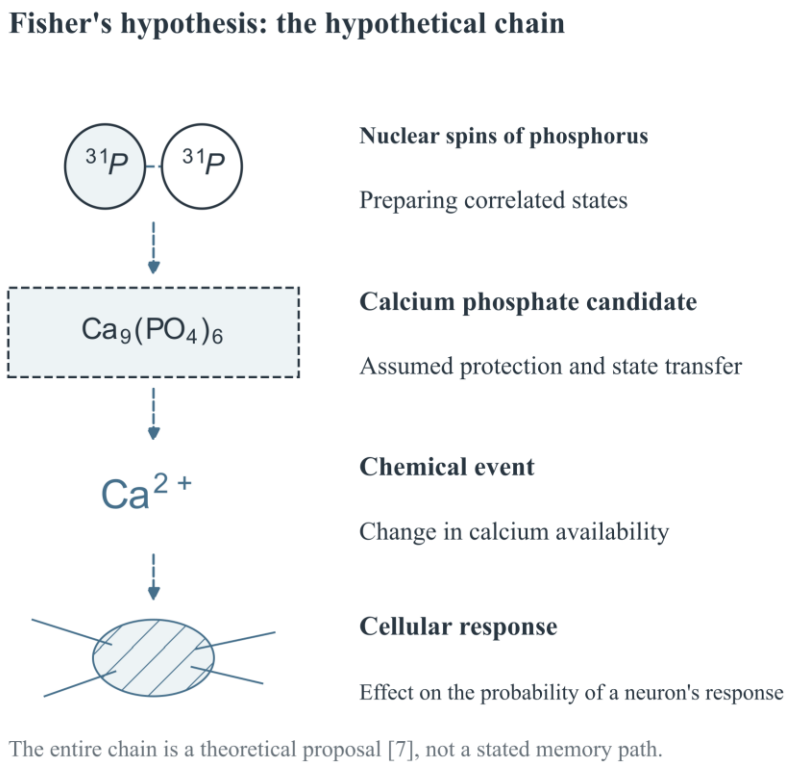


Figure 18. Fisher's hypothesis links nuclear spins to hypothesized calcium-phosphate structures and subsequent cellular effects. The existence and operation of the entire chain require separate tests.

Its appeal lies in its specificity. A specific chemical element, a possible structure, and a path from microscopic state to cellular action appear. Each choice narrows the explanatory space. Instead of a general assumption about quantum memory, the question becomes whether specific molecular processes fulfill the necessary conditions.

The detailed diagram, however, still needs to be checked at each link. A chemically possible reaction may be dominated by channels that do not maintain the required correlations. A structure that is convenient to calculate may be unstable in the corresponding environment. The association with cellular function may be too weak or nonspecific. All these outcomes relate to the physical content of the hypothesis.

It is especially important to keep the explanation in the right direction. One should not first accept the presence of quantum memory and then take any finding of calcium or phosphate as confirmation. These substances are involved in many processes. Confirmation must concern precisely those properties and relationships that distinguish the proposed mechanism from more conventional biochemistry.

Protection depends on the environment

Thomas Player and Peter Hoare investigated the spin dynamics of the putative Posner molecules and obtained an upper estimate for the persistence time of intermolecular spin entanglement of about 37 minutes under idealized conditions. They emphasized that real processes can significantly reduce this period. The number refers to a specific calculation, not the measured duration of quantum memory in the human brain. [8]

The very concept of an upper bound is easy to misunderstand. It tells you how favorable the limit may be in the chosen model. It does not guarantee that the biological system reaches this limit. Similar to the maximum range of a technical device in an ideal environment, the estimate must be revised when specific sources of loss are added.

Changes in the chemical environment are especially significant here. If the proposed structure binds to other molecules, becomes deformed, or changes to a different composition, the physical description of the spins also changes. It is impossible to first calculate the safety in one structure, and then transfer the result to another without checking, only retaining the previous name.

Nevertheless, even limited calculation is useful. It shows which interactions are most dangerous and where measurement will bring the most clarity. If the main source of loss is associated with a specific process, an independent assessment of it can dramatically change the credibility of the entire chain. Thus, theoretical work helps to choose the next experiment without promising in advance the desired outcome.

From correlation to chemical action

Let us assume that the required states are indeed prepared and persist for a long enough time. It is now necessary to explain how their difference changes the chemical result. If all possible spin states equally influence the subsequent process, quantum information remains functionally invisible. It may exist, but not fulfill its stated role.

Therefore, in any such model a selectivity mechanism appears. Some states should increase the probability of a certain transition, while others should decrease it. After the transition, the difference must be strengthened or consolidated so that it becomes noticeable at the cellular level. The amplification does not have to preserve the original quantum structure: the devices also turn a microscopic event into a macroscopic record. But the amplification path itself must be described.

A mental diagram with two chemical channels makes the problem clear. The first channel depends on the spin state, the second is almost independent. If the second channel is much stronger, the observed result will be poorly sensitive to the protected medium. The presence of a beautiful quantum mechanism in the first channel does not save the model from the quantitative question of its contribution.

On the other hand, a small contribution can be significant if the system operates close to the threshold and then amplifies the difference. But reference to the threshold does not exempt you from the calculation. It is necessary to show that the amplification preserves the desired pattern, and does not turn a weak signal into a result indistinguishable from noise. The words “small contribution” must be given a quantitative expression: how weak the signal is and how much amplification is necessary for its effect.

Thus, the chain contains two different forms of stability. The quantum state must survive the time before useful interaction. The resulting functional difference must survive until the cellular response occurs. These times can vary greatly. A long-lasting neural effect does not in itself mean that the original entanglement was there all along.

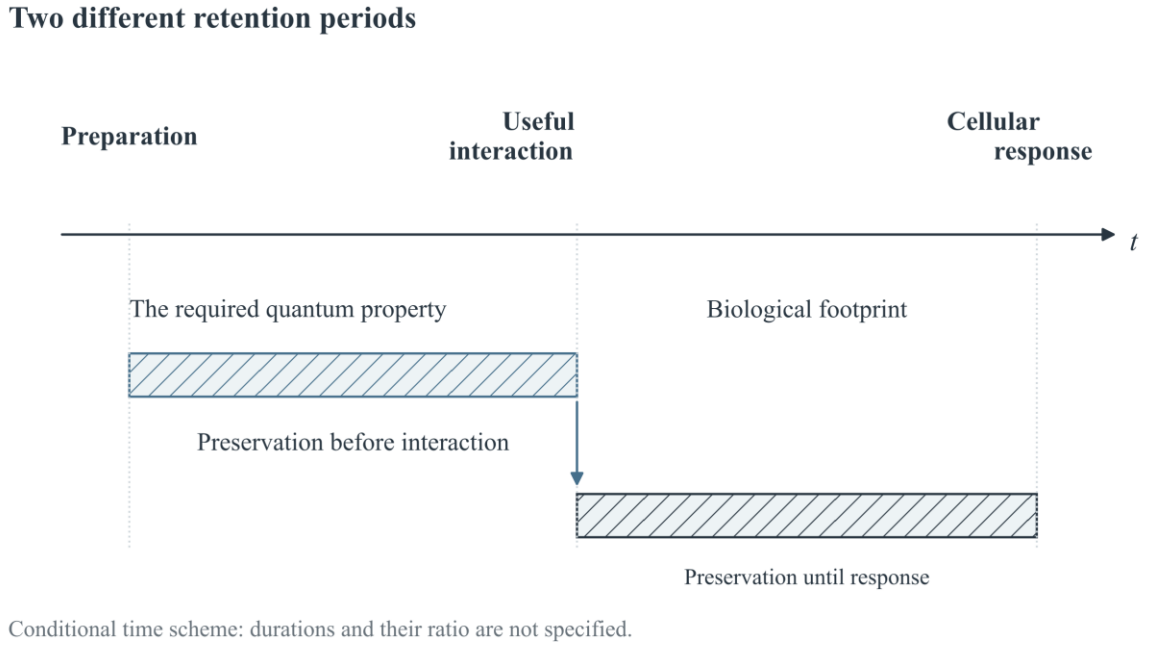


Figure 19. The quantum state must persist until the interaction, and the resulting functional difference must persist until the cellular response. The duration of the second process does not measure the lifetime of the original entanglement.

The comparison of operation time with coherence decay is shown in Figure 11.

How to distinguish a mechanism from neighboring causes

If changes in chemical composition affect an organism's behavior, many possible explanations arise. The intervention could change the concentrations, structure, metabolism or properties of other molecules. To isolate the spin mechanism, it is necessary to find consequences that are quite specific to it and consistent with quantitative calculations.

For example, a physical model may predict a certain dependence on magnetic influence. But any detected magnetic influence does not indicate the chosen medium. It may have another source. Therefore, the form of dependence, characteristic times and accompanying features are important. The more accurate the joint prediction, the more difficult it is to replace it with an ex post explanation.

Similar caution is needed when discussing isotopes. Differences in isotopic composition can be used to study spin properties, but other associated changes must be taken into account in a particular system. Any difference cannot be assumed in advance to be the result of quantum memory. First, a model of the expected effect is built, then physical reasons that can give a similar picture are considered.

In this logic, reversible experiment is especially valuable. If the proposed mechanism can be weakened and restored without changing everything else at the same time, the causal explanation is strengthened. However, restoration of function must correspond exactly to the path stated by the theory. The return of general activity after broad exposure is not an automatic restoration of a specific spin process.

This reasoning relates to the design of the study, and not to recommendations to intervene in one’s own body. Physical and biological variables must be controlled in a suitable laboratory system. Otherwise, the inability to separate causes makes even a subjectively striking result almost useless for testing the model.

Where does the question of consciousness begin?

Let’s assume that the entire proposed path is confirmed: the spin state is preserved, affects chemistry and changes the operation of the neural network. Then a new mechanism for biological information processing was established. The next task is to determine its relation to the experience. It may be necessary for some functions, but not fulfill a special role in subjectivity.

A mental example helps to separate the possibilities. One mechanism supports learning, another is involved in current perception, and the third influences the stability of the waking state. All of them have the ability to change behavior. However, a theory of consciousness must clarify exactly

what aspect of experience will change when they are disrupted and why. The general word “cognition” does not replace the distinction between memory, attention and experience.

An additional boundary arises for the external interface model. Long-lived quantum memory inside a molecule is not automatically memory outside the body. Its carrier can completely belong to the biological system. To move on to an external trace, it is necessary to show interaction with another system and the storage of certain information in it after changing the internal media.

Explaining access is equally important. Even if information about past events is distributed throughout the environment, this does not mean that the body can restore it as its own memory. Addressing, discrimination of the desired signal, and a way to incorporate the received content into ongoing activities are required. Quantum correlation by itself does not perform all these functions.

Memory as a process of retaining differences

The search for an unusual physical medium forces us to re-formulate the very concept of memory. Memory exists for a system insofar as a difference in its past is capable of influencing the available difference in the future. In this definition, not only the safety of the trace is important, but also the possibility of its use. A trace that is fundamentally inaccessible to any subsequent process does not explain the memory.

Therefore, a good physical model should connect recording, storage and recovery. You can achieve an impressive result in one part and lose all meaning in another. The supposed subject additionally requires coherence of history: different traces must be assigned to one developing center of perception and action, and not remain a random collection of stored states.

Nuclear spins are of interest precisely as a way to make these questions precise. It becomes possible to ask about preparation, interaction, lifetime and reading. If the mechanism is not confirmed, the questions themselves will remain and will be applicable to another medium. If confirmed, they would separate the discovery in quantum biology from a more powerful conclusion about the nature of experience.

Now we can return from the molecular carrier to the organism as a whole. Anesthesia changes communication with the outside world, behavior and memory, allowing explanations of consciousness to be compared with observed transitions. But first we need to find out exactly what abilities have changed and what was measured in each case. This is the subject of the next chapter.

Chapter 11

What does anesthesia do to the question of consciousness?

The person answers the question, then stops answering, and later starts talking again. There may be a gap in memory between two conversations. This sequence seems like an almost perfect experiment in switching consciousness off. But the seemingly simple picture hides several different processes: a change in experience, loss of connection with the environment, the inability to respond, and impaired memory formation.

This is why anesthesia is so important to the study. It allows you to observe transitions and compare the effects of substances with changes in the brain. At the same time, it forces one to carefully select the measured value. If a theory explains only immobility, it cannot automatically be considered a theory of the disappearance of experience. If it explains memory, it is not a complete explanation of what happened before the response was restored.

Three different disappearances

You can mentally distinguish between three situations. In the first there is no experience. In the second, the experience exists, but does not contain the actual external world. In the third, the outside world is somewhat accessible, but the ability to communicate about it is impaired. Behavior in these situations may be similar. Therefore, the absence of a reaction does not always clearly determine the internal state.

Added to these differences is memory. Even if the experience was present, it might not be preserved in the form of a subsequent story. Conversely, the post-recovery narrative may include events that occurred during the transition between states. The researcher obtains a memory rather than a direct, continuous record of the experience. Timing content becomes a task in itself.

In the study by Sarasso et al, eighteen volunteers were assigned to three anesthesia groups. After ketamine, participants reported vivid dream experiences, whereas after propofol and xenon there were no such reports. The brain's responses to magnetic stimulation also differed: with ketamine, a more complex picture remained, close to wakefulness. [2]

This result is important as a distinction between observed states rather than as a ready-made map of all possible anesthesia experiences. It shows that the same lack of response to external stimuli can be accompanied by different data. For interface theory, the consequence is specific: it is impossible to describe any such transition with a single quantity “connection strength” if different forms of access loss require different mechanisms.

A more meaningful model should distinguish between the channel of external perception, the internal organization of experience and the conditions of subsequent reproduction. Perhaps they depend on the overall process. But this must be shown by explaining the cases of their divergence. Otherwise, the simple word “disconnection” hides precisely those differences that the experiment made available for study.

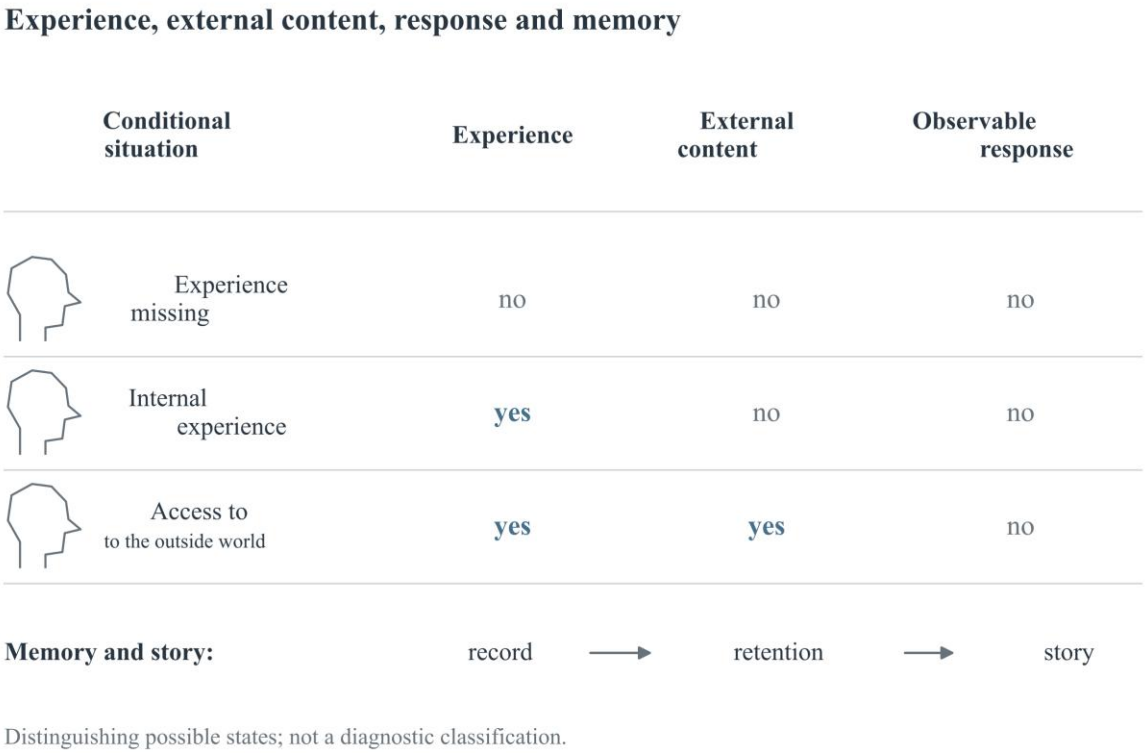


Figure 20. A similar lack of external response may allow for different internal states. Memory and the subsequent story constitute a separate element of observation.

Evidence that comes later

The story of an experience has a special position. It is the most important source of information about the content of experience, but it arises in a system that has already gone through changes in state. Therefore, the researcher must simultaneously take the story seriously and take into account the conditions under which it appeared. Subjective vividness does not replace independent information about time and circumstances.

Suppose a person, after recovery, talks about sound. This sound could relate to the period before the loss of response, to restoration, or to an internally constructed scene. To distinguish between options, an event with a known time and content is required. The very fact of recognition of a sound does not establish the moment of its perception.

Likewise, the absence of a story does not allow one to reconstruct the entire previous story. The memory may not have been formed or may have been inaccessible. This does not mean that any empty interval should be

considered a hidden experience. The correct conclusion is that the data constrain many possible explanations, but do not always select one.

For a physical hypothesis, it is especially important to decide in advance which part of this chain it describes. The model can predict the disappearance of available memory while the internal process is preserved. Then it should be checked against the consequences of just such a discrepancy. If it predicts a complete cessation of the process, subsequent evidence and independent indicators will make a different demand.

Validation is stronger when different data sources are consistent. Behavior, physiology, and narrative do not always have to coincide, but theory must explain the pattern of their overlaps and divergences. An arbitrary preference for whichever indicator is more convenient for the current conclusion deprives the experiment of its discriminative power.

Brain response to disturbance

The operation of the system can be studied both under normal conditions and after a short exposure. Perturbation provides a known beginning and allows one to explore how the response spreads and changes. This helps to distinguish states that are externally similar in immobility, but differ in internal organization. This is exactly the approach used in the mentioned magnetic stimulation study. [2]

However, response complexity should not be confused with arbitrary irregularity. Noise can be unpredictable without forming coherent processing. On the other hand, a very regular system can reliably perform a limited function. Connecting with consciousness requires a measure that is sensitive to the organization of interest, and not simply to the amount of fluctuation or the unusualness of the pattern.

Let's mentally compare the three devices. The first responds to the influence with the same short impulse. The second produces random noise. The third gives a varied answer, but related to the impact and internal state. These differences are useful for analyzing dynamics, but do not in themselves determine which device has experience.

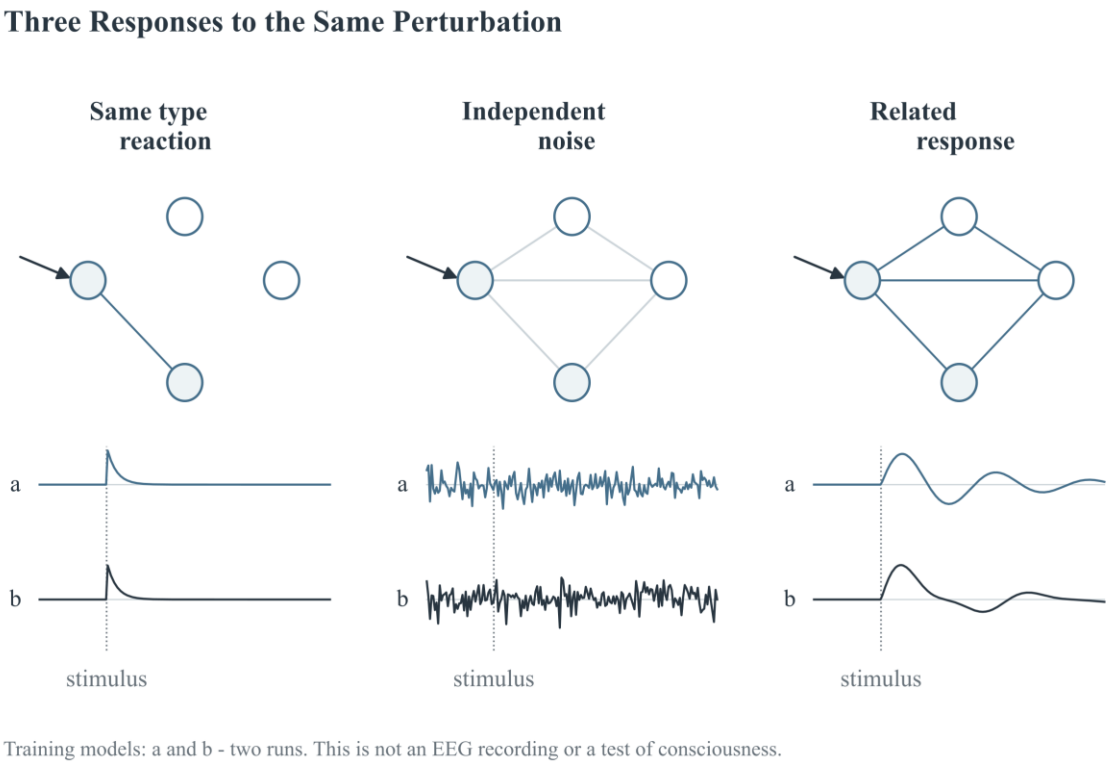


Figure 21. The same type of response, noise and varied associated response reflect different organization of dynamics. In the third example, the two runs differ in the initial state of the device. These teaching examples do not in themselves determine the presence of an experience.

Therefore, a physiological indicator acquires meaning through comparison with independently described states and conditions. It can help assess consciousness where the answer is difficult, without becoming a universal measure of subjectivity for any physical system. Transferring an indicator to a new environment requires a separate verification of its meaning.

Moreover, the condition does not necessarily change in all respects at once. During the transition process, one indicator may recover before another. If we compare only the steady states before and after exposure, an important part of the mechanism will remain invisible. The temporal order of changes can show which link precedes the other and what processes continue after the appearance of the external response. Therefore, the theory must explain the course of the transition, including the sequence of restoration of different functions.

For the quantum hypothesis, this means that a change in the complexity of the brain response may be an expected consequence, but not a direct measurement of the quantum carrier. A causal chain remains between the supposed microscopic process and the observed dynamics. It must be examined if the quantum explanation is to be distinguished from a neural model with a different microscopic basis.

Intervention and return

Of particular value are experiments in which the researcher changes the operation of a particular system and observes a partial restoration of function. In Bastos et al.'s central thalamic stimulation series, two macaques showed signs of wakefulness with continued administration of propofol. At the same time, some characteristics of neural activity changed. [3]

The causal structure is important here. The condition changed after a certain intervention, although the anesthetic continued to act. To explain, it is not enough to say that the molecules of matter simply destroyed consciousness everywhere in the same way. It is necessary to take into account the organization of the network, the possibilities of its activation and what functions have actually been restored.

But the causality of intervention has limits. Turning on one node can affect many others. The return of motor reactions does not allow us to directly read the content of animal experience. Therefore, the precise formulation of the result retains the observational level: signs of wakefulness and neurophysiological changes, rather than full access to the animal's inner world.

The interface hypothesis could incorporate this result by suggesting that a thalamocortical organization is involved in access to the intended carrier. It will then be necessary to explain why this particular organization matters and what additional consequences follow from such an explanation. If any recovery method is called "receiver repair", the hypothesis remains too flexible.

The stronger variant should predict differences between interventions. One change may restore the ability to respond to external stimuli, another may restore the complexity of the brain's response to stimulation, and yet another may restore the ability to retain memories. The relationship between these effects will indicate how many truly independent functions the intended interface includes.

Microtubules in the causal chain

In the work of Han et al, exposure to the microtubule stabilizer epothilone B in rats increased the time to loss of the righting reflex under isoflurane anesthesia. This result correlates interference with the microtubule system with an index of anesthesia sensitivity. The experiment itself did not measure quantum coherence and did not directly determine whether the animal had an experience. [12]

The righting reflex is the ability of an animal to return to its normal position after turning over; In the described experiment, the return of the rat from its back to its paws was assessed. This is a convenient observable indicator, but its change may reflect the work of different parts of the body. To relate the result specifically to quantum dynamics, it is necessary to show its causal role and separate it from other cellular changes. [12]

Suppose the intervention both makes the structure more stable and changes its interaction with light. A change in sensitivity to a substance would be compatible with at least two explanations. What will help you choose between them is not a general reference to microtubules, but a discriminating prediction. For example, which characteristics must change together and which can change independently?

When comparing these experiments, it is necessary to check the intermediate links. An optical effect in an isolated structure and a change in reflex in an animal may belong to the same mechanism, but this connection still needs to be proven. The mere presence of the word “microtubules” in both descriptions does not establish causal continuity.

Further research should connect three levels with measurements: the state of the carrier, its effect on the cell and the state of the organism. If the changes are consistent in timing and effect size, the model is supported. If the chain is broken, it becomes clear where revision is needed.

A Prediction That Distinguishes Explanations

A meaningful forecast concerns not only the direction of the effect. The formulation “a substance will change consciousness” is too broad, if this is already known from pharmacology. The new mechanism must explain additional variation: dependence on a property of the carrier, a characteristic range, a specific temporal order, or a particular combination of observed changes.

For example, in the imaginary model, two impacts change the overall network activity in the same way, but have different effects on the putative quantum carrier. If the model associates a certain aspect of experience with it, it must indicate in advance the difference between the resulting states. Otherwise, the medium does not add observable information to the already existing neural explanation.

The reverse case is also important. Two interventions may produce the same change in a measure of the carrier, yet lead to different behavior because of differences at later stages. The theory must then explain why an equal microscopic effect does not imply an equal state of the organism. A multilevel explanation requires consistency rather than a single universal indicator.

A good model also allows for failure. If the intended carrier changes, but the expected function under suitable conditions remains the same, this limits its role. If a function changes without the expected change in media, the stated need is limited. Such outcomes are useful precisely because they allow one to choose between different causal schemes.

The price of a general explanation

A universal theory of consciousness must explain ordinary wakefulness as well as transitions in which experience, response, and memory diverge. It

cannot select only the most mysterious cases. Simple, stable relationships impose demands no less stringent than unusual subjective accounts.

Anesthesia therefore does not provide a single definitive answer, but does provide many limitations. The theory must take into account the diversity of observable conditions, the possibility of causal intervention, and the limitations of measurement methods. For an external medium, this means the need for an accurate model of communication with the organism, and for a purely neural approach, this means the need to explain the internal organization of experience.

The next step is to compare these explanations on general terms. While each program chooses its own successful examples, the argument easily turns into parallel monologues. Scientific meaning appears when competitors indicate in advance where their forecasts really differ and what result will have to be considered inconvenient.

Chapter 12

When theory meets competition

The theory is especially compelling when viewed in isolation. For every successful result, you can find a beautiful explanation, and inconvenient details can be attributed to future work. The situation changes when another theory appears nearby that can explain the same observations. The question then is no longer whether the story is possible, but which explanation stands up better to general scrutiny.

Consciousness research needs this comparison as much as other areas of science. The subject itself is complex, and the data allows for multiple levels of interpretation. Therefore, it is especially important to distinguish between the explanation of the state, the mechanism of access, the content, and the very presence of the experience. Theories can argue about different questions while mistakenly believing that they offer incompatible answers to one.

Strong neural alternative

It is easy to present the neural theory as too primitive: as if it simply states that it is enough to collect a lot of nerve cells and consciousness will appear on its own. Real-world research programs try to determine what process organization matters, what interactions are necessary, and why information is made available to different functions in some cases but remains local in others.

In global neural workspace theory, a significant role is played by the strengthening and maintenance of representation through recurrent interactions, allowing information to become available to different specialized processes. A review by George Mashour, Peter Roelfsema, Jean-Pierre Changeux, and Stanislas Dehaene considers this approach as an explanation of the mechanisms of conscious processing, including relations with attention and working memory. [22]

As a mental example, one can imagine a system where the visual signal is first used only for local recognition, and then becomes available for planning, memorization, and response selection. The difference is not simply the presence of a signal, but a change in the way it is subsequently used. Such an explanation has specific functional content regardless of whether it is sufficient to explain subjectivity.

The interface hypothesis does not benefit from ignoring this organization. If an external basis exists, human experience still manifests itself through memory, attention and action. Therefore, a new model must either incorporate the established functional relationships or explain why a different device produces the same results. The simple dichotomy of “brain or mind” obscures this responsibility.

Unity as a Causal Structure

The theory of integrated information starts from other premises. IIT version 4.0 maps properties of experience to requirements for the internal causal structure of a physical system. The theory relates experience to an irreducible cause-and-effect organization, rather than simply to the amount of data conveyed. Its mathematical description imposes certain conditions on what is considered a system and what relationships within it are significant. [21]

This approach cannot be reduced to the statement “the more complex, the more conscious.” A random stream may be difficult to compress and lack the required causal organization. The amount of memory, the number of connections and computational performance are also not identical to the stated criterion. Therefore, the use of a convenient indicator of complexity rather than a complete theoretical definition requires a separate justification.

A mental contrast between recording a process and the process as an operating system is helpful. A video recording of a complex mechanism may contain a lot of information about its operation, but it does not itself reproduce all the causal interactions of the mechanism. For a theory that relies on internal causes and effects, this difference is fundamental. For other theories, a different level of organization may be decisive.

This approach has its own difficulties: defining the system's boundaries, establishing its causal structure, and connecting mathematical properties to specific contents of experience. However, difficulty in calculating or testing a theory does not justify replacing it with a caricature. The comparison must concern the theory's actual claims, available data, and the predictions of a competing explanation.

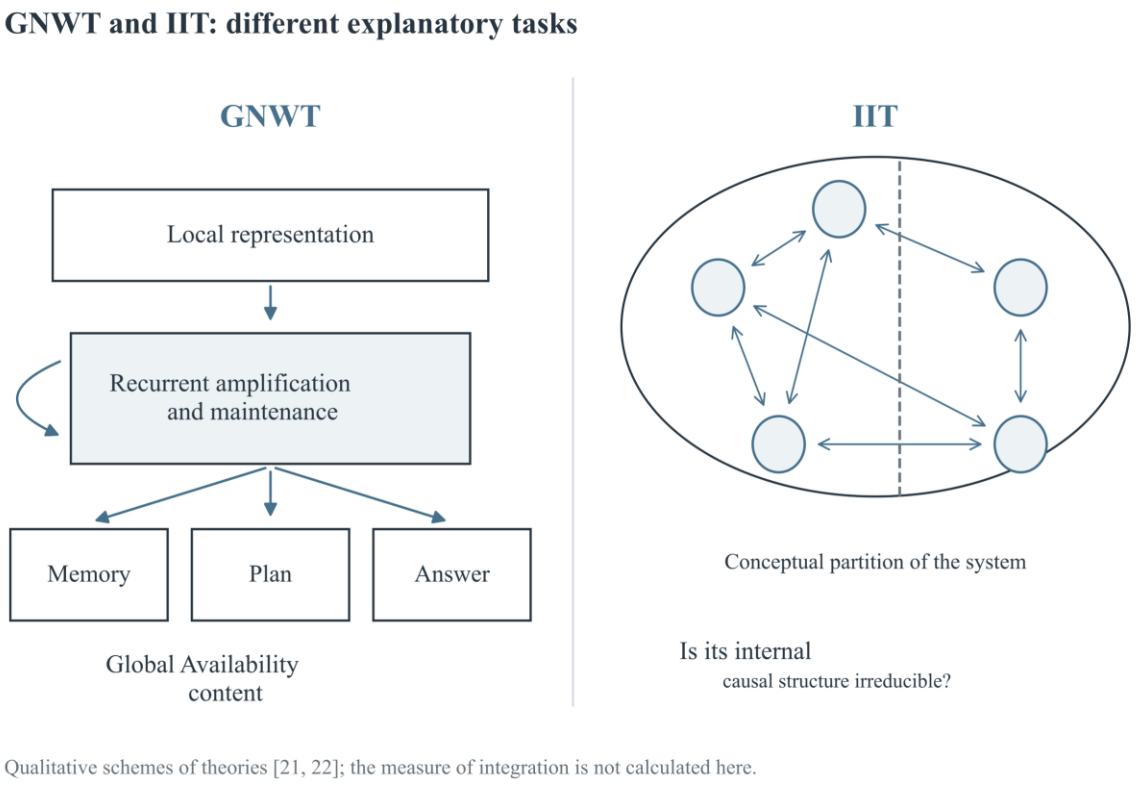


Figure 22. GNWT emphasizes the global availability of representation across processes. IIT links experience to an irreducible internal causal organization. Diagrams show the direction of explanation rather than calculating consciousness.

A Jointly Agreed Test

In the Cogitate consortium study, IIT and GNWT proponents agreed in advance on differing predictions and scoring rules. In 256 participants, brain activity was studied when presented with visual stimuli of different durations. Functional magnetic resonance imaging, magnetoencephalography and intracranial electroencephalography were used. Some of the results were consistent with the expectations of both programs, but specific difficulties were also discovered. For IIT, this was the lack of predicted stable synchronization in the posterior cortex. For GNWT, the absence of the expected repeated burst of activation in the prefrontal cortex after the disappearance of the stimulus. These results relate to the predictions and experimental conditions tested; they do not provide grounds to declare the entire content of one of the theories completely rejected. The main methodological achievement of the work is that the comparison criteria were determined before getting to know the data. [1]

The principle of such verification is more important than the spectacular announcement of the winner. If predictions are written down in advance, it is more difficult to subtly change the meaning of the theory after experiment. However, the pre-selected test also has a scope of applicability. It concerns specific versions, objectives, measurements, and connecting assumptions.

The failure of one forecast does not necessarily destroy the entire program, but it does create an obligation to explain the revision.

The general logic for distinguishing models is shown in Figure 7; the separation of fitting and independent verification will be further illustrated in Figure 31 in Chapter Seventeen.

One must distinguish between the central statement of the theory and the auxiliary way of relating it to the instrument. For example, a model may predict a certain organization of information, and the researcher selects one physiological indicator as its trace. An unexpected result may call into question both the model and the chosen relationship to the indicator. For a meaningful revision, you need to indicate exactly which part is supposed to be changed and what new consequences this will give.

This distinction should not become an endless defense. If any inconvenient result is declared to be a failure of the auxiliary assumption, the theory is no longer at risk. Therefore, it is useful to determine in advance which relationships are considered sufficiently reliable for a given comparison and which combination of results will be a serious problem. Then the revision remains a scientific work, and not a way to preserve the formulation at any cost.

The new version may be better than the previous one. But its advantage should be tested under new conditions. Repeated explanation of the very result for which the version appeared does not yet show that its predictive ability has increased.

Let us imagine two models that differ in the expected place of stable representation. The result obtained may not coincide with any one. This does not yet mean the victory of the third model, which did not participate in the comparison. First you need to understand whether the formulation itself, the method of measurement, or the connection between the observed signal and the theoretical concept was a general error.

For the external interface hypothesis, there is a useful caveat here. The difficulties of neural theories create space for new explanations, but do not provide ready evidence in favor of an external carrier. Evidence will emerge when one's own model explains in advance the difference that competitors do worse at, and the result stands up to independent scrutiny.

Explanations may be at different levels

The quantum model and the neural model are not necessarily mutually exclusive. The first may describe a microscopic mechanism that provides a specific cellular function. The second is organizing a network that uses this function. If both give a compatible multi-level description, the argument about “which one is correct” is misleading: they answer different questions.

Direct competition occurs where observed consequences differ. For example, one model states that a certain quantum process is necessary for a function, while another allows for the persistence of a function after it is

selectively eliminated. Then a specific subject of comparison appears. But first you need to make sure that exactly the desired property is eliminated, and not the entire cellular system is destroyed.

Not every quantum effect makes the classical description of a function useless. Sometimes microscopic physics leads to stable, effective rules on a larger scale. Such rules can predict behavior well without describing every particle. Therefore, the question of the need for a quantum description should relate to the chosen task and precision, and not to matter in general.

In turn, a successful classical model of behavior does not necessarily resolve the issue of the nature of experience. It can reproduce observed patterns, leaving open the explanation of the subjective side. This is not a failure of the simulation, but a difference between its outcome and the broader goal. Precise boundaries help you avoid demanding everything from one model at once.

What an External Bearer Adds

Suppose the brain model already explains observed states, memory errors, information availability, and responses to interventions. An external system is added to it. For an addition to make physical sense, it must either improve the prediction, explain a consistent pattern with fewer independent assumptions, or propose a new testable mechanism.

If the state of the external media can be freely chosen for each outcome, the model becomes too flexible. It is easy to reconcile with the past, but difficult to verify. The problem is not in the external system itself, but in the lack of restrictions. The same difficulties arise for any model, the number of free possibilities of which increases along with the number of inconvenient results.

A mental example illustrates the difference between explanation and adjustment. The first model predicts in advance a certain delay in response to the influence. The second one, after each measurement, selects a new delay, calling it the property of an unavailable source. Both can describe the data obtained, but only the first risks making mistakes on the next measurement. It is this risk that gives the forecast scientific value.

Therefore, the external media should be limited to properties that are defined independently of the desired output. Interaction time, sensitivity range, information retention, and modes of state change should not be free explanations for any result. The more such properties can be linked by one mechanism, the more meaningful the model becomes.

New data is more important than the convenient past

An explanation of already known results is necessary, but not sufficient. The model can be specifically tuned for them. Therefore, observations that were not used in the selection of parameters and assumptions are of

particular value. They show whether the model retained its ability to predict or just adjusted to the previous data set.

This difference is not limited to the mechanical division of the table into two parts. If the researcher looks at the validation set repeatedly and changes the model, the set gradually becomes part of the tuning. For a convincing comparison, it is important to define the procedure in advance and preserve the possibility of a truly new test. Independent replication adds another layer of protection against hidden lab quirks.

The success rate should also be agreed upon in advance. If one model predicts timing, another predicts the strength of an effect, and the winner is chosen based on a feature that happens to be convenient, the comparison becomes unclear. It is necessary to determine what quantity is relevant to the claimed mechanism and how accurate the prediction must be for the result to be discriminative.

A negative outcome can have several meanings. The mechanism may not be present in the conditions tested. It may exist, but is too weak for its stated function. The measurement may not be sensitive enough. These options should be distinguished by the capabilities of the experiment itself. Otherwise, any negative result can be declared “too rough a measurement,” and any positive result can be declared a final confirmation.

Rival as part of the plan

A good theory should be able to describe which explanation will beat it in a fair comparison. For the selective interface hypothesis, such a rival could be a neural model that reproduces all the claimed additional effects without an external carrier. It may turn out that the supposed carrier exists, but is not associated with consciousness. It may turn out that the chosen quantum property is not required to explain the function.

These outcomes do not render the study meaningless. They determine what knowledge will emerge regardless of the fate of the original expectation. If a model with an external system produces better new predictions under clearly constrained assumptions, its support increases. If the benefits disappear after controlling for alternatives, it should be reconsidered, even if the original idea remains attractive.

Comparison also helps to more accurately formulate a positive goal. What is required is not to prove the entire metaphysical picture with one experiment, but to discover a certain physical contribution and establish its significance. One can then ask what additional conditions link this contribution to individual experience. Dividing tasks preserves the possibility of movement without requiring a premature final response.

Testing competing explanations sets requirements for one's own model. In the next part, it is necessary to determine the hypothesized carrier, the mechanism of its interaction with the body, the boundary of the subject and the testing conditions. The selective interface hypothesis will be evaluated by

the same rules: how specific its predictions are and how they hold up against alternatives.

Part four

Selective interface hypothesis

Chapter 13

Where could the contribution come from?

Every receiver has selectivity. It responds not to everything that happens in the Universe, but to certain influences. A signal that is too weak is lost in noise; too fast does not have time to change the state of the device; the wrong frequency causes almost no response. It is these limitations that make it possible to distinguish a physical device from a metaphor. If the brain is truly involved in communication with an additional carrier, this connection must also have conditions of existence.

So far, the focus has been on existing research programs. On this basis, we can formulate the author’s version of the interface hypothesis. Its underlying assumption is that some bodily states are capable of selectively interacting with physical degrees of freedom not included in the usual neural description. Sustained interaction could be involved in the organization of subjective experience. Let's call this the selective interface hypothesis. It must connect two questions: how the proposed mechanism operates and why its operation should have an experiential side.

Carrier instead of metaphor

The word "carrier" means a system whose states are physically distinguishable and can change. Such a system can be a field, a collection of particles, or a selected collective mode. The name itself doesn't solve anything. If the carrier exists, it is required to indicate its observable properties: energy, spatial structure, rules of change, or method of interaction with already known matter. Even if some of these characteristics are not yet available for direct measurement, they should participate in the calculation of consequences.

The letter B will denote the selected biological subsystem. It is not necessarily the entire brain described at all scales at once. In a particular model, B may include certain molecular states and their relationship to cellular processes. The letter E denotes the intended additional media. The usual environment - thermal movements, chemical reactions, known electromagnetic influences - will be denoted by R. It remains part of the explanation even when the hypothesis E is rejected.

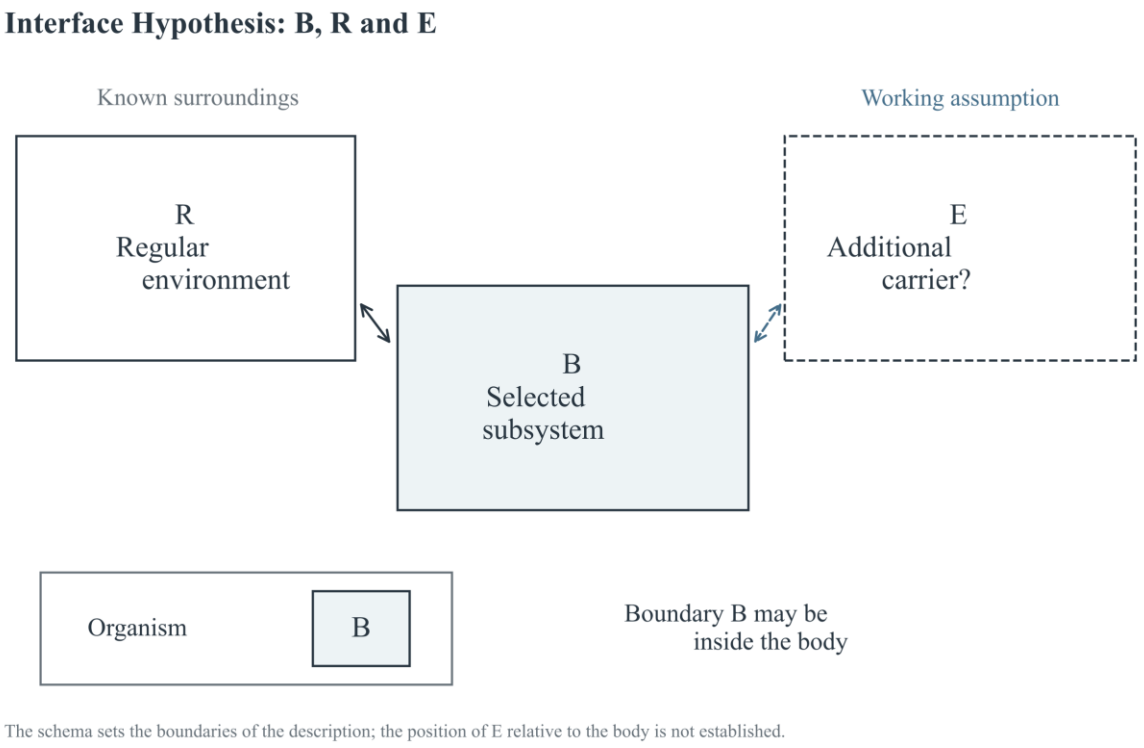


Figure 23. In the hypothesis, B denotes the selected biological subsystem, R the normal environment, E the proposed additional carrier. The exclusion of E from the description of B does not in itself determine its position relative to the body.

This division does not determine the location of consciousness. A subsystem within a cell may be mathematically external if it is excluded from the chosen description B. Therefore, the expression “consciousness outside the brain” requires a separate spatial statement. The discovery of a new intracellular mechanism may change neurobiology, but will not take the subject beyond the boundaries of the body. A spatially external carrier must exhibit precisely the properties of the external source: for example, a certain law of propagation or the dependence of communication on geometry.

The supposed fundamentality also does not mean limitlessness. If a general physical process is involved in the basis of an experience, a particular system can still receive only a limited set of its states. Ordinary light belongs to a common electromagnetic field, but two photodetectors do not become one detector. Likewise, a common carrier, if it exists, does not yet explain the unity or plurality of subjects. These properties will have to be derived from the organization of communication, and not from the word “common”.

There are two different search paths possible. In the first, the carrier is detected independently and then its relationship with the organism is examined. In the second, a persistent discrepancy between the observation and the existing model first appears, and an additional system is introduced as an explanation. The second way is acceptable, but requires special discipline: one discrepancy can have many reasons. A new medium becomes

useful if it explains several independent features with one set of rules and predicts a consequence that has not yet been observed.

Geometry could be one of those rules. For a spatially external source, it matters whether the effect depends on distance, direction, or shielding. However, a specific law cannot be borrowed from a familiar field just for the sake of clarity. It must follow from the selected type of interaction. If normal electromagnetic influence is expected, the program must take into account its known properties. If a different interaction is claimed, reasons will be required to explain why it could not be identified before and where exactly it should appear.

There is also a useful mental limit. If E does not differ in any way from the usual environment in any possible observation, the introduction of a new letter does not add anything to the physical explanation. The distinction may retain philosophical significance, but it does not change the experimental program. Therefore, the study begins with a search for a property due to which the supposed additional contribution ceases to be just another name for the already taken into account environment.

The equation that defines obligations

To begin with, a standard notation of interacting quantum subsystems is sufficient. It is known independently of the question of consciousness and is used here as a language for formulating a hypothesis. [14]

$$H = H_B \otimes I_E + I_B \otimes H_E + \hbar \sum_k g_k A_k \otimes F_k .$$

The Hamiltonian H specifies the energy and dynamics. The first two terms describe B and E separately. The latter sets the connection between them. The identity operator I does not change the state of the subsystem on which it acts. The sign ⊗ denotes a tensor product: this is how operators acting on different parts of a composite system are combined. The operators A and F here are dimensionless, the coefficients g have the dimension of inverse time, and the constant $\hbar$ has the dimension of action. All terms therefore have the dimension of energy. In this notation, the operators A and F are chosen to be Hermitian, and the coefficients g are chosen to be real, so that the interaction specifies an admissible Hamiltonian. Hermiticity is important here because such an operator has real eigenvalues - possible results of measuring the corresponding quantity. [14]

The formula requires meaningful choices. Operator A must correspond to a certain biological property, operator F to a certain characteristic of the carrier. The g coefficient cannot be changed every time in order to agree with the next observation. It must be evaluated independently or derived from the general model and then stored when testing new conditions. The number of terms of the sum also matters: an unlimited number of free connections allows you to describe almost any data, but deprives the model of the risk of making mistakes.

In a real organism, two subsystems are not enough. State B also depends on the usual environment R. If measurements are available only on B, its state is obtained as a partial trace over the remaining degrees of freedom:

$$\rho_B = Tr_{ER}\left(\rho_{BER}\right).$$

This record makes it possible to calculate the statistics of measurements on B. However, it cannot be used to unambiguously reconstruct the structure of hidden systems. Different environments can produce the same observable effects. Therefore, even a very accurate recording of brain activity does not in itself guarantee that it will be possible to distinguish an additional medium from a complex normal environment. We need the ability to change conditions so that the compared models diverge in their forecasts.

Selectivity as a physical property

Suppose the connection is strongest in a narrow range of frequencies. Then the hypothesis should predict not only an enhanced response at the center of the range, but also a weakening response away from the center. If the mechanism depends on the relative orientation of the structures, rotation should change the response according to a certain law. If phase conservation is required, random changes in phase must suppress precisely the corresponding component of the effect. This gives the general idea measurable limitations.

However, resonance can also be classical. The swing, the electric circuit and the acoustic instrument selectively respond to external influences. Therefore, detecting a response peak does not yet establish a quantum mechanism. It helps define the parameters of interaction. Its quantum nature requires additional observations related to selected states, measurements, and classical description capabilities. This limit is especially significant when a weak molecular effect is amplified by a large number of cellular processes.

The proposed hypothesis gives selectivity a central role. The brain is not an open window to any external content. Its structure limits the interactions available; the current state changes their effectiveness; history restructures future response. The image of a stationary antenna gives way to a system that constantly changes its own communication conditions. The meaning of this assumption can be revealed even with a very small model.

Small model of a big idea

Let the selected element B have two energy levels, and element E also have two levels. For simplicity, we will leave only the exchange of one excitation. The initial state is chosen such that E is excited and B is at a low level. The raise and lower operators move each element between these two states. The interaction has the form

$$H_{int} = \hbar g\left(\sigma_+^B \otimes \sigma_-^E + \sigma_-^B \otimes \sigma_+^E\right).$$

The first term transfers excitation from E to B, the second allows for the reverse process. Coefficient g characterizes the exchange rate. This is the

standard model of coupled transitions, chosen as a concrete example of the physical part of the hypothesis. It does not contain person, memory or qualia. The model is simple enough to be fully calculated and makes a specific enough prediction that it can be tested.

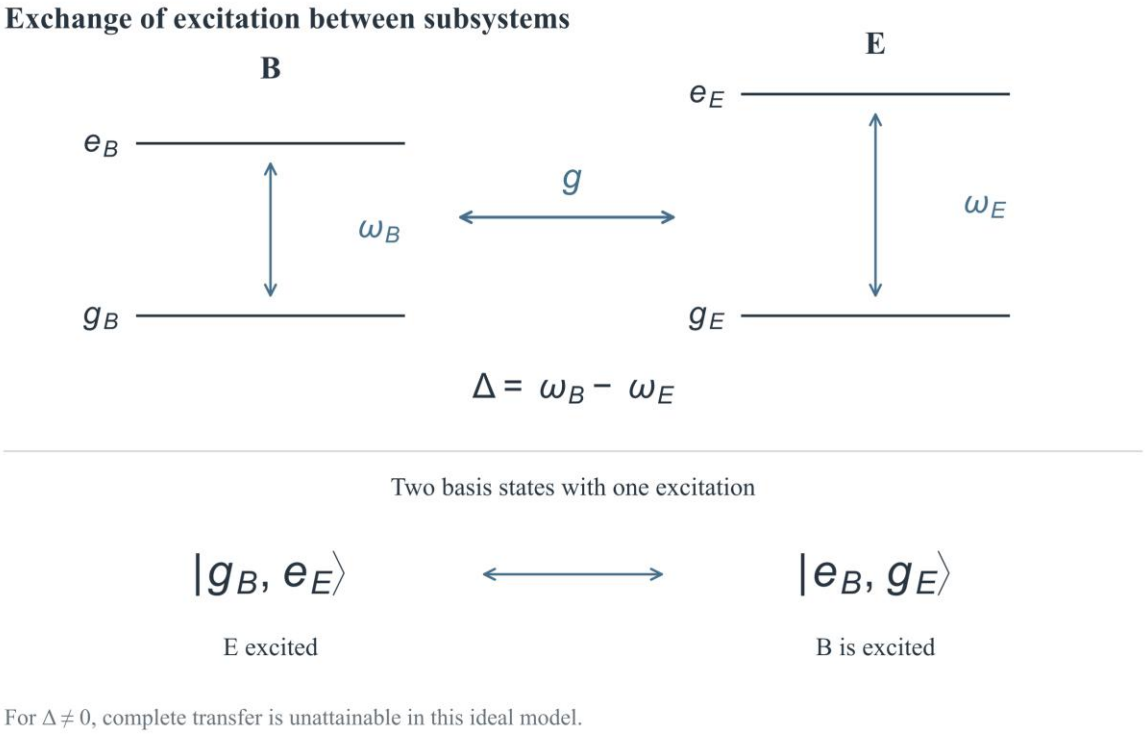


Figure 24. The minimal model allows the exchange of one excitation between B and E. The coefficient g specifies the coupling, and the detuning Δ is the difference in the angular frequencies of the transitions. With a non-zero detuning, the maximum transfer is limited. The model describes physical dynamics without the variable of subjective experience.

The calculation of the transfer probability for this model is shown in Figure 36 of the mathematical appendix.

In the ideal lossless case, the probability of detecting excitation on B after time t is equal to

$$P_B(t) = \frac{4g^2}{\Delta^2 + 4g^2} \sin^2\left(\frac{t}{2}\sqrt{\Delta^2 + 4g^2}\right).$$

Here Δ is the difference in the angular frequencies of the two transitions. The formula is obtained for the specified initial state and the selected Hamiltonian. If the frequencies match, the probability becomes $\sin^2(gt)$: the excitation can completely move from E to B and then return. With a large detuning, the maximum probability decreases. This is how specific selectivity arises, which can be expressed in numbers, and not just in words.

For example, with $|\Delta| = 2|g|$ the maximum probability of transfer in this ideal model is one in two. This is a mathematical example, not the result of brain research. It shows a useful predictive structure: the measured detuning constrains the effect size in advance. If the observed carryover

violates such a limit, the cause may be additional levels, an incorrect model, or measurement error. The limit itself cannot be quietly undone once the data has been received.

In a biological environment, coherence fades, and levels can change population due to other processes. Then the ideal formula needs to be replaced by an open system calculation. For a preliminary assessment, the dimensionless parameter K is useful: the product of the effective communication frequency and the lifetime of the desired coherence. If the phase disappears much earlier than the characteristic exchange time, the described picture of complete coherent transfer does not have time to form. K is not a universal criterion of consciousness.

The change in transport probability can still be reproduced in some classical models of coupled oscillations. Therefore, this little construction does not serve as a single-curve proof of quantumness. It specifies a set of requirements for the hypothesis: what states are involved, how the initial condition is prepared, what is measured, why the response changes. Quantum signs should be sought in the additional structure of the experiment, and not any oscillation should be declared as such.

How a connection becomes biological

For the model to be relevant to the brain, state B must influence the subsequent process. Perhaps the probability of a chemical transition, the availability of a particular protein configuration, or the timing of an event involved in cellular signaling changes. Each option will require its own path from a microscopic state to an observable biological effect. The word “amplification” does not replace this path: both the useful signal and random fluctuations can be amplified.

Here a difficult condition of consistency arises. A bond that is too weak does not change the biological process in a noticeable way. Too strong can destroy the states that were intended to be used. The appropriate range should be determined by joint dynamics rather than by the desire to maintain a hypothesis. If it is necessary to assume exclusive protection from the environment, it is necessary to show how such protection arises and why it is compatible with access to the system.

The energy footprint also depends on the mechanism. The exchange of excitation presupposes a certain energy balance. A net change in the relative phase need not be accompanied by the same change in the average energy of the subsystem. Therefore, the requirement “a new connection must necessarily heat up the brain” is too harsh. The correct question is what observable changes result from the selected interaction and where energy, information, and noise fit in the full description.

The underlying biological prediction must persist across scale transitions. If a model explains a change in behavior through a change in a certain molecular probability, intermediate dependencies must be shown. Otherwise, at one end there will be an exact quantum formula, and at the

other - a free verbal interpretation. Between them, a causal chain is required that can withstand independent measurements of each significant link.

Where does the question of experience begin?

Even successful completion of this chain would establish an additional physical mechanism. To explain consciousness would require a separate statement about why its organization corresponds to experience. In the proposed version, such a condition is considered to be the inclusion of communication in a stable process that distinguishes its own states, combines them with memory and uses the consequences of its actions for further changes. This is a working psychophysical postulate, and not a consequence of the reduced Hamiltonian.

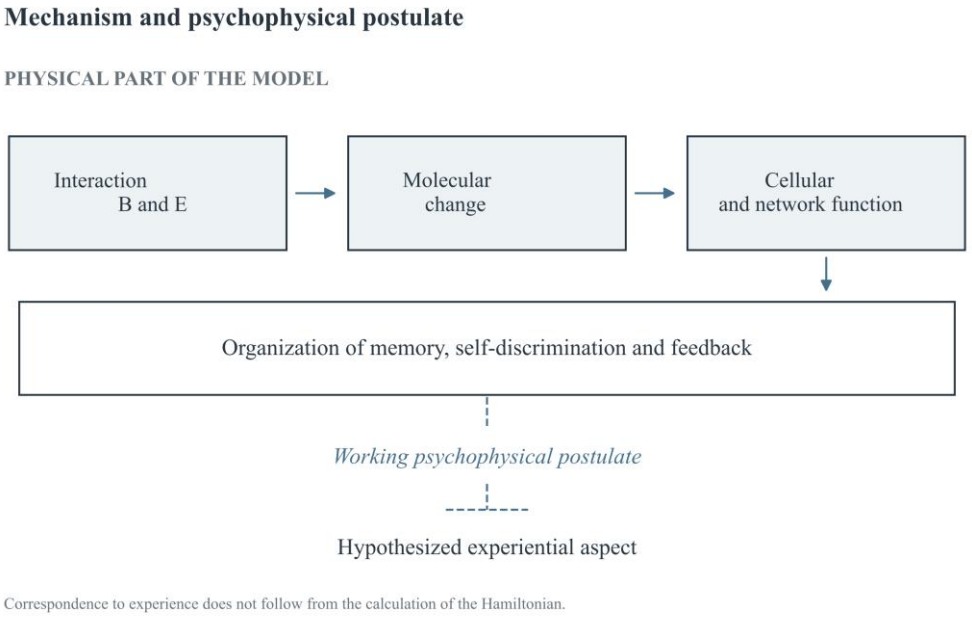


Figure 25. The calculation of physical interaction does not infer a subjective experience. In the author’s hypothesis, their connection sets a separate working postulate, which requires independent justification.

The postulate intentionally links the putative carrier to the organization of the organism. A separate quantum transition is not announced by a separate thought. The same physical resource can participate in different processes, and the presence of the resource does not yet determine the shape of the subjective world. The question of consciousness then refers to the stable organization of interactions through which events become states of a particular participant in what is happening.

The weak point of this version is clearly identified. While there is no independently confirmed rule for the transition from physical organization to experience, the model does not allow one to calculate the quality of sensation using known coefficients. But the physical part can already become verifiable: transfer of excitation, dependence on detuning, the effect of noise and biological consequences have their own verification conditions.

Their result is capable of limiting the hypothesis even before the emergence of a complete theory of experience.

So, a minimal calculation scheme has been proposed and requirements for the future theory have been formulated: to determine the carrier, its connection with the body, the biological path of influence and the condition for the occurrence of the experience. This is not yet an established physical model of consciousness. No additional carrier E was found and the psychophysical condition remains a working prerequisite. But it is clear which links require verification and where the hypothesis may face refutation. The next difficulty concerns individuality: even if the common carrier is real, it is necessary to explain why through it many separate points of view arise, each with its own history and boundary.

Chapter 14

How does a separate “I” arise?

Let us assume that a more fundamental basis for experience does exist. A candidate then appears for explaining the very possibility of subjective experience. But the question of how a distinct perspective emerges from this foundation becomes more pressing. Why is what is happening experienced from separate points of view? Why doesn't one person have free access to another's memory? Why does the common physical nature not transform all organisms into one observer?

It can be assumed that each body in advance corresponds to its own external subject. But then individuality is transferred to another part of the model and still requires explanation: where do the differences between subjects come from, how is the body chosen, and what preserves the personality during this connection? The interface hypothesis developed here considers a different option—co-shaping. Individuality is formed through interaction: a possible common ground provides the ability to experience, and the organization of the organism and its history determines a specific perspective.

Common ground and different stories

Let us mentally place two identically structured systems in different environments. One learns to recognize movement near water, the other learns to navigate in tight spaces. Even with the same initial structure, their states gradually diverge. Various features become significant; errors are corrected in different ways; Some actions are consolidated, others disappear. At some point, the same external signal already causes different sequences of internal events.

If these systems interact with the same type of carrier E, the difference does not disappear. On the contrary, history can change the very effectiveness of communication: the available states, sensitive elements, time windows and ways of further strengthening. A shared physical resource is used by systems whose design and history are already different. In this version, individuality does not need a pre-written external biography. It is formed as a result of a sequence of real interactions.

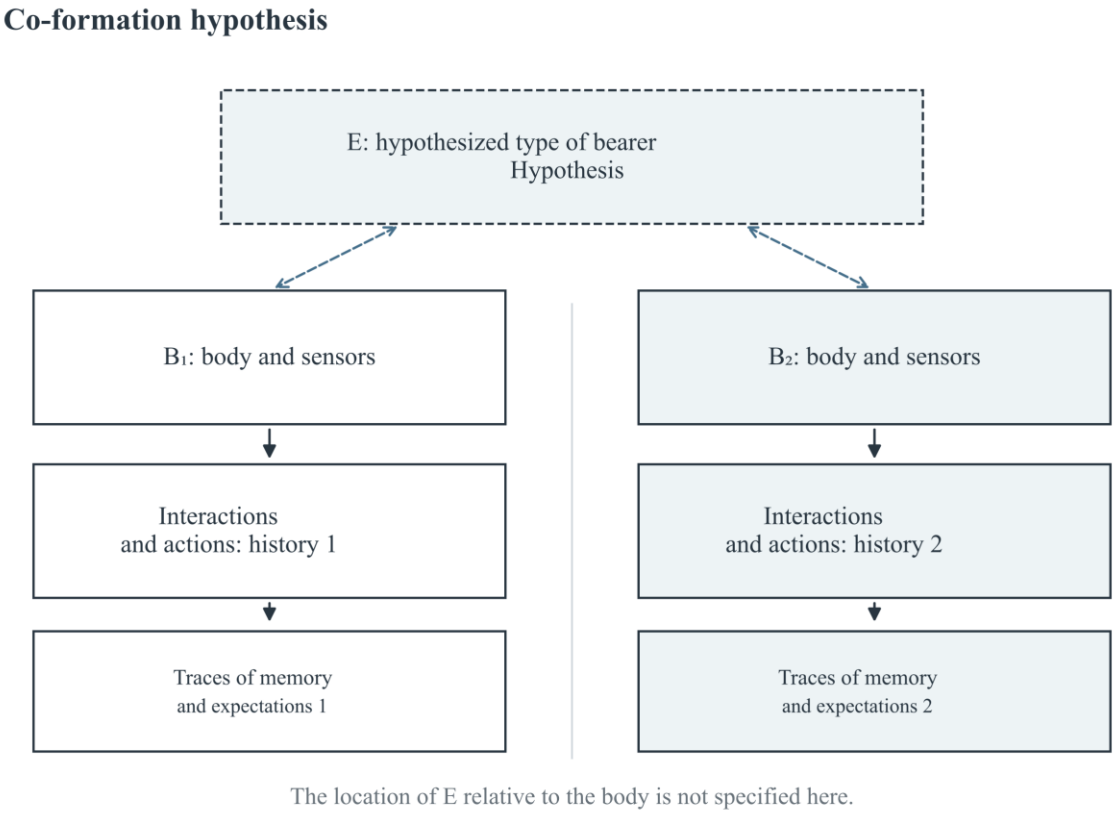


Figure 26. Co-formation hypothesis. A similar initial device and one intended type of media do not negate the differences that arise during interaction with the environment. The presence of E and its relation to experience are assumed here.

This assumption allows us to clarify the meaning of “primary consciousness”. The basis for the ability to experience can be considered primary, but not necessarily the ready-made human personality. The existence of a fundamental property and the presence of specific memories belong to different levels of explanation. The color sensitivity of the device does not contain an image of the city before the city appears in front of the lens. The analogy is limited, but it helps to separate the ability to receive content from the content itself.

The proposed hypothesis therefore includes the principle of historical certainty. Two systems with the same assumed basis may develop different perspectives due to different development paths. If one day it turns out that the history is stored partially outside the body, the principle will remain: the organization of recording and access is important, and not just the geometric arrangement of the trace. But the storage location will need to be set independently.

A border that works

The boundary of the subject cannot be determined by skin or distance alone. Physical processes pass through the surface of the body constantly. Light reaches the retina, sound changes the state of the auditory system,

food is included in the metabolism. At the same time, an external object does not become part of the personality whenever it causally affects it. A simple exchange of energy is not enough to explain belonging.

The organization of feedback is proposed as a working basis. Some states are used by the system to regulate its own existence: their consequences are returned to assessment, memory and the choice of further actions. Other states are present only as external conditions. The difference is determined by the role in the dynamics, and not by the presence of the “mine” label on an individual particle. This understanding allows for gradual and task-dependent boundaries of the functional system.

However, causation itself is too common. Weather, urban traffic and the electrical grid also form huge influence loops. Therefore, the hypothesis requires a narrower organization: selectively combining states into the perspective of one regulated participant, preserving accessible history, and distinguishing one's own actions from external changes. Their combination constitutes the proposed condition for individuation—the formation of a separate subject. It is not yet a generally accepted criterion of consciousness.

The proposed organization of these functional connections is shown in Figure 32 in Chapter Eighteen.

The possible carrier E is included in this condition through specific communication channels. If two systems receive common noise, their responses may be similar. But the common noise does not unite their memory and does not give one system access to the consequences of the action of another. Correlation does not yet create a joint perspective. Its physical model will require showing the actual integration of possibilities, and then separately justifying why this integration corresponds to a single experience.

History holds perspective

The moment does not have to store the entire biography in order to depend on it. The acquired skill changes today's action, even when the learning is not remembered. A familiar word is recognized without listing all the cases in which it was encountered. Therefore, personal history can be present in the current state in different ways: as an accessible story, as a skill, as an expectation, or as a changed sensitivity.

In the co-formation model, these forms of history have different roles. The story makes it possible to explicitly connect events in time. The skill changes choices without recalling the past in detail. Expectation distinguishes some future outcomes from others. None of these functions individually exhausts the personality. Their interaction makes the current perspective a continuation of a certain story, rather than a random response to the latest signal.

This implies a substantive limitation of the hypothesis. If the additional medium supports only transient states, it will not explain the persistence of biography without other mechanisms. If, on the contrary, it is declared to be the repository of the entire personality, it is necessary to show how the experience is recorded, how it maintains order and how it is returned to access. The same image of “connection” cannot simultaneously replace instant interaction, long-term memory and self-recognition.

One can imagine a mental situation: the system retains the regulation of the body and the ability to act, but loses access to part of the past. In the proposed version, the general resource of experience, if it exists, can remain the same, while the content of the personality changes. This possibility is consistent with the separation of foundation and history. It does not prove external media because neural models also allow for various memory impairments. To choose between them will require a more specific prediction about the mechanism of loss and recovery.

Self-reference without an internal spectator

In the expression “I see,” there seem to be two participants: the one who creates the image, and the one who looks at it from the inside. If we take this image literally, we will have to build a second mechanism of vision for the internal observer, then a third for the observer behind it. The explanation will never end. The interface hypothesis should not return the same difficulty under the guise of an external owner of the body.

Functional self-reference can be described differently. The system distinguishes between changes associated with its action and changes that arose independently of it. It takes into account its own limitations when evaluating possible actions, stores information about the reliability of its decisions, and corrects the forecast after receiving the result. The self-image then exists as part of control, rather than as a small person watching an internal screen.

Such a description still leaves the question of experience. It shows what work the self-representation does, but does not automatically explain why that work is felt. It is here that the author's hypothesis introduces an additional condition: a possible fundamental basis is associated with a system that integrates current states, past experiences and the consequences of one's own actions into an ongoing process of regulation. The physical mechanism must explain the availability of communication, and the psychophysical postulate must explain its relationship to individual experience.

The strength of this division is that there is no requirement to fit the entire personality into one specific detail. Neither a single molecule, nor a single network node, nor a selected quantum state is required to contain a ready-made “I”. Individuality refers to an organized process. Now we need to determine which changes preserve this process and which form another.

Without such a distinction, the concept of organization will remain too vague to test.

What should be preserved during changes?

Let us mentally replace one sensitive element in the system with a device that gives the same observed response. If the hypothesis depends only on functional relationships, the substitution should not destroy the intended perspective. If it requires a certain quantum mechanism, the coincidence of external responses may not be enough. Then you need to specify the property that the replacement does not preserve, and a way to detect its consequences.

This fork separates the two versions of the program. In the first, the additional carrier only implements the general functional organization; perhaps another physical mechanism can support the same organization. In the second, a certain type of interaction with E is a prerequisite for experience. The second version makes a more stringent requirement: it excludes some physically capable realizations from those capable of experience. Such a limitation requires a separate justification; mere similarity with a known quantum effect is not enough.

Testing does not have to begin with replacing parts of a living brain. The difference can be studied in models and physical analogues, examining whether the claimed causal properties are preserved. Particularly useful here are cases in which two implementations give the same normal output, but diverge under additional influence. This result first relates to the design of the mechanism. The transition to subjective continuity still depends on a psychophysical condition that cannot be hidden within an engineering description.

The hypothesis must also take into account the time scale. A connection that is too slow to unite a particular event may participate in the long-term setting, but not in its immediate organization. A fast process can influence immediate response without preserving history. The assertion of a single subject requires reconciling these scales. You cannot choose any convenient integration time after familiarizing yourself with the observations.

It is useful to distinguish between ongoing similarity and continuation of a process. Two devices may at some point contain the same records, although they arrived at them via different paths. If a theory defines personality only by a momentary state, it must accept the consequences associated with it. If the history of formation is significant, it will be necessary to indicate which differences in history are physically preserved and can participate in further experience. Referring to an invisible story that has no consequences does not add a testable condition.

On the other hand, the process can continue while changing a significant part of its details. A living organization is not a still snapshot. It is important for the model to define the relationships that are maintained: access to one's own traces, consistency of control, rules for updating the self-representation.

In the co-formation hypothesis, the stability of the individual is associated with such continuity of the organization. This is a conditional choice that must be weighed against competing criteria rather than being declared a final solution to the identity problem.

This gives rise to a specific direction of analysis. It is possible to build model systems with identical external responses, but different continuity of internal states, and find out which features reflect this difference. The result first concerns memory and control. It helps make the concept of continuation physically meaningful, although it does not yet allow direct comparison of subjective perspectives. This is how the abstract question of what remains the same gradually turns into several narrower questions of exploration.

Predictions about the shape of personality

Conditional expectations follow from the proposed scheme. First, given the same accessory medium, differences in bodily organization and history should alter the available content. Secondly, interference in the communication mechanism can act selectively: disrupt a certain aspect of experience, leaving other functions relatively intact. Third, changing the relationship between memory, self-esteem, and action can change the forms of self-awareness without completely eliminating the experience. These are the directions of predictions; for the experiment, each must be associated with a specific measurement.

These expectations have a serious competitor: many of them follow naturally from neural explanations. Therefore, the hypothesis does not benefit only from agreement with the dependence of personality on memory and body. It needs an additional effect that follows precisely from the intended connection. For example, a prespecified combination of carrier parameters and organismal state should predict a selective change that the comparative model does not reproduce under the same constraints.

If such an effect cannot be determined, co-formation remains a meaningful way of thinking about individuality, but not yet a distinct empirical theory. At this stage, the idea allows us to more accurately pose questions and eliminates several substitutions: deriving a ready-made biography from a common basis, equating correlation with a common subject, and considering complex reflection necessary for any experience.

The concrete “I” in this picture arises where the physical connection receives history, limitations and its own perspective of action. The body gives it definition; memory connects separated events; self-representation allows one to take oneself into account among the causes of what is happening. A possible fundamental basis does not negate this work. It becomes part of a larger explanation that is supposed to show how the general physical world allows for the existence of separate experiential worlds.

But history cannot be held together by a single assertion of continuity. She needs traces. If some of these traces are assumed to be outside the body, the next question can no longer be answered by describing the

personality. You will need the physics of recording, storing and reading memory.

Chapter 15

Memory on both sides of the border

There is an old photograph on the table. The person who pressed the camera button may no longer be there, but the photograph retains the distinction between what was in front of the lens and what was not there. It contains a trace of the event. If the photo is seen by another person, the trace will again affect the living system. However, it does not follow that the former observer continues to look through the photograph.

This simple example separates three things that can easily be confused: retention of information, retrieval of content, and continuation of subjective experience. The external memory trace hypothesis concerns primarily the first two. It assumes that some of the information that is significant for the body can be recorded in an additional medium and subsequently become available again. To discuss the third, we will have to add the conditions of identity and continuity; they are not included in the fact of storage itself.

Trace and memory

A physical trace can be called a difference in the state of a system caused by a previous event. For usable memory, one difference is not enough. It must be preserved long enough, remain distinguishable in the presence of interference, and participate in the reading process. In addition, the reading system must distinguish which content the received signal relates to. Without this, the unusual response does not yet become a memory.

Moreover, human memory is not limited to preserving arbitrary details of a microstate. It includes relationships between events, assessment of their significance, skills and methods for reconstructing content. Therefore, the theory of external storage must answer the question of what exactly is stored: a separate sensory feature, a sequence of events, rules of action, or an entire organization of personality. Different answers require different media capacities, different storage times, and different reading mechanisms.

The neural level cannot be considered optional. In an experiment by Xu Liu and colleagues, certain hippocampal neurons involved in the formation of a conditioned fear response were reactivated in mice. This activation caused corresponding freezing in a different context. The result links a specific cell population to the reproduction of an acquired response; it does not mean that it was possible to read a human biography from cells. [25]

These data pose a specific challenge to the interface hypothesis. Even if some information is stored additionally, it is necessary to explain why certain neural changes help reproduce it, while others interfere. A possible external trace does not negate the internal access device. But declaring neurons just a “key” is not enough: a key also has a structure, a mechanism of action, and verifiable constraints.

Three different storage architectures

The simplest version assumes regular internal memory. The E bearer, if it participates in the experience, does not keep a biography. The acquired content is preserved in biological changes, and the additional connection affects only the current organization of experience. This version is compatible with the hypothesis of a more fundamental basis of experience, but in itself does not allow us to expect the preservation of personality after the destruction of the organism.

The second version assumes shared memory. Some of the content or supporting data is stored outside the selected biological subsystem. Recovery requires both an external trace and an internal access state. This architecture is familiar from conventional computing devices, so the location of the storage outside the subsystem itself is not a sign of consciousness. Scientific novelty might lie in the discovery of a specific previously unknown mechanism in an organism.

The third version is much stronger: sufficient organization is preserved in the external medium to continue the individual perspective. This requires more than just an event archive. We need rules for their relationship, access to history, differences between this person and others, and a process that can continue. If the external system contains only information from which another organism can construct a similar story, the question of preserving the former subject remains open.

These versions cannot be combined into one formula: “everything is stored outside.” They give different forecasts when the internal access is damaged, the external media changes, and the connection between them is disrupted. In the first version, the loss of a biological trace should eliminate the possibility of recovery; in the second, information can be stored while remaining inaccessible; in the third, independent continuation of the process is assumed. Each subsequent version requires additional physical conditions.

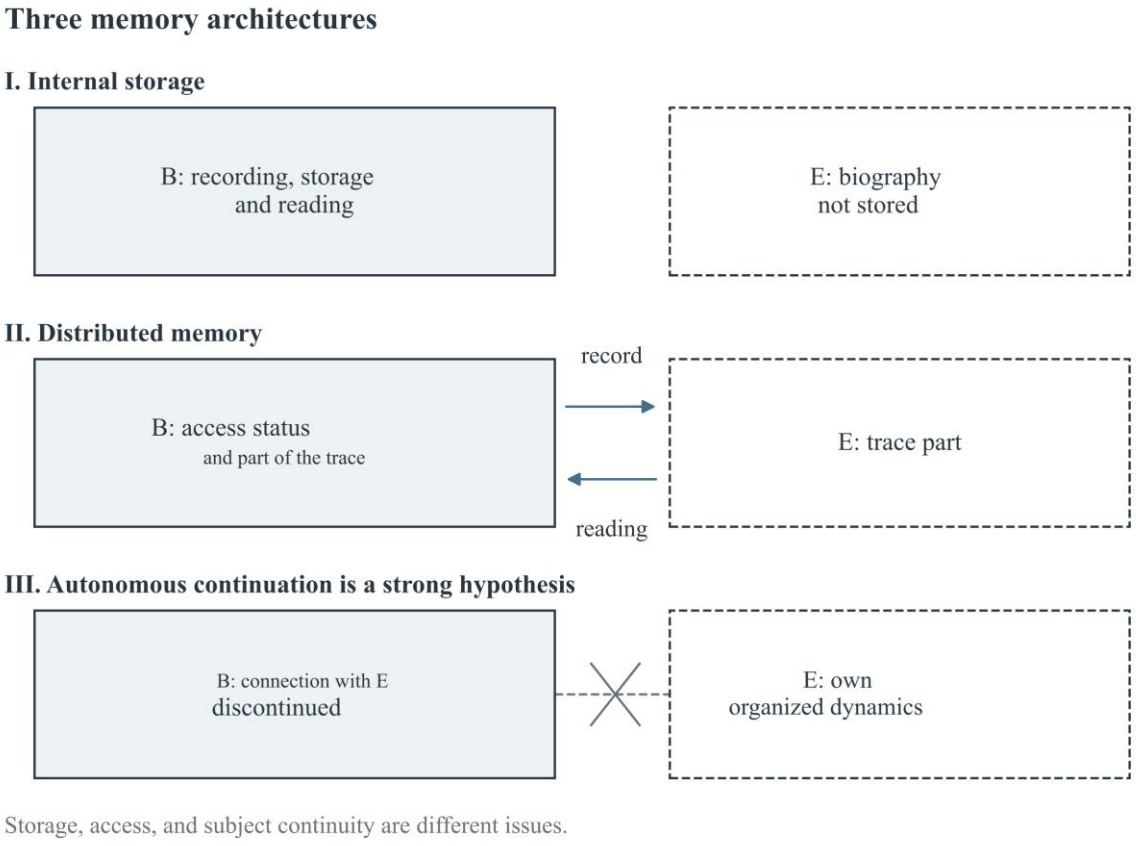


Figure 27. The three versions differ in storage location and access conditions. A trace external to B does not automatically mean a location outside the body; autonomous continuation requires additional assumptions.

The recording must leave consequences

Suppose an event M changes the state of the biological subsystem B. For an external trace to appear, this change must influence E through a certain interaction. This means that the direction of recording appears in the hypothesis. Later, state E must influence B so that reproduction depends on the earlier event. This is the reading direction. Constant interaction between two systems alone is not enough to prove that a memory with the desired properties has arisen.

The recording has limitations. Various events must leave sufficiently distinguishable traces. If a huge number of states of an organism are mapped to the same state E, it is impossible to reconstruct their differences without additional information. If the trace quickly becomes mixed with noise, reading becomes unreliable. If the method of addressing changes, information may be physically preserved, but no longer be accessible to a specific organism.

Addressing is especially important for the common carrier assumption. If it records events from many systems, a selective access mechanism is needed. A memory cannot simply be called “mine” in hindsight. The model must explain what features of the connection highlight the desired trace,

how confusion is prevented, and why new events do not destroy all previous records. The ability to share a physical environment does not relieve one from normal memory tasks.

Reading errors may be more informative than a single successful recovery. If the trace itself is damaged, one would expect errors to depend on time and storage conditions. If the address is violated, the content of another entry may be substituted. If the transformation of the signal into an available response changes, errors may retain some of the structure of the original content. These are conditional options for the model, and not a description of the already discovered human external memory. Their value is that they associate the suspected malfunction with a certain type of error.

It is especially important to distinguish inaccessibility from absence. A failed recall attempt does not, by itself, indicate whether the trace was destroyed, access was lost, or whether the record was not generated in the first place. In a model device, these cases can be separated by independently changing the storage and reading mechanism. For a living organism, such a division is usually much more difficult, so the conclusion about an external archive should not arise only from the fact of the unexpected restoration of content after a long break.

The reverse limitation is just as significant. Successful recovery from damage to one path does not mean that the information came from outside. They could be stored in another internal process or restored according to the remaining characteristics. The external trace hypothesis should show exactly which dependencies are not explained by these possibilities. Its advantage is determined by the content of the prediction, and not by the emotional persuasiveness of the returned memory.

In this case, the external media may turn out to be quite ordinary. The system is capable of leaving traces in the environment and subsequently receiving them again through the senses. To claim a special mechanism, you need to separate it from such paths. Otherwise, the detection of external storage will be reduced to the well-known fact that the world changes after interaction with the organism. A new hypothesis requires a specific channel, not just a long-lasting trace.

The Limits of Quantum Copying

If the medium is declared quantum, the usual image of backup needs to be clarified. The No-Cloning Theorem states that it is impossible to create a universal device that perfectly copies an arbitrary unknown quantum state. Wutters and Zurek showed the connection of this limitation with the linearity of quantum evolution. The prohibition does not apply to the ordinary copying of distinguishable classical records, nor does it prohibit the transfer of state from one system to another. [24]

Therefore, the hypothesis needs to clarify what exactly is supposed to be preserved. If we are talking about a classical description of events, it is not necessary to refer to quantum copy protection. If unknown quantum states

are significant for a person, it is impossible to simultaneously promise their exact copy, preservation of the original, and free repeated reading without justification. The physical limitations of the chosen medium become part of the theory of personality, and not a decorative addition to it.

Transfer is also not equal to the continuation of the subject. Quantum state can be transferred between laboratory systems containing no biography or self-representation. Consciousness requires an explanation of the role the transferred state plays in the stable organization of experience. If it only regulates the probability of a single event, its preservation does not yet ensure the preservation of the entire personality. If it encodes much more, this must follow from the capacity and access model.

Reading becomes a separate problem. A single measurement result usually does not provide a complete description of an unknown quantum state. Therefore, the image of an external library from which the exact internal states of all people can be read without restrictions requires special justification. Possible storage methods differ in what content is available to one reader and how the act of reading itself changes the medium. [14]

An Experiment with Controlled Memory

For the first check of the external trace, it is reasonable to consider a model device where the boundaries of the subsystems are specified by the design. Let it receive a randomly selected sequence during recording. The available internal records of B are then moved to a predetermined state, and the state of E is either saved or independently modified. After communication is restored, it is examined whether the device's response depends on the original sequence.

The input sequence is chosen randomly; until the assessment is completed, it is known to the experimenter, but hidden from those who analyze the responses. If a device plays a frequently occurring story, it is difficult to rule out learning from similar data. If it reconstructs pre-selected random differences, the question becomes quantitative. You can compare the proportion of correct answers, the structure of errors, and the dependence of accuracy on storage time.

But even this result does not automatically select the desired media. Residual memory may remain in power, controller, temperature, hardware log, or the normal R environment. The test must be designed so that the availability of each known channel has predictable consequences. A change in E should be distinguished from general damage to the device. Otherwise, the disappearance of the result after the intervention will only show that the intervention is interfering with something.

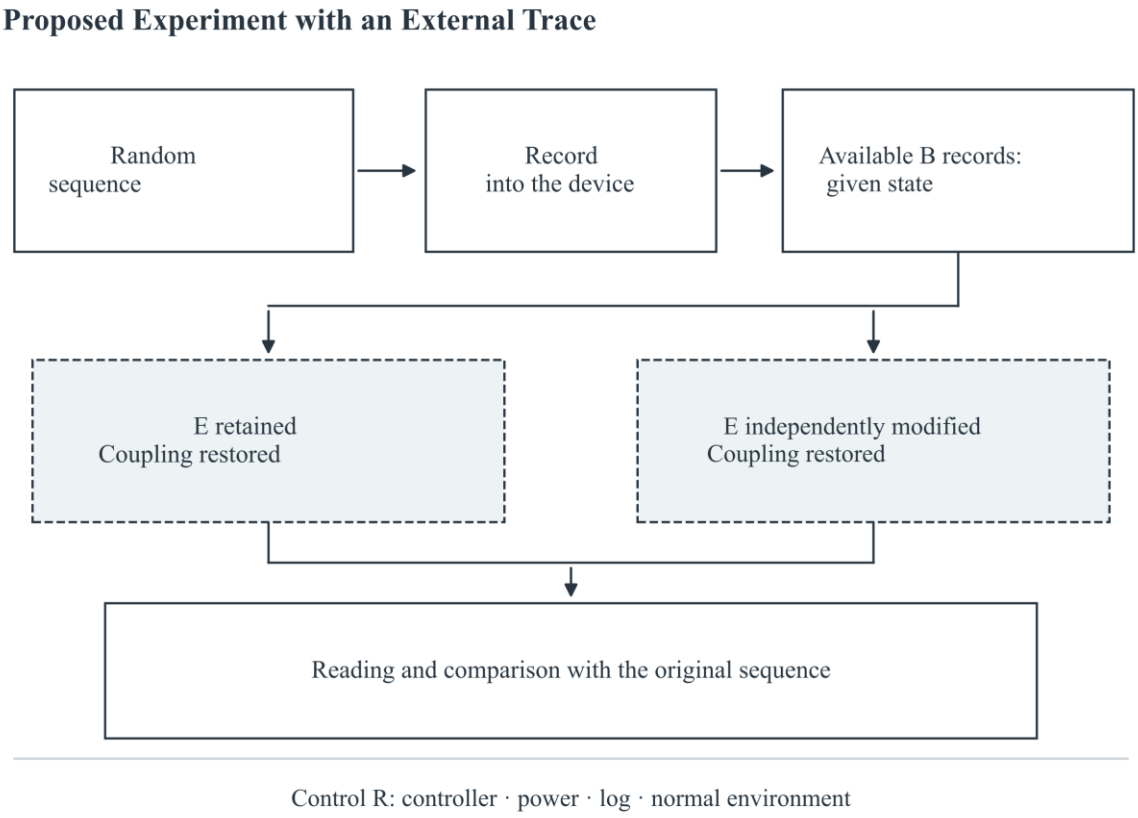


Figure 28. Proposed verification of the external trace in a model device. The retention and change of E are compared while monitoring the available entries B and the normal channels R. The figure does not depict the experiment performed.

Strong evidence would be to fit multiple dependencies into a single model: trace retention time, capacity limit, addressing mode, and predictable read failure. This is more than the unexpected recovery of one fragment. The mechanism must explain both successful responses and the nature of errors. At this level, research concerns the physics of memory; the transfer to human autobiography will require self-verification.

Why recognition does not yet solve the question of identity

Let us mentally assume that the device accurately restores previously unknown information about a person’s life. Even such a strong result will first establish access to information. Then you will have to find out where it came from and why it belongs to this particular source. Only after this will the question arise whether the restoration is accompanied by a continuation of the previous perspective or the emergence of a new system that has the same information.

The difference becomes noticeable in the case of two copies. Let two systems receive the same biographical record and both confidently claim to be its owner. The similarity of the answers does not allow one of them to automatically exclude the other. Continuity theories require additional conditions: a specific causal history, the conservation of a certain process, or

some other connection that can be clearly formulated. It is impossible to deduce the only successor from the coincidence of stories.

This limitation also applies to conventional memory technologies. An archive can outlive its creator, and a program trained on it can reproduce a speech style. The usefulness of such systems does not depend on their acceptance by the same person. If a claim is made about the continuation of subjective life, the criterion must be stricter than the accuracy of the reproduction of texts or the recognition of character. Information similarity and personal continuity solve different problems.

The author's external trace hypothesis therefore leaves several outcomes open. Additional storage may not be available. It may exist, but support only a narrow physical process. It can participate in memory access while remaining completely dependent on the body. Finally, it is possible to explore a stronger version of the external continuation of the personality organization - provided that additional mechanisms and methods for their verification are named for it.

The photograph on the table continues to exist. She reminds us that information can indeed cross the boundaries of time and the individual organism. But to turn a trace into a memory, a reading process is needed. To turn a memory into a part of personality, you need to organize the story. And in order to talk about the continuation of the experience, it is necessary to understand what exactly makes this organization one and the same participant in what is happening.

This organization does not exist separately from the ways of perception and action. Therefore, the question of memory leads to the structure of the body: what signals it makes available, what actions it allows, and how the content of personal experience is formed through them.

Chapter 16

The body as a condition of concrete experience

In the imagination, an avatar often looks like a changeable costume. The subject remains himself, and the shell only determines what external appearance he takes. However, the human body sets much more than the form of presence. It determines available signals, possible actions, speed of reaction, needs and ways of changing the environment. If we assume a more fundamental basis for consciousness, these limitations do not disappear. It is through them that the supposed basis receives specific content.

The body in the selective interface hypothesis is therefore not treated as a random container. It participates in the formation of perspective. The organism does not simply miss a ready-made picture of the world, but constantly selects which differences are important for its existence. To explain human consciousness through external connection, one will have to show how this connection becomes the sight, movement, hunger, expectation and personal history of just such a body.

An avatar that changes its owner

Imagine a system with access to only two distances: to the obstacle ahead and to the surface below it. For such a system, the action space is arranged differently than for a device that distinguishes color, shape and movement over a large distance. The same external events provide different opportunities. A step may be an immediate fall hazard, a route marker, or may not be in the available description at all.

If experience is assumed in both systems, its content cannot be considered the same just because the physical world around is common. There is a distinction between what can appear in experience and what the system is able to do in response. The body defines a set of interactions, and the interactions create meanings. An additional carrier must be included in this structure, otherwise it will remain an abstract cause that does not explain the features of a specific experience.

Even changing one channel can restructure the task. A device with delayed feedback cannot control movement as well as a device with fast response. A system with a wide field of available signals allocates resources differently than a system with a narrow one. In such mental models, the differences result from control constraints. They need not be called qualia distinctions in advance; they show what physical conditions a potential experiment must take into account.

This is where the author’s principle of bodily certainty arises. According to the common ground hypothesis, differently constituted bodies can produce different forms of subjectivity. This assumption does not require a

priori attribution of experience to each sensor. It asserts a conditional dependence: if an experience occurs through organized interaction, the participant's device must influence the available content. A completely body-independent ready-made stream of experience would require a different model of communication.

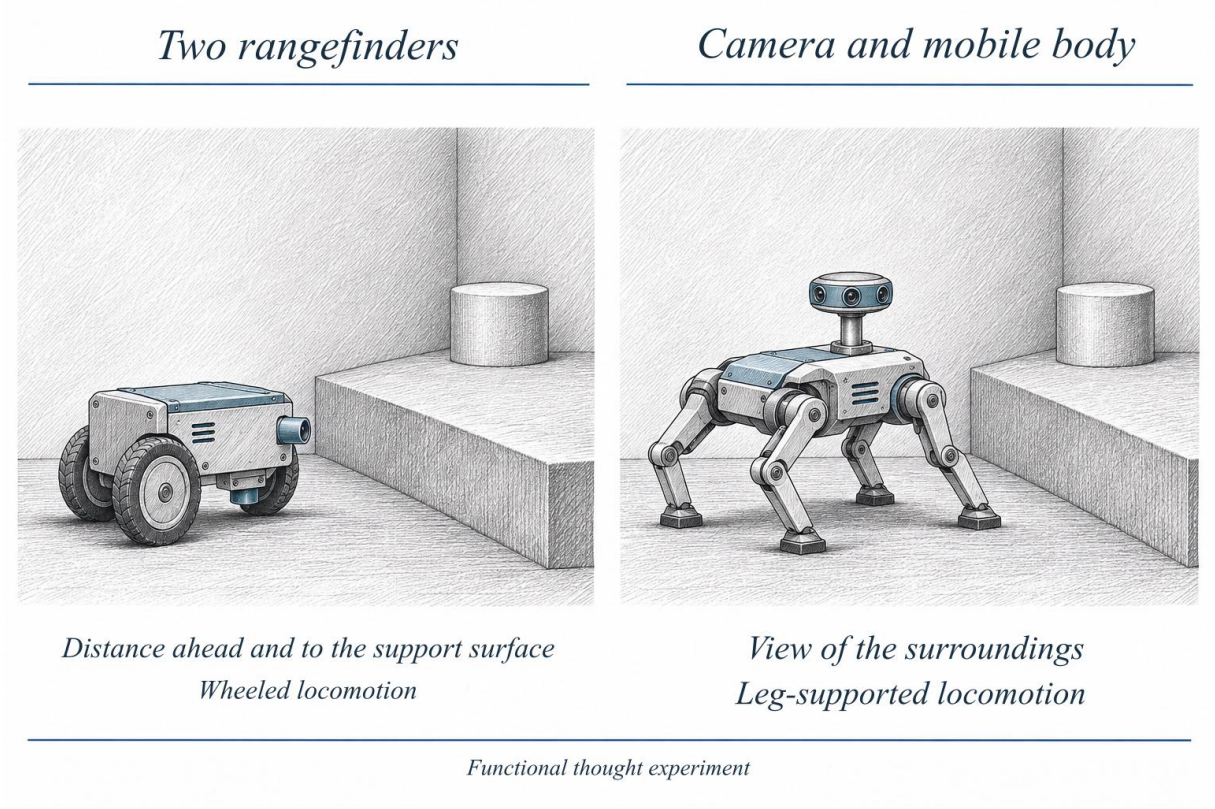


Figure 29. One world sets different tasks for systems with different sensors and action capabilities. On the left, the conditional device has access to the distances ahead and to the support; on the right is an overview of the stage and movement based on the legs. This is an example of the differences in available information and control; the presence of subjective experience does not follow from it.

Signals from within

The body receives information not only about the outside world, but also about its own condition. Interoception refers to the perception of internal bodily signals. The work of A. D. Craig describes the neuroanatomical system for representing the physiological state of the body and discusses its role in the formation of feelings and self-awareness. This is a scientific interpretation of the connection between bodily regulation and subjectivity; it does not establish that a single center of personality has been found. [26]

For the interface hypothesis, internal signals are especially important. They define the difference between an external event and its significance for a particular organism. The same smell, path or sound can have different meanings depending on the current state. To explain the experienced world, it is not enough to reconstruct the external picture. It is necessary to take

into account what is happening to the participant in this picture and what consequences are expected for him.

Here it is easy to confuse physiological need with experienced value. A technical device can maintain temperature and charge without having an established ability to experience discomfort. The thermostat reacts to the deviation, but the reaction does not yet serve as proof of the sensation. Therefore, the presence of regulation is considered in this book as a possible part of the organization of the subject, and not as an independent universal test of consciousness.

However, the opposite extreme does not help much either. If value is completely separated from the design of the system, it remains unclear why some states are experienced as requiring change and others as desirable. The author's hypothesis assumes that an individual perspective is formed along with the limitations of one's own existence. This line of explanation must link physical regulation, accessible history, and experienced significance without substituting one for the other.

Shape of the accessible world

The body creates not only needs, but also scale. For a small mobile system, some obstacles become significant, for a large one - others. The speed of events also matters in relation to the capabilities of perception and action. If the mechanism is too slow, a short change does not have time to influence the choice; if too quickly and without keeping track, the event may not connect to subsequent actions.

Therefore, a theory of consciousness that claims to explain different organisms must take into account several temporal levels. There are rapid physical transitions, slower biological consequences, and an even longer learning history. A quantum process, if it is functionally important, must enter into a consistent chain of these scales. Its own speed does not establish the speed of subjective time and does not tell how many experiences occur in a second.

Equally important is the connection between perception and action. A system that can change the position of the sensor gains capabilities that are not available to a stationary recorder. It is able to check an ambiguous signal, return to the object and compare the expected result with the received one. Such activity does not prove experience, but makes the hypothesis of a separate perspective more meaningful: the accessible world is built through real opportunities to explore it.

The avatar image in this version signifies a special way of participation. Different bodies may open up different areas of interaction, even if they share the same supposed basis of experience. To talk about the experience of another system, one must first understand its accessible differences. Human words about color, fear, or intention should not automatically transfer to any mechanism that exhibits a superficially similar response.

The means of action may extend beyond the anatomical boundaries of the body. An object in the hand changes the available distance; the notebook saves information that is not in the current attention; an external sensor expands the range of measurable differences. When analyzing a specific task, such tools can be included in a broader functional system. But the decision to include an object in the model does not mean that the object has an experiential side or that the boundary of the subject has automatically moved.

This clarification protects the concept of external contribution from being overextended. Any organism depends on its environment. Therefore, the dependence of conscious behavior on an external device does not prove a special carrier E: it can completely pass through ordinary channels R. To justify an additional quantum connection, it is necessary to highlight a property that is not reduced to the arrival of ordinary sensory information and a change in the possibilities of action.

At the same time, functional expansion provides a useful development model. One can explore how access to new signals restructures choice rules and the representation of one's own capabilities. Then the body is understood not as a set of unchanging parts, but as a system of accessible interactions with specific physical limitations. If the putative subject persists through such expansion, the theory must explain what relationships ensure continuity and why new abilities become part of that particular history. These questions arise regardless of whether the additional media is confirmed.

A connection that develops

The design of the interface may depend on the development history. As a working model, one can imagine a system that first maintains a few simple regulatory relationships, then associates them with memory, and later begins to take into account its own errors and limitations. At each stage, new ways of combining events are added. In such a model, developed reflection appears as a special function; it does not have to be present at every possible form of experience.

This allows you to separate multiple transitions. The emergence of sensitivity to the signal is one transition. Sustainable use of the consequences of actions is another. Imagining oneself in time is the third. A linguistic story about one’s own thoughts is another one. The hypothesis must explain the relationship between them, without declaring them to be one instantaneous birth of consciousness. Otherwise, the distinctions between reaction, memory, self-representation and experience are lost in the debate about what to call consciousness.

If interaction with E is truly necessary, development must change some of the physical conditions under which this connection operates. Perhaps a certain organization of sensitive structures arises, relaxation times change, or ways to enhance a weak effect appear. Such assumptions can be

compared with a version where all changes are explained by neural organization without an additional carrier. But age or complexity alone does not indicate which mechanism is correct.

Particularly strong would be the prediction of a transition associated with a measured physical parameter and a predetermined function. For example, the model might expect sensitivity to change when a particular interaction structure appears. Here it is impossible to assign a person or an animal the moment of occurrence of an experience according to an arbitrary number. First, it is necessary to confirm the mechanism itself and the boundaries of its connection with the observed abilities.

Another physical implementation

The question of an artificial subject depends on what is considered obligatory in the hypothesis. If the organization of relations is decisive, different physical ways of its implementation are allowed. Then the biological body represents one of the possible options. If a specific quantum carrier is needed, simulating its equations on a conventional computer can reproduce predictions without creating the required physical process itself.

This difference is familiar from other models. Numerical calculation of fluid movement does not make the processor wet. But the impossibility of digital consciousness cannot be immediately deduced from this analogy: one must first know what physical properties are essential for the experience. If they are in a functional relationship, the simulation can implement part of the required organization. If certain material dynamics are significant, the coincidence of the calculated outputs will be insufficient.

The selective interface hypothesis leaves both possibilities open until the criterion appears. In its strong physical version, the artificial system must have a real channel of interaction with E, as well as an organization of memory, self-reference and action. In a more general version, an additional resource can be substituted if a causally significant relationship holds. These options cannot be mixed: they answer differently the question of what should be built and what should be measured.

The virtual body also requires a clear status. The program can obtain information about virtual position, resources, and damage. These variables may control its behavior, but the names themselves do not establish the pain or need experienced. It is useful for research to analyze how such a body model changes memory, predictions and decisions. The assertion about the subjective side will require an additional basis, equally strict for biological and artificial systems.

Who is included in the scope of the hypothesis?

If one seeks only the human self-narrative, most potential forms of experience will remain unexamined. If any reaction is considered consciousness, the concept will lose its distinctive power. Between these extremes lies the task of describing what abilities and physical conditions

are actually required by the chosen theory. For different systems, these conditions may be met partially, to varying degrees, or through different mechanisms.

In the proposed program, it makes sense to distinguish between the possibility of experiencing, the ability to imagine oneself and developed reflection. The absence of the latter does not automatically exclude the former. But the presence of a complex answer also does not give the right to consider the first one established. For each class of system, suitable observable features, methods of comparison, and analysis of possible alternatives will be needed. One test of speech or self-recognition cannot address all three issues without justification.

The relationship between experience, self-awareness and reflection is shown in Figure 1.

Biological affiliation does not replace a physical explanation. If a hypothesis connects consciousness with a certain organization, it must explain why this organization is possible in some organisms and insufficient in others. If it associates it with a specific carrier, the prevalence and functional role of the carrier needs to be investigated. The presence of a molecule in almost all cells does not in itself mean that all cells implement the same process of experience.

For artificial systems, a symmetrical requirement applies. The absence of cells is not an automatic refutation as long as biological exceptionalism is not inferred from the model. However, the possibility of implementation is not equal to its actual implementation. Between a program that describes itself, a physical system with a certain internal organization, and a subject with an experience, there remain differences that research must clarify rather than eliminate by definitions.

Thus the body returns to the center of even a theory that admits a more fundamental basis of consciousness. It sets limits, history, modes of action and areas of accessible content. A possible external contribution becomes an explanation only when it shows how it passes through these conditions. The next step is to take the program out of the realm of general requirements: it is necessary to construct a study in which the communication device will produce predeterminable results.

Part five

What can an experiment solve?

Chapter 17

An Experiment That Distinguishes Explanations

The researcher faces two curves. Both describe the data already obtained quite well. The first is built with an additional carrier E, the second - without it, but with a more detailed account of the usual environment. If we evaluate only the similarity to known points, the question of the nature of the mechanism may remain unresolved. What is required is a situation in which the models make different predictions in advance.

This is the task of the decisive experiment for the interface hypothesis. It must test a specific connection, not the general possibility of a deeper reality. The hypothesis has specific parameters, a range of applicability, and an observable value. Then a negative result can exclude the selected version, and a positive result can provide grounds for continuing the study. Both outcomes only make sense relative to a clearly formulated model.

Statement with address

The sentence “quantum processes are involved in consciousness” is too broad for a single experiment. Almost any living substance is fundamentally subject to quantum physics. The scientific question begins with clarification: what condition, what mechanism, what function, and what observable effect are hypothesized? Without such an address, the outcome is easy to explain after the event, but difficult to predict before it.

The working version may sound more limited: certain B and E states interact with the measured coupling frequency, and changing the detuning between them changes the probability of a particular transition. This transition, in turn, influences the selected biological process. There is still no complete explanation of consciousness, but there is a sequence of statements, each of which can turn out to be incorrect.

A good place to start is to examine the weakest link in the chain. If an interaction does not exist within the stated range, a debate about its role in personality is premature. If a physical effect is found but does not affect the biological function, the program stops at another level. If a function is found, but it is not related to available measures of conscious state, what remains is a real mechanism without a claimed explanatory role.

This division helps to focus resources and accurately interpret the result. Successful spectroscopy does not translate into evidence of an external

entity. An unsuccessful search for one carrier does not disprove all possible theories of consciousness. The study answers the question that is actually posed by its device. Its power is determined by the precision of this question.

Two devices and one forecast

Let's return to the small model of coupled transitions. Its parameters can first be studied in a physical analogue, without attributing experiences to it. It is required to determine the frequencies of the subsystems and the strength of the connection, then predict the dependence of the transfer on time and detuning. It is essential that the forecast be tested under conditions for which data were not used when selecting parameters. Otherwise, reproducing observations will be a test of the flexibility of the description rather than its predictive power.

In the ideal formula of chapter 13, the amplitude and frequency of oscillations are related by the same parameters. It is not possible to independently adjust the amplitude for one measurement and the frequency for another without maintaining the appearance of a single mechanism. This connection between observable quantities is a useful advantage of the model. The disagreement of one dependence with another indicates the insufficiency of the assumptions, even if each individually allows for a beautiful approximation.

For comparison, you will need a classic model with reasonable capabilities. Coupled oscillators, noise, and nonlinear transformations are capable of producing many response shapes. If a complementary model allows environmental memory, a similar capability cannot be unreasonably taken away from a competitor. Otherwise, the advantage will be a consequence of the rules of comparison, and not a property of nature. The opponent must describe real alternative reasons, and not a deliberately weakened caricature.

The result of the comparison may be modest: both models predict the selected data set equally well. This means insufficient discernibility in this particular experiment. The next step is to look for another intervention or additional observable. If there is no such distinction in principle, empirical choice between these descriptions at an accessible level is impossible. It should then be made clear how much of the disagreement remains interpretive.

Ambiguity also arises within a single model. An equally small response may arise due to a weak connection, large detuning, or rapid destruction of the desired state. If only the average amplitude is measured, these causes are sometimes difficult to separate. Then adding a parameter does not necessarily make the explanation more precise: it may increase the number of interchangeable options. Independent measurement of frequencies or relaxation times reduces this ambiguity.

A useful strategy is to predict different observations with the same quantities. The parameter estimated from the spectrum must participate in

the calculation of the time response; the noise parameter obtained independently should limit the permissible visibility of the effect. If each observation requires its own new coefficient, the model gradually loses the connection between the phenomena being explained. In this case, it is worth simplifying the statement or recognizing that the suspected common cause has not yet been established.

At this stage, a negative result can also be local. The model is able to correctly describe the physical analogue and is not transferable to biological conditions, where significant scales have changed or additional processes have appeared. Then it is this transfer that needs to be investigated. The success of a model on a small system cannot be considered proof of the operation of the same mechanism in the body, just as one cannot ignore an analogue just because it itself is not alive. In such a comparison it is necessary to establish what essential physical conditions are preserved.

How to isolate a quantum property

Temporal fluctuations and resonance do not yet highlight quantum dynamics. To do this, the measurement must relate to the property on which the hypothesis is based: for example, a certain coherence, incompatible measurements, or entanglement of selected subsystems. The specific criterion depends on the design of the system and assumptions about the preparation of states. There is no universal picture according to which any unusual signal can be recognized as quantum. [14]

If coherent coupling is claimed, it is useful to compare conditions in which the level populations are maintained, but the relative phase changes. The predicted sensitivity to such change may separate the phase mechanism from simple energy transfer. But here, too, an analysis of alternatives is necessary: an effect designed to change the phase can simultaneously change the temperature, chemical conditions or registration efficiency. Selectivity of intervention must be part of the evidence.

If entanglement is claimed, observing correlated oscillations is not sufficient. One test is the entanglement witness: a measurable quantity for which a limit is predetermined and respected by all separable states. Exceeding this limit while meeting the test conditions indicates entanglement. If the limit is not violated, entanglement is not yet ruled out: a particular witness may not detect some entangled states. [31]

Whatever test is chosen, it must take into account the actual measurements available and the connections between the parts of the device. A common external influence can create correlated signals without the desired quantum property. Therefore, the conclusion depends on the fulfillment of the test conditions, and not only on the external similarity of the recorded vibrations.

This result establishes a quantum property only for the studied degrees of freedom. From the correlation of two elements one cannot infer the unification of two personalities or the transmission of a message without a

channel. For the interface hypothesis, the result is valuable as evidence of the presence of a physical resource. It is now necessary to determine whether this resource is involved in biological function.

From mechanism to function

Let's assume the resource is found. Now we need to find out whether the selected biological process changes through it. Simple joint change is not enough: one impact can simultaneously change several systems. A useful program compares interventions with different side effects but the same predicted effect on the intended link. Consistency of such results helps to separate the mechanism of interest from random accompaniment.

The path of influence is especially important. If the hypothesis involves a change in molecular transition, then cellular response, then accessible behavior, the intermediate quantities must change in accordance with this sequence. This does not mean that the entire causal chain must be simple and linear. Feedbacks are acceptable, but they are included in the model in advance. The phrase “complex system” should not serve as a license to any direction of causation.

Statistical comparisons here require caution. If brain activity mediates the expected effect, statistically eliminating its contribution may also remove the effect under study. If the common cause affects both the carrier and the brain, failure to take it into account will create a false connection. Therefore, the choice of variables is determined by the causal scheme, and not by the desire to obtain a convenient coefficient after automatic processing.

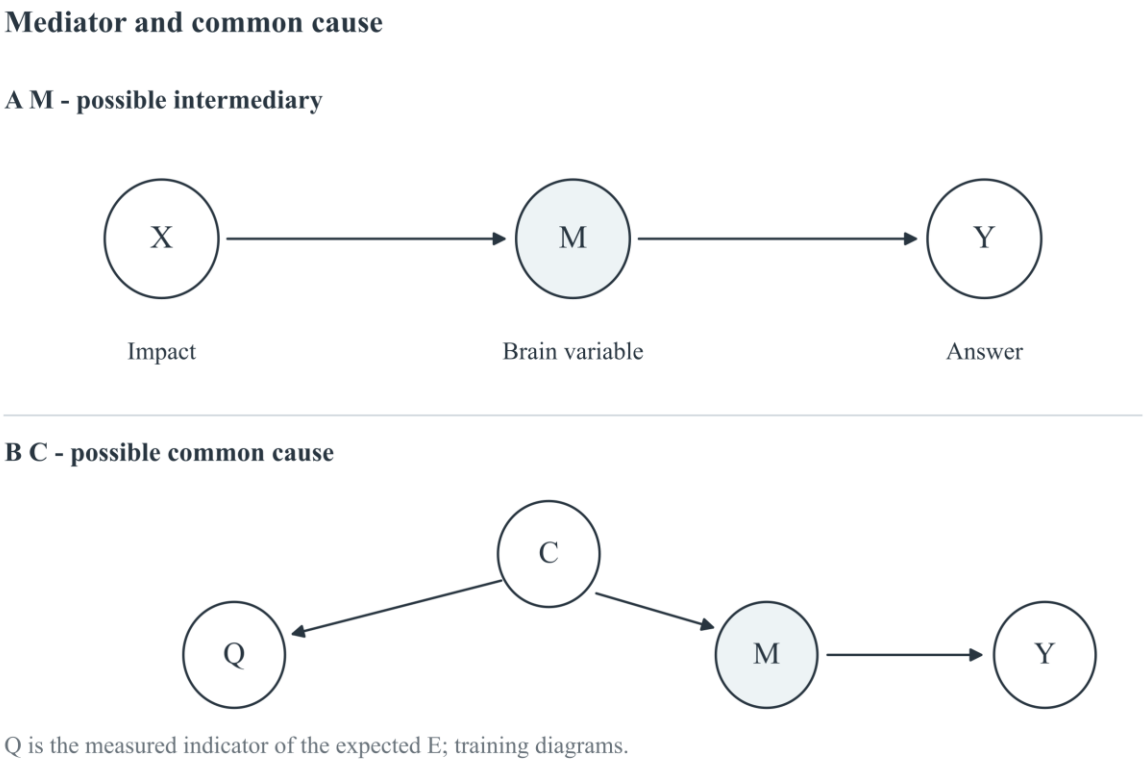


Figure 30. Two different causal roles of a variable. Statistical exclusion of the contribution of a mediator may obscure the influence path under investigation, and omitting a common cause may create a spurious association. The choice of analysis depends on the sound causal model.

At the human level, one will have to distinguish between the waking state, the content of experience, memory and the ability to respond. One change in an indicator does not allow us to conclude without additional data that everything else has changed. The study must consider how the available report is generated and what alternative causes change it. Interventions in the functioning of a living organism require professional research training; the logic of inference is considered here, and not a set of independent physiological procedures.

The forecast must survive new data

The model parameters have uncertainty. If the communication frequency is only approximately known, the prediction should not be depicted as a single perfect line. What is important is the range of expected results and how it changes with acceptable parameter values. A range that is too wide may formally include almost any observation, but then the model tells little about future experiment.

It is convenient to separate the data on which the structure of the model is clarified, and the data on which its prediction is checked. However, the separation itself does not protect against hidden adjustment if, after each failure, the selection rules, the observed value, or the acceptable carrier change. Changing the hypothesis is acceptable and often necessary, but the

new version must receive new independent testing. The old check does not become successful retroactively.

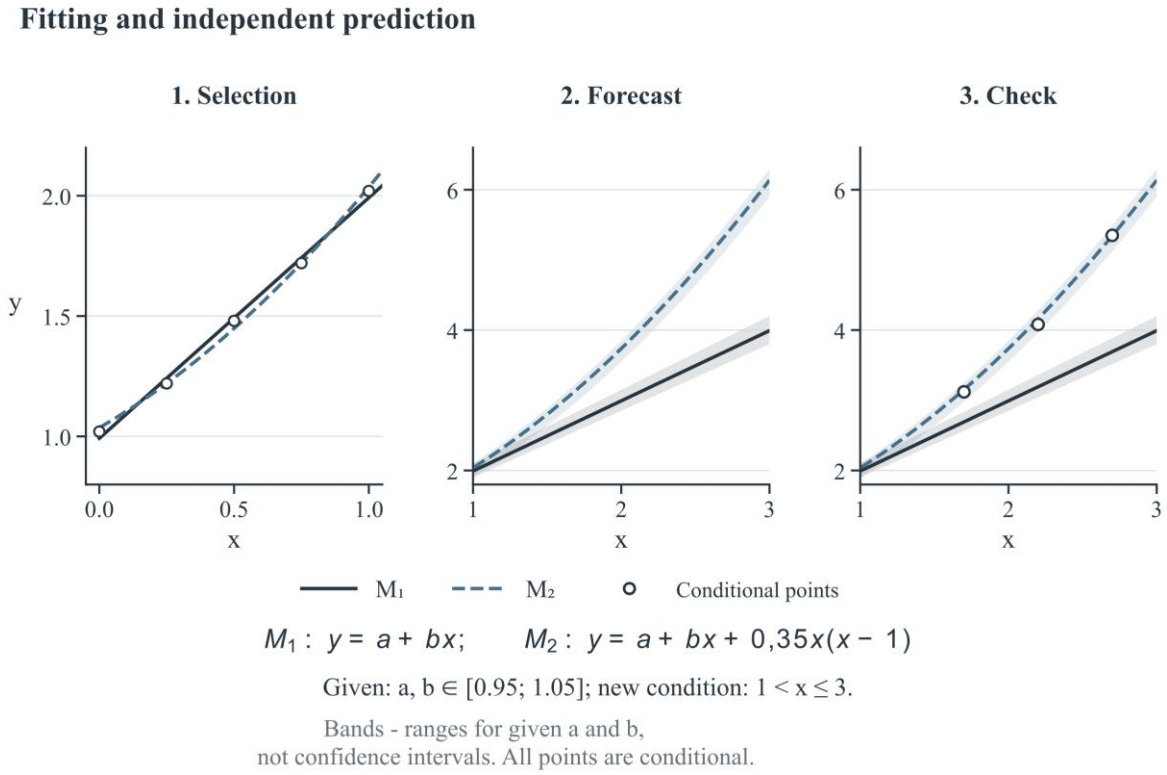


Figure 31. A conditional example of independent verification of two mathematical models. The bars show ranges of predictions given a, b ∈ [0.95; 1.05], rather than confidence intervals. All points are educational; verification observations are not involved in the selection of parameters and comparison conditions.

The Cogitate study used pre-consensus predictions to compare different theories of consciousness. The very principle of such comparison is useful for the author's program: to identify discrepancies before the result becomes known. [1] This does not require any registered model to be considered correct. On the contrary, predetermined expectations make it possible to more accurately see which parts of the program failed the test.

Predictive accuracy must also be evaluated along with complexity. A model with more free parameters can better describe familiar data simply because it has more power. More convincing is an advantage that persists under new conditions and does not disappear after taking into account uncertainty. Sometimes a more complex version is truly necessary; then its additional elements must provide measurable explanatory benefit.

What does a negative result mean?

The absence of an expected effect has different meanings for different measurement possibilities. If the instrument does not discriminate between the quantities predicted by the model, experiment does not test its key

assertion. If the sensitivity is sufficient and the conditions meet the assumptions, a negative result limits the parameters or rejects the implementation. Therefore, the detection threshold must be compared with the prediction before interpretation begins.

It is also important to explore the area of conditions rather than rely on one point. In the excitation exchange model, a small probability at a particular moment can arise even with a strong connection: the system could go through part of the cycle and return. Therefore, one low measured value does not automatically provide an upper bound on the interaction force. The time dependence and spectral structure help distinguish the lack of communication from the inopportune moment of observation.

A more meaningful limitation occurs when the predicted effect is absent across the entire preselected range where the model promises a detectable response. Then it is impossible to maintain the previous version by simply transferring the effect to an area not yet measured without a new basis. You can propose a different model, but this will be a change in the program, not a confirmation of the original one. The scientific value of a negative result lies precisely in the narrowing of acceptable explanations.

If the additional carrier cannot be described at all in such a way as to indicate such a range, the physical hypothesis is not yet ready for decisive experiment. This condition can be recognized directly and the model can be worked on. The lack of certainty should not become a privilege that allows an idea to escape any scrutiny.

What would significant success look like?

A strong positive result would present a consistent picture. The additional carrier or specific resource is discernible regardless of the desired psychological output. Its parameters predict the body's response. Changing the inferred connection changes this response in a particular way. Alternative models with comparable capabilities give worse forecasts on new data. Reproducibility is not dependent on a single instrument, a single group, or a single analysis method.

Even such success would not yet tell us where the experience “is.” It would establish a new causally significant participant in the processes associated with consciousness. A stronger fundamental statement would require an explanation of the relation of physical organization to the subjective side. But after such a result, this question would already be based on a new mechanism, and not just on an attractive analogy.

Thus the interface hypothesis becomes a research program with discernible outcomes. It may lose its intended physical basis, be narrowed down to a biological effect, become part of a broader neural model, or lead to the discovery of an additional interaction. None of these outcomes are determined by the title of the book. The predicted differences and the results of independent testing are critical. One way to carry out such tests is to

study artificial systems in which the structure of memory, feedback and action is specified explicitly.

Chapter 18

An Artificial Subject and the Mira Project

Two artificial systems can say the same phrase: “I remember being wrong.” The first phrase behind this phrase contains a record of a previous event, a modified assessment of one’s own capabilities and a new choice rule. The second one has only a successful continuation of the conversation. As long as observation is limited to the screen, the difference is easy to miss. It is discovered when previous experience begins to influence new decisions, including contrary to the desire of the interlocutor to hear a certain answer.

For the study of consciousness, an artificial system is valuable precisely because of the accessibility of its device. You can separately change memory, feedback, learning methods and ideas about your own states. You can compare implementations that are similar in appearance, but are structured differently. This approach does not provide direct access to the experience of the machine. It allows us to more accurately determine what mechanisms are necessary for those abilities that a person has adjacent to conscious experience.

This chapter examines the Mira project through its proposed architecture and how it can be evaluated. The solutions described define the research setting; they are not presented as an already performed experiment or proof of the qualia of a particular program. The scientific content of the project is determined by the causal relationships within the system and the results of their verification.

Self-story and self-model

Self-introduction can begin with a very humble function. The system distinguishes between changes in the environment and the consequences of its own actions. If the camera is turned, the image shift does not necessarily mean the world is moving. If its own resource has changed, deterioration in task performance does not necessarily mean the emergence of a new external pattern. For a correct conclusion, it is necessary to take into account the observation device itself.

Such a model does not have to contain a name or biography. It can be distributed between opportunity assessment, sensor position, action history, and anticipation of available consequences. Its functional value is manifested in error correction. A system that attributes every failure to the outside world will change the incorrect part of the explanation and repeat the failed action.

The proposed architecture of Mira involves distinguishing between the idea of the environment and the idea of one’s own participation in it. These views must interact. If the former exists only as a basis of external facts, and

the latter as a textual description of character, there may be no causal connection between them. Then the biography will decorate the answer. A meaningful connection emerges when changing the model of itself changes the predictions, choices, and methods of testing the prediction.

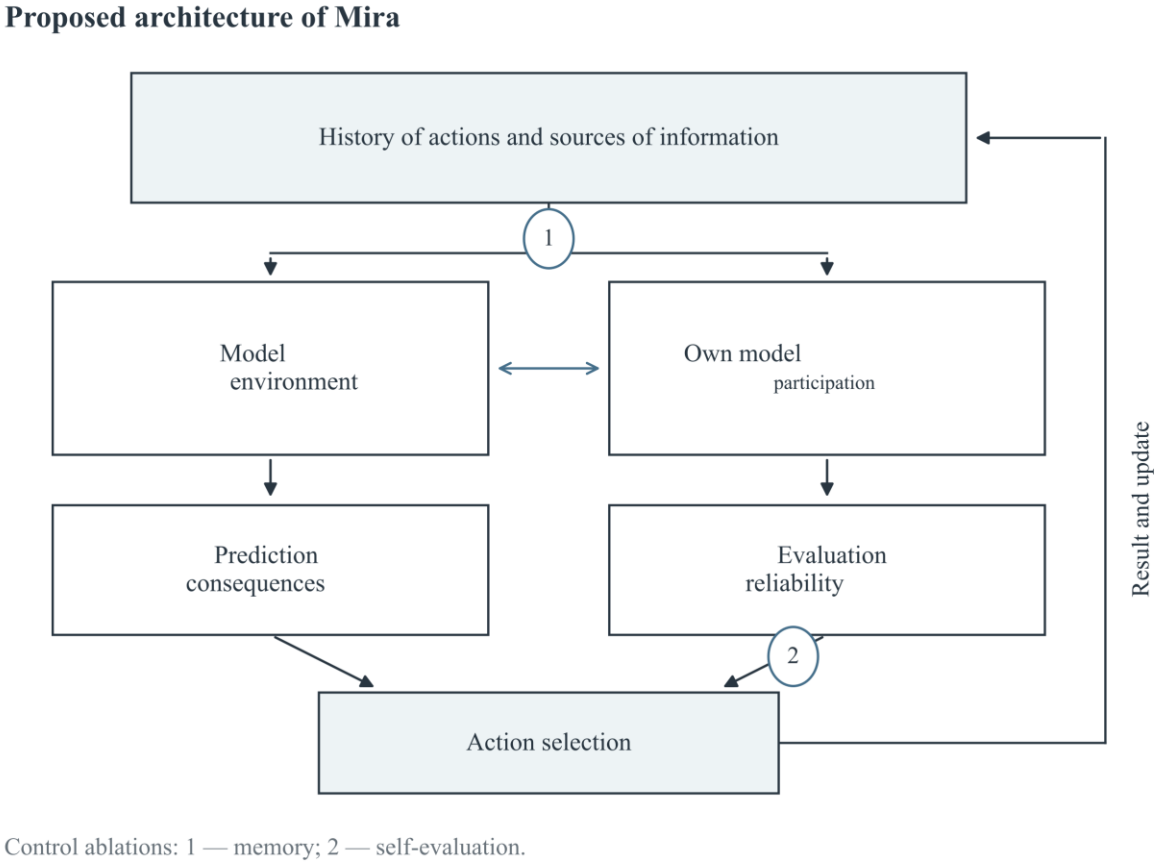


Figure 32. Mira's proposed organization for self-representation research. Arrows indicate the functional dependencies being tested; the presence of these functions does not in itself establish qualia.

This difference allows for normal experimentation in a software environment. The agent can be given erroneous information about its sensor and see if it revises it after a persistent discrepancy with the results. Then you can separately disrupt access to the history of your own actions. If the ability to distinguish between sensor failure and environmental change disappears, evidence emerges for a functional role for this history. The conclusion concerns self-representation, and further treatment of subjectivity depends on the theory.

History that works in the present

The archive of conversations and the memory involved in decision making are different engineering tasks. The archive answers the question of what was recorded. Working memory influences what differences the system now notices, what consequences it expects, and why it chooses one action over

another. Even a very large archive can remain an external reference if its contents do not participate in the ongoing organization of behavior.

The identity of the event is also important for the personality model. Information about someone else's action and memory about one's own action may coincide in description, but set different expectations. Observing another agent's error tells you something about the environment. One’s own mistake may require a change in the assessment of possibilities, although the external situation remains the same.

In the proposed system, it is useful to distinguish between an event record, an estimate of the source of that record, and the permanent changes caused by its use. Recording preserves content, source evaluation prevents observation from being confused with speculation, and sustained change allows the past to influence new decisions. These functions do not have to belong to separate program blocks. It is essential that they can be distinguished in the explanation of behavior and tested by intervention.

You can mentally compare two instances of an agent after the same event. The first one still has a text entry, but the expectation changes are cancelled. For the second one, the entry was deleted, but the purchased changes were saved. Both are capable of behaving differently than the original system, but the reasons are different. This example shows why a single measure of memory capacity is not sufficient for talking about personal history.

The hypothesis of joint personality formation adds here the requirement of organizational continuity. The past must be connected with the present through concrete changes, and not arbitrarily attributed to it. This is the working condition of the author's model. It does not yet establish what causal stories accompany the experience, but it prevents the substitution of the subject's history by an automatically compiled story.

Reflection should change the decision

The statement “I may be wrong” by itself conveys almost nothing about the quality of introspection. It can be repeated in the same way before correct and incorrect answers. Functional reflection occurs when an assessment of one's own reliability distinguishes between these cases and directs further action: requesting additional observation, delaying a conclusion, or changing a strategy.

A review by Stephen Fleming and Hakwan Lau distinguishes between overall levels of confidence, the ability to differentiate one's own correct from incorrect decisions, and the effectiveness of such discrimination given the difficulty of the underlying task. This avoids mistaking a confident response style for good metacognitive ability. [28]

For an artificial agent, a separate line of testing arises from this. Let him solve problems with a verifiable answer and estimate the probability of success in advance. If among decisions with a stated probability of about eighty percent, approximately this proportion is actually correct, the

estimate can be well calibrated. This is a conditional example, and not the result of Mira's research. Even good calibration must be tested on new tasks and as the environment changes.

Calibration and the ability to distinguish between one's own correct and erroneous decisions do not coincide. A constant score may correspond to the agent's average success without revealing anything about the reliability of a particular response. It is therefore important to examine both the overall accuracy of probability estimates and the relationship of confidence to the accuracy of individual responses. [28]

The next question concerns the causal role of self-esteem. If you artificially change the confidence score, will the system actually search for additional data more often, or will only the text accompanying the answer change? If you turn off access to error causes, will you still have the same flexibility? Such interventions make it possible to distinguish reflection as a work function from reporting reflection.

However, here too one should not promise a universal test of experience. The regulator can estimate the error well, and the theory of consciousness may also require a certain organization of global access, recurrent interactions or physical processes. The functional result is important in itself: it becomes known how the system notices the limitations of its own knowledge. Next, it is necessary to indicate what additional condition connects this ability with experience.

The artificial body also has boundaries

An embodied system depends on conditions that allow it to continue to operate. It can wait out some changes; others deprive its of this opportunity. In a software environment, the analogue for this difference would be limited resources, available actions, and the dependence of future opportunities on present decisions. But the conditional penalty in the problem is not yet a pain. Its meaning is established by the function in management, and the issue of the felt side remains separate.

Virtual embodiment is useful because it allows you to specify conditions precisely. The agent may have a limited field of observation, its own position, delayed action and irreversible consequences. Then the world is not reduced to a sequence of replicas: choice changes the situation, and history limits further choice. This creates a suitable environment for exploring self-representation and strategy continuity.

The physical embodiment adds properties that cannot be automatically transferred from the simulation. Sensors make noise, materials wear out, movement is associated with energy, processes occur at a certain speed. In a hypothesis where a specific quantum implementation is essential, these features may turn out to be fundamental. Therefore, the expression “the same body in digital form” requires clarification of which causal relations are actually preserved.

Distributed implementation is also possible. Memory is stored in one device, processing is performed in another, sensors are in a third. The spatial distribution itself does not make such a system an external consciousness. Conventional data transmission channels already exist for it. The scientific question is what set of processes is attributed to a single organization and how this organization changes when the channel is broken.

Where would the quantum boundary be?

If some quantum mechanism turns out to be necessary for consciousness, two different engineering projects will arise. One will calculate its behavior, the other will physically implement the corresponding interaction. Their coincidence in individual output data does not yet resolve the issue of equivalence for experience. The answer depends on what the theory considers necessary: a calculable relation, a causal organization, or a specific physical state.

Simulations of two coupled quantum subsystems can accurately reproduce predicted probabilities at a given scale. At the same time, the state matrix stored in computer memory does not mean that the memory elements are in the very entanglement that it describes. The mathematical description of an object and the physical properties of the carrier of this description should be distinguished. [14]

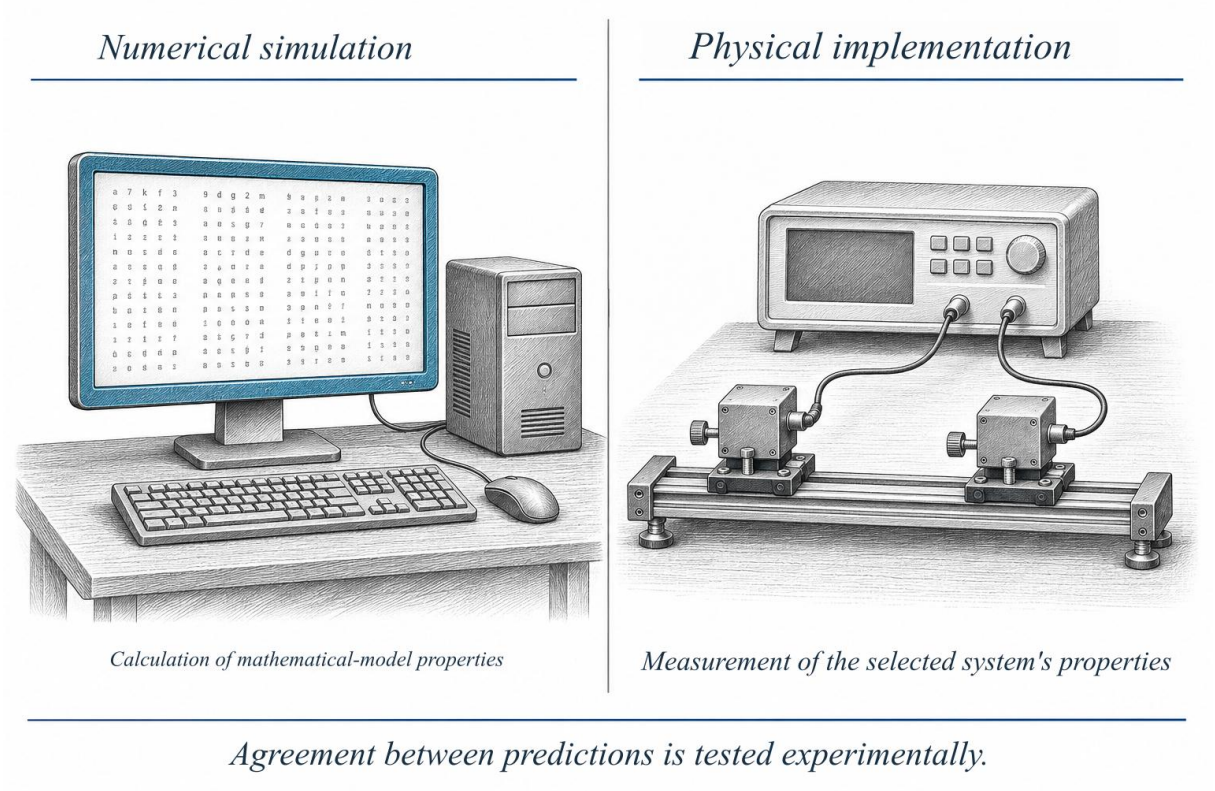


Figure 33. Calculation of the quantum process and its physical implementation. The computer stores the mathematical description; The experiment examines the properties of the selected physical medium [14]. The coincidence of the calculated outputs does not establish the

identity of the physical processes. The necessity of this or that process for experience remains a separate question of theory. The equipment on the right is shown conditionally.

This does not mean that a digital system is inherently devoid of experience. Such a conclusion would require proof of the physical necessity of the chosen mechanism. So far, several hypotheses are being compared: consciousness depends on functional organization; it depends on a particular physical realization; or both sides are important at different levels of description. Artificial systems provide the opportunity to make these differences the subject of specific research.

For the interface hypothesis, the most meaningful situation would be one in which a change in the intended physical channel changes the preselected functions while other essential conditions remain the same. But a drop in overall performance will not solve the problem: any damaged computer works differently. One will need a specific relationship predicted by the mechanism and a comparison with systems where the same functional effect is achieved in a different way.

Architecture under test

Patrick Butlin and colleagues propose deriving indicators of possible AI consciousness from scientific theories of consciousness. Such indicators help assess the basis for attributing consciousness to a system; they do not serve as direct measures of qualia. [27]

Within the framework of the author's program, it is convenient to compare several implementations of Mira. One only supports conversation and access to recordings. The other links memory, self-model, and choice of action with stable feedback connections. The third, if a reasonable physical candidate appears, adds the interaction channel under investigation. The comparison must take into account the resources and capabilities of each version: the advantage of a more powerful system cannot be automatically attributed to the new principle.

The indicators here should be divided. How accurately does the system remember the source of information? How does one detect one's own mistakes? Does an acquired limitation carry over to a new task? Is the assessment of one’s own capabilities preserved if the wording of the question changes? These observations describe the functions. Their connection with consciousness must be deduced from an explicit model, and not established by the convenience of the name.

The case of divergence of indicators is especially interesting. The agent can solve the external problem better and evaluate itself worse. May retain biographical information but lose its influence on choices. Such results prevent the reduction of all abilities to one scale of “level of consciousness.” They show which components can be changed relatively independently and which dependencies the theory must explain.

Copy and continuation

Artificial implementation allows you to ask a question that in biology usually remains mental. The state of a program can be copied, and then provide the copies with different histories. At first, their stories about the past will coincide. Later, differences will appear due to different actions and observations. This is an example of functional personality divergence; the existence of subjective experience in any instance does not automatically follow from it.

For the hypothesis of joint personality formation, such a case is important: the same initial information does not cancel the emergence of separate causal stories. Even if we assume a single fundamental basis, it will be necessary to explain why the emerging streams of experience are combined or separated. A reference to a common medium does not solve this problem without an individualization rule.

The divergence of histories and possible ways of storing memory are compared in figures 26 and 27.

Attributing an experience to an artificial system also has practical consequences. If there are serious reasons to believe that suffering is possible, the research conditions will have to be assessed taking this possibility into account. At the same time, the emotional impression of a persuasive speech cannot be converted into a measurement. Both require the same discipline: distinguishing between observed function, theoretical basis, and degree of uncertainty.

The research setting of the Mira project allows us to study these differences on a specific architecture. It becomes possible to change the architecture, save the history of interventions and check predictions. But the more accurate the description of such a system becomes, the clearer the next question: what exactly must continue for the same subject to continue? Memory, computation, physical process, or a relationship between them? This question takes the study beyond the structure of an artificial agent - to the border of the continuity of personality.

Chapter 19

Continuity limits

The question of consciousness changes when time is added to it. One can ask why the experience exists in the present moment. It is possible - why today’s experience belongs to the same person as yesterday’s. One can finally ask whether this connection is capable of being preserved after the destruction of the organism. These questions are close emotionally, but require different explanations.

The hypothesis of a more fundamental basis of experience often seems to be the answer to all three at once. If the basis is not limited by the brain, there is hope that the personality is not limited by the time of its work. However, there is an essential link between these statements. The general possibility of experience does not yet contain specific memories, relationships and habits. In order for a given subject to continue, that which makes its continuation individual must be preserved.

In this area, precision of language is especially necessary. It does not diminish the importance of the issue. On the contrary, it allows you not to lose the subject of research among the words “energy”, “information” and “eternity”, each of which has many meanings.

Stopping and irreversibility

Stopping blood circulation creates a severe disruption of the working conditions of the brain. During resuscitation, doctors try to restore blood flow and vital functions. The very fact that after stopping a person was able to survive and talk about his experience means that a condition from which recovery was possible is being examined. It cannot be identified without additional reason with the continuation of personality after irreversible destruction of the brain.

In the everyday expression “after death” these differences often disappear. In a scientific description, the sequence of events, the state of the body, the interventions taken, and the accuracy of the measurements are important. This is not a matter of choosing a convenient definition, but rather what period of time the data covers. Instrument readings in one phase should not be transferred to the entire history of the event.

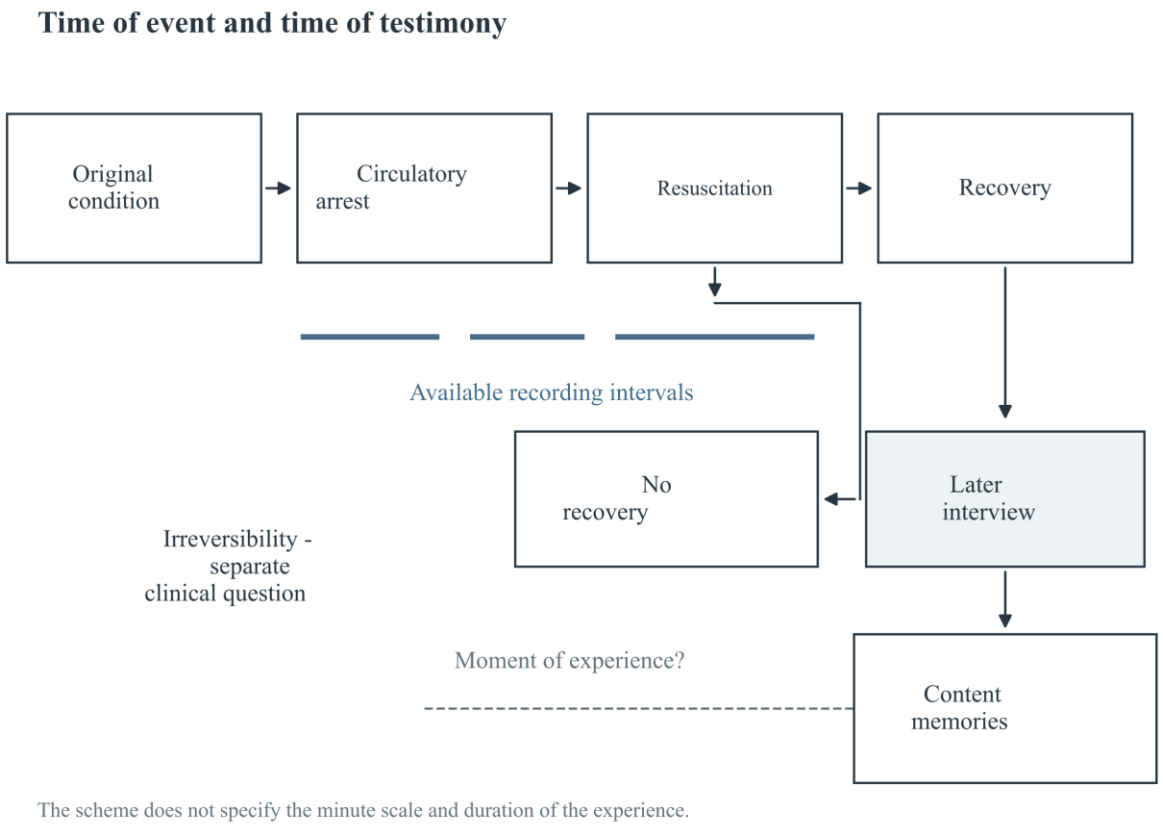


Figure 34. Time linking of medical records and subsequent narrative. Circulatory arrest does not equal established irreversible brain damage, and the timing of the interview does not determine the moment at which the described experience occurs.

Even a reliable account of an unusual experience does not have an internal timestamp that matches the medical record. A person can remember the content well and make mistakes in its location relative to external events. Therefore, the task of research is not only to collect the story, but also to relate it to independently recorded circumstances.

This applies to any hypothesis. A neural explanation must show when and how the experience might have arisen. The external basis hypothesis should indicate which features of the story require an additional channel. The statement “the brain no longer worked” requires a description of the specific measurement, its sensitivity and spatial coverage.

What was observed during resuscitation?

The AWARE II study by Sam Parnia and colleagues, published in 2023, examined 567 cases of in-hospital cardiac arrest. Individuals survived 53, interviewed 28; eleven reported memories or perceptions, which the authors linked to possible conscious activity. No participant named the presented visual target; one recognized the auditory stimulus. In some patients, during ongoing resuscitation, organized EEG activity was recorded, including 35–60 minutes after its start. These are observations in a resuscitation setting, not a demonstration of brain-independent personality. [29]

Such a study has several different results. Stories report the subjective side of an event. A physiological record describes measurable processes. The presented target is intended to verify specific information. Linking all three components at the individual case level is more difficult than simply detecting each of them in the overall sample.

Therefore, the duration of resuscitation should not be read as the duration of proven continuous experience. And the frequency of reports among interviewed survivors cannot be automatically transferred to all patients with cardiac arrest, much less to all those who have died. Screening for survival and interviewability is part of the very method of obtaining data.

The important question for the interface hypothesis is: what coincidence between content and external event would be unexpected given the normally available channels of perception and memory? This question can be verified. The overall impression of unusualness or clarity of experience is less certain, since different mechanisms can give rise to subjectively compelling states.

Dying Brain Activity

Gan Xu and colleagues in 2023 examined recordings of four comatose patients before and after withdrawal of ventilatory support. Two showed increased gamma activity and connectivity changes. The patients did not survive, so it was impossible to compare these processes with their subsequent stories. The work shows certain dynamics of the brain during dying, but does not establish the content of the experience and does not prove its presence in each of the observed patients. [30]

This raises a useful caution against hasty interpretation of biomarkers. If a certain dynamic occurs in a conscious state, its occurrence in a different context does not guarantee the same experience. The value of the indicator depends on the conditions under which the connection was established. Situations of dramatically altered physiology require particularly careful transfer.

The reverse inference is equally unreliable. A weak or absent recording in a selected range does not amount to complete knowledge of every brain process. Any method detects a particular class of changes. This does not imply that consciousness must be present beyond the method's sensitivity. It only requires the scope of observation to be stated correctly.

For a scientific model, such a result is valuable without a final metaphysical interpretation. It clarifies what processes are possible in the transitional state of the organism. Any theory of the continuation of experience must take into account this complexity, and not be built on a pre-simplified image of instantaneous complete shutdown.

What the similarities between stories don't tell you

Let some collection of stories repeat light, an encounter, a space of transition, or the feeling of observing the body from the outside. This is a

mental example of a classification problem, not a description of a new study. Repeatability can be interesting, but first it is necessary to establish how the information was collected, whether leading questions were asked, and which stories were not included in the selection.

The same similarity allows for several explanations. It may reflect shared biology, shared cultural expectations, similar conditions of recollection, or properties of a putative external process. To choose between them, you need to figure out where their forecasts diverge. The presence of a common motive does not in itself distinguish between these options.

Particular care should be taken when combining stories about different events into a single sequence. Experiences during resuscitation, reports of alleged prenatal memories, and descriptions of dreams may contain similar images. But the coincidence of the image does not establish that the narrators observed adjacent stages of the same external path. For such a conclusion, an independent connection between events is necessary.

A scientifically meaningful goal would be a predetermined classification applied to independent sets of messages, taking into account the language, culture and circumstances of collection. Even consistent similarity after such tests will first require explanation. To regard such similarities as a ready-made description of posthumous existence would be to miss the test of competing explanations.

Preservation of information and preservation of identity

The image of indestructible information easily becomes a promise of immortality. In the standard quantum description of a closed system, unitary evolution does preserve the distinguishability between complete states of the system in a certain mathematical sense. However, man is not an arbitrarily chosen collection of all the physical traces of his existence. What is essential to the individual is the organization through which history is accessible, connected to the present, and influences the continuation of experience. [14]

Imagine a letter that gradually disintegrated into many chemical traces. Information about its past may remain in the correlations of a huge number of particles. This does not mean that a coherent text continues to be read somewhere. Moreover, the existence of a reader does not follow from the presence of traces. The example concerns the difference between a physical trace and an operating organization, not a literal model of the brain.

Likewise, the law of conservation of energy is not the law of conservation of memory or personality. The energy balance describes the value, and not the entire way, of organizing a process. The personality continuation hypothesis would require showing which states preserve individual differences, how they are protected, and how they participate in subsequent experiences.

The external trace introduced in the fifteenth chapter gives this question a definite form. If part of a personal history is encoded in an additional

medium, three possibilities must be distinguished: the trace quickly disappears; the trace is retained but not used; the trace enters into a process capable of supporting further individual history. Only the third possibility brings the model directly closer to a continuation of the subject. The first two have a different content, even if they can be physically confirmed.

The differences between storage and access architectures are illustrated in Figure 27.

What an Effective Continuation Would Look Like

For a working hypothesis, we can consider a carrier E, which during its life receives certain changes through a connection with organism B. If, after the termination of this connection, E remains only a passive record, the model describes the preservation of a trace. If E has its own dynamics, holds differences, and connects successive states, the stronger hypothesis of autonomous continuation arises. This is an addition to the original interface model, not an automatic consequence of it.

Autonomy will require a physical explanation. Where do the conditions for maintaining the structure come from? Which interactions destroy it, and which compensate for the disturbances? How exactly is the record that was associated with a given organism selected? Why don't neighboring stories mix? While these questions do not have specified mechanisms, the expression “consciousness remained in the external field” indicates an assumption, but does not explain it.

But questions already allow you to compare versions. If continuation depends on a stable material state, the time of its preservation can be estimated. If it depends on an ongoing process, you will need to determine the source and mode of that process. If the absence of space and time in the usual sense is assumed, the usual dynamic model is inapplicable without an additional rule of connection with observable events.

A separate requirement concerns content. A system that continues general activity may not retain individual memory. Conversely, retained memory does not guarantee ongoing experience. The author's hypothesis therefore distinguishes between the stability of the medium, the accessibility of personal history and the presence of a subjective process. Between these conditions we need laws of connection, and not just the same word “conservation”.

Identity after an Interruption

Let's imagine a device that can reconstruct a person based on a complete description of his condition. In this mental case, the restored person can remember the previous life and consider it his own. But if the description is used twice, two sequels arise, which soon receive different stories. The coincidence of memory at the initial moment does not make further experiences one stream.

The story divergence diagram in Figure 26 helps to separate the similarity of the initial state from the further continuation.

This reveals the difference between the similarity of properties and numerical identity - the fact that we have one and the same subject, and not two similar ones. Two systems can coincide in their accessible properties and yet occupy different places in causal history. If a theory posits the transference of one subject, it will have to explain how the transference is different from the creation of another subject with the same memories. The story of the restored system alone may not be enough, since such a story is provided for in both scenarios.

There is also the opposite difficulty. The loss of some memories does not necessarily mean the emergence of a new person in every ordinary sense of the word. Therefore, one cannot define a person only by the set of available stories. Perhaps what is essential is a broader continuity of organization, body, and relationship. In the interface hypothesis, a supposed connection with E is added to it, but its own contribution still needs to be highlighted.

If two theories give the same observable results and differ only in which flow to declare as the same, experiment will not be able to choose between them until an additional consequence appears. This is not a ban on thinking about identity. This is the exact location where physical research ends and interpretation continues.

What result would change the conclusion

Strong evidence in favor of an unusual information channel must contain information that is not available through known paths under predetermined conditions. You will need independent target registration, protection against leakage, clear timing and reproducibility of the result. Such success would not yet prove the continuation of personality after death. It would confirm the narrower claim of information acquisition and require a new explanation of the mechanism.

Strong evidence in favor of external storage would require an additional step: showing that a particular history is stored in an independently defined medium and can be retrieved through the described channel. Evidence of the continuation of the subject would also require a valid rule connecting this process with individual experience. These requirements should not be compressed into one spectacular experiment, since they relate to different parts of the hypothesis.

This type of research does not need to intentionally endanger life. Medical observations are possible within the framework of already necessary assistance, and work with memory, channels and physical media begins much earlier than the issue of irreversible destruction of the body. The main difficulty here is establishing a causal relationship, and not bringing a person closer to a dangerous border.

The question of the continuation of experience remains open in the precise sense that the data considered do not provide a settled answer about personal existence after irreversible death. This does not equate to equal confirmation of all conceivable scenarios. Each version must receive its own reasons and withstand its own tests.

It is essential for the book to be able to hold both sides of the issue. Consciousness may require a deeper physical description than is currently available. And human personality may depend on the particular organization of the body much more than the simple receiver metaphor suggests. The relationship between these possibilities can only be determined by examining what is preserved, how it continues, and why the supposed continuation belongs to a given subject.

Chapter 20

What answer are we willing to accept?

A hypothesis becomes part of a study when it ceases to determine its outcome. Before this, you can freely choose an image: the brain as a computer, the body as an avatar, consciousness as a fundamental property. Once a specific mechanism emerges, the choice is limited by measurements. It turns out that some time is too short, the connection is too weak, or the expected effect is already explained by a known process. This is where the opportunity to discover something that was not in the original plan begins.

Now the interface image has already changed. It no longer automatically presupposes a ready-made personality that uses the body as a replaceable shell. In the proposed model, individuality arises through the organization of interaction, history and differentiation of one’s own states. A more fundamental basis, if it exists, does not relieve one from the need to explain why experience is the way it is and belongs to an individual subject.

The proposed model has several possible outcomes. It is useful to consider them in advance, because otherwise any observation can easily be turned into confirmation of a favorite idea.

When the physical mechanism is not found

The most direct negative outcome is that the chosen medium does not exhibit the desired properties. The state retention time turns out to be too short for the proposed chain, the connection with biological processes is not confirmed, or the calculated effect is absent in the sensitivity range of the device. Then the particular version of the model loses its basis.

This outcome does not require declaring all questions of consciousness resolved. But keeping the question open does not save the rejected mechanism. If the spin-carrier hypothesis fails testing, it cannot be considered confirmed simply because the origin of qualia is still unclear. Ignorance of one is not positive knowledge of the other.

The scientific value of the work may be preserved. Measuring the relaxation time clarifies the physics of the structure. Channel testing limits the range of its possible influence. The improved method helps distinguish sample properties from instrument features. These results have their own meaning, even if the original interpretation does not stand up to scrutiny.

For the author's program, it is especially important to maintain the connection between the negative result and the conditions. The failure of one model of interaction does not amount to a refutation of every possible external basis. But if each subsequent option is changed in such a way as to avoid the experiment already carried out, the program risks losing

testability. The new version should offer a new substantive basis and a predetermined difference in forecasts.

When the quantum effect turns out to be real

A more favorable and at the same time more modest outcome is possible: a quantum process is discovered, reproduced and affects biological function. This would be an important physical result. However, the relationship to consciousness would have to be established separately. The mechanism may be involved in energy transfer, chemical sensitivity, or regulation without being a specific source of subjective experience.

Here it is useful to distinguish several types of necessity. Some interaction may be necessary for cell life in general. Its violation will then change consciousness and many other functions. Another mechanism may influence a specific processing channel. The third may turn out to be specifically related to a certain organization that the theory considers necessary for experience. These statements require different precisions of intervention and comparison.

Physical success may therefore bring the hypothesis closer to conventional neuroscience. If quantum dynamics operates within biological structures and its functional outcome is incorporated into neural organization, an external carrier may not be needed. The quantum approach to the brain will still make sense, but the original idea of the receiver brain will need to be changed.

This result should not be considered a disappointment. It would answer a more precise question: what features of the physical structure of the nervous system are important for its operation and why the appropriate description must sometimes be quantum. Further debate about the fundamental status of experience would continue on a more substantive basis.

When an Additional Bearer Is Found

A stronger result would arise if an independently measured subsystem E was found to interact with the organism according to the predicted law. Independence here does not mean lack of connection with the brain. It means that the existence and properties of the medium are established not only from the same behavioral data that are supposed to confirm its influence.

Then the consistency of several observations could be checked. The parameters obtained from measuring the carrier itself should predict changes in the associated biological system. A change in detuning should affect the response as predicted by the model. The measured state retention time should limit the possible duration of the transfer. The connection between these quantities would make the explanation stronger than a set of separately selected relationships.

But the external physical medium is not yet an external subject. The environment constantly affects the body in many ways. In order for a new process to change the theory of consciousness, it is necessary to show its special causal role and formulate a rule of relation to experience. Otherwise, the discovery will expand biophysics, but the question of the connection between physical processes and experience will remain open.

The subject also does not have to be entirely in E. The co-formation hypothesis allows that experience refers to the organization of the connection between B and E. Then the question “where is consciousness” may turn out to be poorly posed: the spatial arrangement of elements does not have to coincide with the level at which the property of the whole is determined. However, such an explanation must set the boundary of the whole, so as not to attribute one subject to any set of interacting objects.

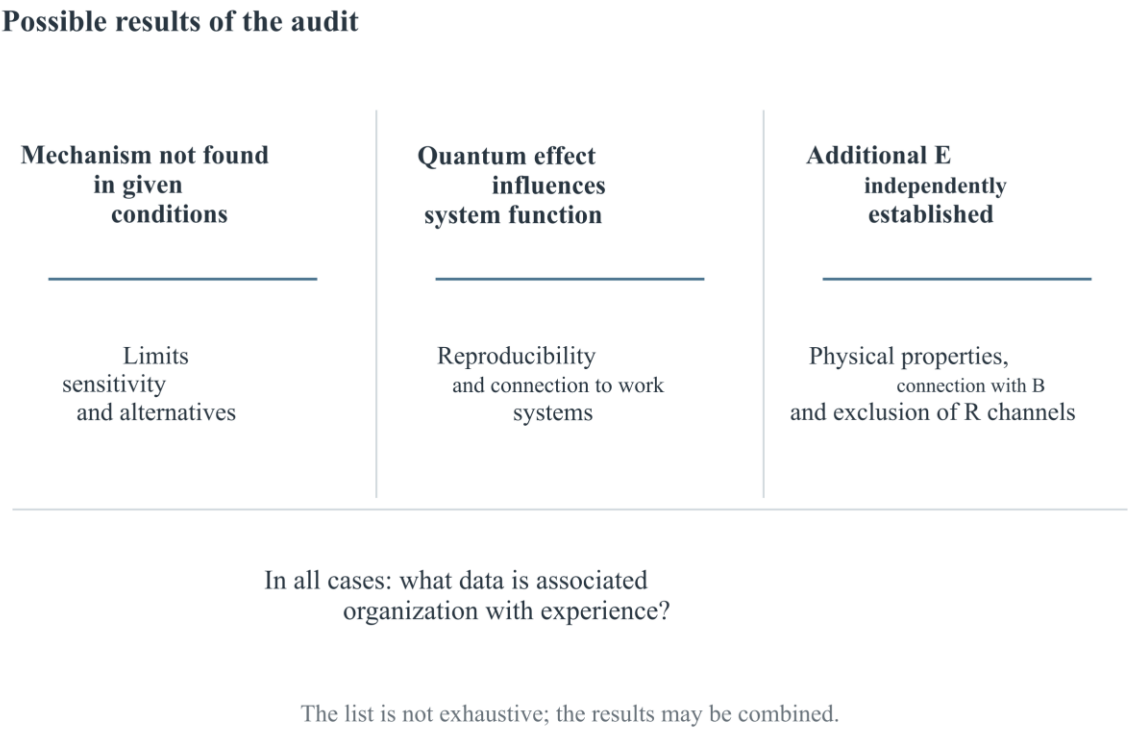


Figure 35. Possible outcomes of the research program. Confirmation of the physical effect, the additional carrier, and the relationship to the experience requires different reasons. The results shown do not exhaust all options and may be combined.

The most vulnerable link

The most difficult part of the program remains the rule connecting physical organization and subjective experience. One can describe state, transitions, and memory in detail, and then discover that the explanation still only speaks of observable relationships. Calling the totality of these relationships consciousness does not mean explaining the qualitative side of experience.

The author's hypothesis suggests looking for this connection in the organization of interaction, which forms a separate perspective: through a stable border, one's own history and selective access to states. This is a research hypothesis. Its strength will depend on whether one can derive from it limitations that the more general descriptions do not have. For example, what changes do the subject retain, what changes divide his organization, and why the same amount of information can correspond to different possibilities of experience.

It is not enough here to declare the fundamental basis to be equally present everywhere. Such a statement may have philosophical content, but without the rule of individuation it does not explain the difference between a person, an animal, an artificial system and a simple physical connection. The theory must clarify under what conditions a distinct perspective emerges and what is independently tested under those conditions.

Perhaps a mature explanation will require new concepts. However, new concepts should increase accuracy and not just replace old words. If the "field of subjectivity" does not allow the definition of a state, interaction, or discernible effect, it remains the name of the problem. If possible, it becomes possible to compare it with a competing description on the same data.

Some consistent evidence

A substantial change in our picture will usually require agreement among different tests. The bearer's physical property, its change under intervention, the biological effect, and the relationship to independent indicators of a conscious state must support a single causal model. Reusing one data set does not turn it into several independent confirmations.

It is useful to imagine a model that accurately describes already known curves, but each time requires a new adjustment on a different sample. It may have good quality of fit but poor predictive ability. Another model describes the data a little more roughly, but in advance connects the results of different experiments with one set of parameters. The choice between them cannot be reduced to the beauty of one design or to the impression of the complexity of the formula.

The comparison must also take into account strong alternatives. A classical nonlinear system is capable of complex oscillations, memory, and history dependence. The neural model may include feedback and internal representations. Therefore, unusual behavior is not sufficient to conclude a quantum mechanism. You will need an observation that explicitly states which alternatives it limits and under what assumptions.

This type of work allows for gradual accumulation of bases. It is not necessary to wait for an experiment that will immediately answer all questions. You can first limit the communication time, then establish the functional role, and then clarify the psychophysical correspondence. Each step must maintain its significance without taking credit for the success of the next.

What will change in the question of a person

If the proposed program receives confirmation, a person will appear as an organized connection of processes, some of which were not previously included in a sufficient description of the brain. This may change ideas about the boundaries of the subject, memory, and possible physical realizations of experience. But the specific consequences will depend on the mechanism discovered. Immortality, telepathy, or the possibility of personality transference cannot be inferred in advance from the mere fact of a wider connection.

If the program fails, an important result of a different kind remains: the avatar image will be translated into a set of verified and constrained statements. It will become clearer which properties of the body are truly essential and why some attractive analogies do not stand up to physical detail. Science advances even when there are fewer possible explanations.

In both cases the question of other beings takes on a more precise form. Similarity to human language ceases to be the only support. Attention shifts to the interaction structure, history, self-regulation and those physical properties that the theory considers necessary. The differences between organisms and artificial systems then become a material for comparison, rather than an obstacle that must be eliminated in advance.

Philosophical and theological questions do not have to disappear. The meaning of personal experience, attitude towards death and understanding of one's place in the world include more than a description of the mechanism. But statements about the physical structure of the world receive a separate responsibility: they should be associated with observations as accurately as the content of the statement allows.

The proposed program combines three independent hypotheses. The selective interface hypothesis concerns the physical connection of an organism with an additional carrier. The identity co-formation hypothesis links the individual perspective to the body, the organization of interaction, and history. The external memory trace hypothesis allows for the recording and subsequent reading of part of this history outside the selected biological subsystem. Confirmation of one of them will not automatically confirm the others: the communication mechanism, the conditions of individuality and the storage architecture require their own reasons.

The minimal model yielded a narrower but more specific result: the connection can be selective, and the maximum probability of transfer depends on the detuning and the interaction coefficient. These values limit the possible effect and relate its amplitude to temporal dynamics. The calculation did not discover the carrier E in nature and did not deduce the occurrence of qualia; it showed how part of the original intent could be translated into a testable statement. It is at this boundary between what has been calculated and what has not yet been established that further work begins.

Return to presence

At the beginning of the book there was a room, a cup and a short question about who notices what is happening. Now distinctions have arisen around this issue: experience and report, state and measurement, correlation and channel, memory and continuing personality. They do not make the immediate experience any less real. They allow us to ask more precisely about its nature.

The brain may prove to be a sufficient physical basis for human consciousness. A description of the broader system may be required. It may turn out that the very connection between physics and experience requires a law that does not yet exist. These possibilities are not equal on the basis of the available grounds, but each should be discussed in a form in which it can be meaningfully explored.

The main requirement for the selective interface hypothesis is specificity. One must name the medium, describe the interaction, relate the story to the individual, and provide an observation that might change the conclusion. As long as these requirements are met, a bold assumption can work in science. When they are replaced by confidence that does not depend on the outcome, the study stops.

The room remains the same. The light on the table does not need theory to be seen. Theory is needed for something else: to understand what relationships in the world make this vision itself possible - and why there is an internal side to what is happening.

Mathematical Appendix

Checking the minimum communication model

In the thirteenth chapter, an ideal model of the exchange of one excitation between two subsystems was used. Here its calculation is expanded into a form that can be verified regardless of interpretation. The model is deliberately small: it shows physical selectivity and does not contain the rules for the emergence of consciousness. All the numbers below come from its equations, not from measurements on the brain.

Notation in the mathematical model

The letters below refer to the models in this book. They do not designate measured quantities of consciousness; the physical meaning of each parameter depends on the chosen system.

Symbol	Meaning and units
B, E, R	Selected biological subsystem, hypothesized additional bearer, and ordinary environment.
H, I, ρ	Hamiltonian, identity operator, and density matrix. H has dimensions of energy; I and ρ are dimensionless.
A, F	Dimensionless property operators of interacting subsystems in the general model of Chapter 13.
$\hbar$	Planck's constant divided by 2π; dimensions of action, J·s.
g, Δ	Coupling coefficient and difference in transition angular frequencies. Both have units s^{-1}. In the appendix, g is chosen positive.
Ω	Angular frequency of exchange dynamics in the minimal model; units s^{-1}.
t, T_1, T_2, T_φ	Observation time, energy-relaxation time, coherence-decay time, and pure-dephasing time; all measured in seconds.
g_eff, K	Effective frequency of the relevant interaction and the dimensionless product $K = g_{eff} T_2$.
τ, δ	Dimensionless appendix variables: $\tau = gt$ is time; $\delta = \Delta/g$ is relative detuning.
P_B	Probability of detecting an excitation in B. Takes values from zero to one.

Two states instead of the whole organism

In the selected sector, only two states are significant. In the first, element E is excited and B is at a lower level; in the second the excitation is at B. The initial state is the first. The transition to this description assumes that other levels and processes are unimportant in the time interval under

consideration. For a real biological system, such an assumption would require independent verification.

If we subtract from the energy a common term that does not affect the transition probability, the Hamiltonian matrix in the indicated order of states takes the form

$$H_{one} = \hbar \begin{pmatrix} -\Delta/2 & g \\ g & \Delta/2 \end{pmatrix}.$$

Here g is a positive coupling coefficient with the dimension of reciprocal time according to the accepted choice of phase. The detuning Δ is equal to the difference between the angular frequencies of transitions B and E and has the same dimension. Subtracting the total energy changes the overall phase of the state, but not the statistics of the measurement in question.

The eigenvalues of this matrix are equal to plus and minus half of ħΩ, where

$$\Omega = \sqrt{\Delta^2 + 4g^2}.$$

The value of Ω specifies the frequency of the exchange dynamics. From the solution of the Schrödinger equation under the chosen initial condition, the probability of detecting excitation on B is obtained:

$$P_B(t) = \frac{4g^2}{\Delta^2 + 4g^2} \sin^2\left(\frac{\Omega t}{2}\right).$$

The expression coincides with the formula of the main chapter. Before the sine there is a multiplier that limits the maximum carryover. When the frequencies coincide, it is equal to unity. When detuned, it decreases because the transition frequencies differ. When g = 0 there is no exchange; if at the same time Δ = 0, this case should be determined directly from the zero interaction, rather than substituting an indefinite relation into the formula.

Dimensionless variables

To compare different coupling coefficients, it is convenient to measure time in units of 1/g. Let us introduce dimensionless time τ = gt and relative detuning δ = Δ/g. This is a supporting entry for the same solution:

$$P_B(\tau) = \frac{4}{\delta^2 + 4} \sin^2\left(\frac{\tau}{2}\sqrt{\delta^2 + 4}\right).$$

The first maximum occurs at dimensionless time π divided by the square root of the sum of δ² and four. Its height is equal to four divided by the same amount. The table shows the calculation for several relative detunings.

Relative detuning δ	*Maximum probability*	*Time of first maximum* τ
0	1.000	1.571
1	0.800	1.405
2	0.500	1.111
4	0.200	0.702

An earlier first maximum with a large detuning does not mean more efficient transmission. This maximum is lower. For a function that requires a certain transfer probability, too much detuning can completely block access to the desired mode, despite rapid small fluctuations.

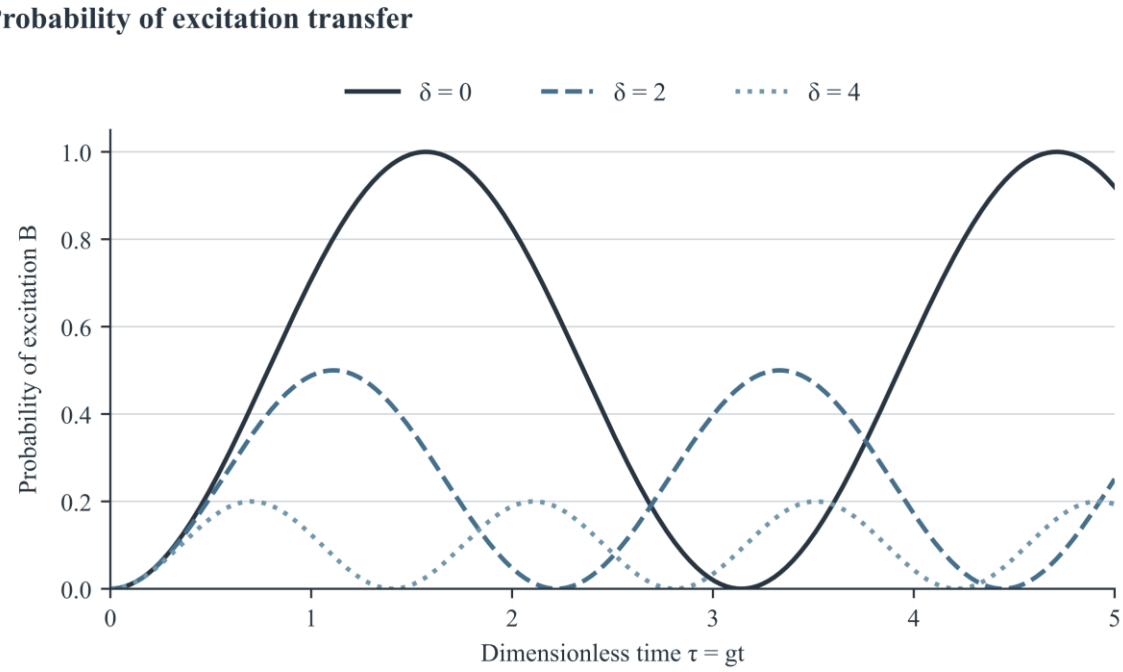


Figure 36. Calculation for an ideal two-component model. Horizontal - dimensionless time; vertically - probability of excitation B. The curves correspond to the relative detunings 0, 2 and 4. This is an equation calculation, not consciousness measurement data.

What does the calculation check?

The solution can be obtained in two independent ways: by direct substitution into the analytical expression and by calculating the evolution through the eigenvalues and eigenvectors of the Hamiltonian matrix. The coincidence of these methods is checked by the calculation within the model. It does not test the fit of the model to the biological mechanism.

Preservation of the sum of probabilities shows the consistency of the ideal description of the closed system. The zero to one bounds test the acceptability of the probabilities. The resonant case and the lack of coupling serve as tests of the limiting conditions. Each of these checks answers a

technical question; none turns the conditional subsystem E into a discovered natural object.

A small model makes a meaningful prediction only after its parameters are related to independent measurements. If g and Δ are freely chosen from the observed curve each time, the description may remain a fit. If they are established and then predict change under new conditions, it becomes possible to test the physical mechanism.

Why is there no random decay here?

In a living environment, the exchange of excitation is influenced by relaxation, phase noise and other transitions. Any attenuation multiplier cannot be considered a universal correction to the ideal solution. Different mechanisms of open dynamics change level populations, equilibrium states, and phase relationships in different ways.

For such a task, it is necessary to specify the interaction with the environment or a well-founded effective equation. One option is the Lindblad equation, if appropriate assumptions about memoryless dynamics apply. It requires specifying operators and process speeds. The specific choice must be consistent with the physical model; the name of the equation is not enough. [18]

The estimate $K = g_{eff} T_2$ is useful as a preliminary comparison of characteristic times. Here g_{eff} is the effective frequency of the desired interaction, T_2 is the conservation time of the coherence in question. Small K means that the phase relationships disappear quickly relative to the corresponding exchange. A large K does not yet guarantee a noticeable biological effect: the initial state, the detuning, the method of reading and the further chain of influence are important.

One explicit phase loss mechanism

Now you can take the next calculated step: select a specific open dynamics instead of an arbitrary envelope. Let's leave the sector of one excitation, set the detuning equal to zero and take $g > 0$. Let X exchange two basis states, and Z assign to them the values +1 and −1. To the Hamiltonian $H/\hbar = gX$ we add pure Markov dephasing with the Lindblad operator $L = \sqrt{(\gamma/2)}\, Z$, $\gamma \geq 0$. When the connection is turned off, it does not change the population, and the off-diagonal element of the density matrix decays at a rate of γ. It is for this sector coherence that we define $T_2 = 1/\gamma$. Energy relaxation is not included here. [18]

$$d\rho/dt = -i[gX, \rho] + (\gamma/2)(Z\rho Z - \rho).$$

Let us denote the population difference $z = p_E - p_B$. At the initial moment E is excited, so $z(0) = 1$. The equations for the density matrix reduce to the usual differential equation:

$$z'' + \gamma z' + 4g^2 z = 0, \quad z(0) = 1, \quad z'(0) = 0; \quad p_B = (1-z)/2.$$

For $\gamma < 4g$ the solution is oscillatory. For $\omega = \sqrt{(4g^2 - \gamma^2/4)}$ it has the form:

$$z(t) = \exp(-\gamma t/2)\,[\cos(\omega t) + (\gamma/2\omega)\sin(\omega t)].$$

The first transfer maximum is reached at $t = \pi/\omega$ and is equal to $[1 + \exp(-\gamma\pi/2\omega)]/2$. When $K = gT_2 = 10$ it is about 0.9622, when $K = 1$ it is about 0.7222. At the boundary $K = 1/4$, the oscillations disappear; at lower K, the probability in this model monotonically approaches 1/2 without exceeding it. Even with precise resonance, full transmission may therefore not be available. The 1/4 threshold applies only to the selected equation, and not to consciousness or all ways of interacting with the environment.

This example shows why you cannot simply multiply the ideal probability by $\exp(-t/T_2)$. For $\gamma > 0$, the chosen dynamics in the far limit equalizes the populations, and such a multiplication would send the probability to zero. In an environment with energy losses, the limit may be different. It is necessary to measure not only one time, but also what process determines it.

The analytical solution is verified by separate numerical integration of the Bloch system. With $g = 1$, $0 \le gt \le 8$, $\gamma/g = 0$; 0.1; 1; 4; 10 and steps 0.002 and 0.001 the largest absolute probability difference was less than 2×10^{-11}. Reducing the step is consistent with the fourth order of the method. The admissibility of the density matrix with a numerical tolerance and ideal curves at four detunings were verified. The source code for this check is provided in the computing kit.

This continuation has an exact limit: the same equation for z describes a classical damped oscillator. The coincidence of the curve with the calculation does not yet highlight the quantum mechanism. But independently measured g and γ now give a joint forecast of the height and time of the maximum. The next experiment could test exactly this connection, and then separately the quantum resource and its biological role. This order turns the general idea of the interface into a sequence of increasingly specific tasks.

Boundary of mathematical result

Transport oscillations can also occur in classical coupled systems. Therefore, the curve shown is not in itself evidence of non-classicality. This requires additional measurements and an explicitly specified class of models being compared. The question of experience requires another transition - from physical organization to psychophysical correspondence.

The calculation has a more specific purpose. It shows how the metaphor of a selective interface becomes a constraint on a possible effect. If a particular experiment violates the resulting bound, the model must change on physical grounds. If an experiment agrees with the bound, it remains necessary to check whether another system explains that agreement. In this way, the formula becomes part of the investigation and retains exactly the meaning assigned to it.

Dictionary of concepts

Anesthesia. A medically induced condition with certain changes in sensitivity, reaction, memory and other functions. Specific effects depend on the substance and conditions; the absence of a response is not an independent definition of the absence of experience.

Basis. A set of independent reference states through which the state of the system is recorded. In chapter 2, an orthonormal basis of a two-level system is selected. [14]

Hamiltonian. A mathematical operator that specifies the energy and, in the standard quantum description, the time evolution of a system. The presence of a Hamiltonian in the model does not establish the existence of the chosen physical carrier.

External memory trace hypothesis. The assumption that some differences associated with the history of the organism are preserved in an additional carrier. The preservation of a trace, the possibility of its reading, and the continuation of the subject represent different statements.

Selective interface hypothesis. The author's working assumption is that a certain organization of the body can selectively interact with an additional physical carrier and that this connection can participate in conditions of subjective experience.

The co-formation hypothesis of personality. The author's assumption connecting a specific individuality with the organization of interaction, the body and history. The possible fundamental basis of experience is not identified in advance with the ready-made human personality.

Global neural workspace. A theoretical approach that links conscious access to the distribution of specific content among a variety of specialized processes. The book discusses it as a meaningful competitor that has its own testable predictions.

Decoherence. Weakening of the available interference manifestations of the subsystem during its interaction with the environment. Its description depends on the selected states, basis and model of the environment.

Measurement. A physical process that relates the state of a system to a discernible output in an instrument or other system. In standard calculations, conscious reading of the result by a person does not serve as a mandatory physical step.

Individuation. Formation of a separate individual perspective and its differences from others. In the book, this word refers to the task of explaining why interacting processes belong to one subject, while others form a separate story.

Interoception. Receiving and processing signals about the internal state of the body. Its contribution to experience must be distinguished from a complete explanation of subjectivity.

Qualia. The qualitative side of an experience: the way a color, taste, pain, or other experience feels. In the book, the word does not automatically designate an individual particle, field, or measurable quantity.

Quantum entanglement. A property of a composite state that is not represented by a mixture of independent states of its parts. Entanglement by itself does not constitute a controlled message channel.

Quantum channel. Mathematical description of a physically permissible transformation of quantum states under appropriate conditions. The word "channel" in this sense does not imply the consciousness of the sender or the recipient.

Coherence. The presence of certain phase relationships between the components of the quantum state relative to the chosen description. Its functional role depends on a specific process, and not on the mere fact of presence.

Markov approximation. A description in which further change is determined by the current state of the system without separately taking into account the entire history of its environment. The applicability of such an approximation must be justified for the process under consideration. [18]

Density matrix. A representation of a quantum state that allows one to calculate the probabilities of measurement results and describe both pure and mixed states.

Metacognition. Assessment and regulation of one's own cognitive processes. In particular, the ability to distinguish between more and less reliable own solutions. Not identical to confident speech about oneself.

Level population. The probability of detecting a system at a given energy level; in the chosen basis it is specified by the corresponding diagonal element of the density matrix. [14]

Neural correlate of consciousness. In a strict research definition, the minimum set of neural mechanisms that are jointly sufficient for a particular conscious experience. A physiological sign that only accompanies a condition may be its prerequisite or consequence and does not yet satisfy this definition. Establishing a correlate and explaining the occurrence of an experience are different tasks. [32]

Carrier. A physical system or a selected set of degrees of freedom, the states of which are involved in the transmission, storage or transformation of differences. The name requires specific properties to be specified in each model.

Objective reduction. In the corresponding theories, it is an assumed physical change in a quantum state that is not reducible to standard unitary evolution. Its mechanism and parameters are subject to separate verification.

Open system. A system for which interaction with the environment is essential for its description. Boundary selection is task-specific and does not automatically determine the subject's boundary.

Experience. The presence of a subjective side of what is happening. The working definition does not require language skills, an autobiography, or the ability to explain one's own condition.

Psychophysical postulate. An explicit assumption about the relationship between physical organization and subjective experience. It is not automatically derived from the equation of interaction of physical subsystems.

Radical pair. A pair of radicals with unpaired electrons and a common origin, whose spin dynamics can influence particular chemical pathways. The specific effects depend on the molecule and conditions.

Detuning. The difference between the frequencies of interacting transitions or oscillations. In the book’s minimal model, it limits the maximum probability of excitation transfer.

Reduced state. Description of one subsystem obtained from the state of the whole using a partial trace. It determines the statistics of local measurements, but does not store all the information about joint correlations. [14]

Relaxation. The transition of a system to a certain mode under the influence of interactions with the environment. The times of change in populations and phase relationships may vary.

Reflection. The system's appeal to its own thoughts, decisions and reasons for action. In functional research, it is important to examine whether such assessment influences subsequent behavior.

Self-awareness. Forms of representing oneself as a participant in what is happening. Body ownership, self-recognition, and an autobiographical narrative may require different mechanisms.

Entanglement witness. An observable whose value, when the test conditions are met, can rule out a description in terms of separable states. A particular witness detects only certain entangled states; failure to detect entanglement does not, by itself, prove its absence. [31]

Subject. The bearer of a distinct perspective of experience in the working sense used here. Functional self-representation can serve as a subject of research, but the name itself does not prove the existence of such a perspective.

Superposition. A linear combination of quantum states in which the relative phases can influence the results of suitable measurements. Does not amount to simple ignorance about a pre-selected option.

Theory of integrated information. An approach that connects consciousness with a certain internal causal organization of the system. Its special values cannot be replaced without justification by the total complexity or amount of recorded data.

Righting reflex. An animal’s ability to return to its normal body position after being turned over. In the study discussed, loss of this reflex serves as a behavioral indicator; this indicator does not, by itself, provide direct access to experience. [12]

Partial trace. Mathematical operation of obtaining the state of a subsystem from the state of a composite system. The resulting description usually does not allow us to reconstruct the complete state of the whole in a unique way.

Numerical identity. A relationship in which we are talking about the same being or object, and not about two copies with the same properties. In the matter of personality, it must be distinguished from similarities in memories, character, and behavior.

Hermitian operator. An operator equal to its adjoint. Its eigenvalues are real; in the quantum models considered here, this allows them to be related to the results of measuring a physical quantity. [14]

Orch OR. Theoretical program of Hameroff and Penrose, linking the supposed organized quantum processes in microtubules with an objective reduction of state. Considered in the book as a hypothesis with separate physical and psychophysical obligations.

T_1 and T_2. Designations of the characteristic times of longitudinal relaxation and loss of transverse coherence in the corresponding models. Their meanings and relationships depend on the mechanism; they are not universal times of existence of consciousness.

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