The World Hologram

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Abstract: As shown in The Quantum Mechanical Frame of Reference, Everett's formulation inherently defines idiosyncratic effective physical environments for each version of the functional identity of the observer, defined solely by observations, in the manner of Rovelli's Relational Quantum Mechanics. This accounts for determinate measurement records, and completes his resolution of the measurement problem. The remaining task is to make everyday sense of Everett's concept. He defines the functional identity as the record of sensory observations and machine configuration, which seems merely an epiphenomenon of the body-mind of the observer.

This functional identity is intensely familiar to each observer. It is simply the subjective reality, the known world, here the 'world hologram'. In Everett's formulation, the cut in the von Neumann chain is implicitly made at the level of conscious sensory awareness. Thus, not only is the effective physical environment defined solely by the record of observations, the self-identity synthesised from observations defines the sole determinacy of the body-mind of the observer. Everett's formulation is not addressing obscure issues of brain state, but the determinant of the effective physical reality of the observer, including the body-mind. Although highly counter-intuitive, it is nonetheless empirically coherent. On the 'inside view', as defined by Tegmark, Everett's relative state corresponds, directly and precisely, to human experience.

1 Introduction

Everett's formulation is doubly obscure. Firstly, there seems to be no explanation of how the observer is to be understood as having unique determinate measurement records. Secondly, he describes the appearance of collapse to the observer, but the functional identity, with respect to which the appearance of collapse is applicable, appears to bear little relationship to the full definition of the body-mind with which a human observer naturally identifies.

In The Quantum Mechanical Frame of Reference (Soltau, 2010), it is shown that Everett's formulation inherently defines an effective physical environment, idiosyncratic for each individual functional identity of the observer. This resolves the central problem in understanding his formulation, demonstrating how the observer inevitably makes specific observations, and forms determinate measurement records. This is a unique solution. The dynamics of the effective physical environment applies only to the functional identity Everett defines. Thus, in order to complete his formulation, an explanation is required of how this applies to the human observer as ordinarily defined, as physical body-mind.

Everett (1957, p. 457) defines the functional identity of the observer as the state of the memory, in turn defined as the record of sensory observations and machine configuration. While this structure of information seems to be the definition of only a minuscule fraction of the identity of a physical observer, the role it plays in the life of the observer is as remarkable as it is straightforward. In the human observer, this structure of information is formulated into a concept of the world, here the world hologram. At each moment, the next observation of reality updates the world hologram. Thus it is intensely familiar; this is the subjective reality the observer experiences at all times, the known world. However, this world one knows is, also, the record of correlations with the effective physical environment. This, and this alone, defines the determinacy of the effective physical environment of the observer. Thus the known world is effectively 'the real world', and it is indeterminate except where observed.

This functional identity is very different to the accustomed identity, the body-mind. However, while conceptually one identifies with the body-mind as a whole, one knows only that much of the physical and mental system one has observed. Just as the world hologram is formed from observations of the world, the self-identity is formulated from observations of the body-mind, and forms the central feature of the world hologram. On this view, the cut in the von Neumann chain[1] is made at the level of the sensorium. Thus, just as the record of sensory observations is a record of the correlations with the physical world, the record of observations of machine configuration is a record of the correlations with the

1 The sequence of causal steps between an event in the world and conscious observation.

physical body-mind. Moreover, from the perspective of the functional identity, the body-mind is indeterminate except where observed, just like the rest of the effective physical environment. in everyday life one naturally assumes that the known world is 'the world', and the self-identity is 'me'. Both assumptions are effectively correct.

Everett demonstrates that there is the appearance of collapse with respect to the state of the memory (1973, p. 10), which he defines as the functional identity. He also makes clear that the physical body is in a superposed state of instantiating all possible variations of the state of the memory, thus all possible functional identities. The appearance of collapse is therefore a phenomenon that occurs only with respect to the functional identity: the body exists in a superposed or mixed state, following the time evolution of only the linear dynamics. All conscious observers experiencing the appearance of collapse, in other words making observations, are necessarily of this type.

2 The Quantum Mechanical Frame of Reference

Everett (1957) resolves the measurement problem by demonstrating that it is not necessary to postulate physical collapse, since the appearance of collapse is inherent in the linear dynamics. Everett's formulation seems incomplete, however, precisely because there seems to be no physical instantiation of this appearance of collapse as a specific and singular outcome. This, however, is only the case on the objective view. On the subjective view, collapse is enacted. Everett's formulation hinges on this distinction. As Tegmark states:

> Everett's brilliant insight was that the MWI *does* explain why we perceive randomness even though the Schrödinger equation itself is completely causal. To avoid linguistic confusion, it is crucial that we distinguish between
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> - the outside view of the world (the way a mathematician thinks of it, i.e., as an evolving wavefunction), and
> - the inside view, the way it is perceived from the subjective ... perspective of an observer in it.
>
> (1997, p. 2; his italics)

As he goes on to describe, while the objective or outside view is of a superposition of all possible states of the observer, which evolves in time maintaining the strict causality of the linear dynamics, the subjective, inside view, the perceived view of an observer described by a typical element of the superposition, is of a random series of specific observations. These two views are personified by those of Wigner and his friend in the Wigner's friend concept (1961).

Everett's formulation is held to be incomplete, because on the outside view there is usually no single determinate outcome of observation, or measurement record. All possible outcomes, and corresponding records, exist in superposition or mixture. On the inside view, however, in each Everettian relative state, here the quantum mechanical frame of reference, of each different version of the functional identity, there is only a single specific determinate outcome of the observation, and a specific determinate record made. The vital concept required to complete Everett's formulation is a clear rationale for the validity of the inside view, as distinct from the outside view: the basis on which the effective quantum state on the inside view is different from the standard outside view. Given multiple realisability of the functional identity, this is inherent.

The functional identity of the observer, a structure of information, is multiply realised: it is instantiated in every version of the physical environment commensurate with the existence of this structure of information. Since, in Everett's no-collapse universe, all these worlds exist simultaneously, the effective physical environment of this structure of information is the physical simultaneity of all of them, a 'universe superposition'. The record of observations that forms part of the functional identity is, naturally, the record of correlations established with the physical environment. Thus, the simultaneity of all of them, the universe superposition, is determinate with respect to that much of the physical environment correlated with the observer. Equally, since every possible variation of the physical environment concomitant with the existence of this correlations record is included in the simultaneity, the universe superposition is otherwise indeterminate: except where defined by the correlations record, the environment is necessarily a simultaneity of all possible, different, variations of the environment. Thus the effective physical environment of the observer is determinate where observed, and thus defined by the correlations record, and otherwise indeterminate.

This defines a system in which each such version of the identity is in a different, idiosyncratically defined, effective physical environment, defined by a specific quantum state. Although unfamiliar, this relativisation of the quantum state is inherent in quantum mechanics. Just as different observers can have different frames of reference in relativity, as Rovelli states, in an exact parallel:

> ... a quantum mechanical description of a certain system (state and/or values of physical quantities) cannot be taken as an “absolute” (observer independent) description of reality, but rather as a formalization, or codification, of properties of a system relative to a given observer. (1996, p. 6)

On the inside view of each relative state, inside each quantum mechanical frame of reference, specific observations are made and determinate measurement results recorded, while on the outside view, all possible variations exist in superposition or mixture. Thus a reconstruction of Everett's formulation clearly demonstrates the difference between the outside and inside views. Objectively, after Wigner's

friend makes a measurement, from Wigner's point of view, all possible outcomes exist in a simultaneity. Subjectively, however, on the inside view of the quantum mechanical frame of reference, for each version of the friend, a specific measurement result has been observed. To each functional identity there is the appearance of collapse, all within the context of the unitary linear dynamics.

3 The Known World

There is one major puzzle left. What does it mean? Everett's definition of the functional identity of the observer is a far cry from the human observer as ordinarily defined, as the physical body-mind. The full nature of this functional identity is the final concept required to make sense of his formulation.

The first point to note is that the functional identity exactly defines the experiential reality of the observer. In the human observer, the functional identity Everett defines is a structure of information with which one is inevitably intensely familiar. The record of observations is integrated to form an accessible map or model of the environment, the known world. Whenever one recalls the appearance of a significant place one has visited, or where one might have put the house keys down, it is this structure of information one is accessing.

As we can all attest, when accessing one's record of the known world, it is experienced as a spatially distributed environment, exactly alike in representational form to the way we understand the physical world to be arranged: in terms of three dimensional objects and the distances and spaces between them. Since this inner representation of the world is experienced as spatially distributed and three dimensional, while in fact being encoded in the neural network of the brain, it is effectively a hologram of the world known through observations.[2] The observation of the present moment is the immediate and lucid view of the real world, which is added to this 'world hologram' at each moment. The observation is here defined as the structure of sensory information representing "... current sensory data and machine configuration." (Everett, 1957, p. 457), formulated, and thus registered, in the neural network of the observer. The world hologram is defined as the cumulative integrated record of the sequence of such observations.[3]

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2 Naturally the observations and the consequent world hologram are structured not solely in terms of visual information but in all five senses.

3 This definition of the world hologram is purely functional and unrelated to any specific areas of the brain or class of memory. While the world hologram obviously comes under the banner of memory, there are properties of the mind associated with memory, such as learned stimulus-response associations, which would not be observed unless the observer experienced their effect, and thus would not necessarily be part of the world hologram.

4 The Experiential Interface

Everett models observers in the simplest possible way, as:

> … automatically functioning machines, possessing sensory apparatus and coupled to recording devices capable of registering past sensory data and machine configurations. We can further suppose that the machine is so constructed that its present actions shall be determined not only by its present sensory data, but by the contents of its memory as well. Such a machine will then be capable of performing a sequence of observations (measurements), and furthermore of deciding upon its future experiments on the basis of past results. (1957, p. 457)

Thus he defines the functional identity as the state of the memory:

> If we consider that current sensory data, as well as machine configuration, is immediately recorded in the memory, then the actions of the machine at a given instant can be regarded as a function of the memory contents only, and all relevant experience of the machine is contained in the memory. (p. 457)

In the human observer, sensory observations are recorded in memory, and thus the world hologram forms a straightforward implementation of the structure of the functional identity in this regard. This corresponds to a specific cut in the von Neumann chain, placing the division between observer and observed at the final step, between the sensorium, the field of inner awareness, and experiencing consciousness.

Although memory is not physically separate from the rest of the neural network, the functional separation is obvious. Machine configuration is more problematic. In Everett's idealised machines, machine configuration could be recorded in the same way as a computer backup, the memory being a separate component, but the human neural network can have no functionality of this nature. There are a number of difficulties in storing the machine configuration of a unitary holistic system defined solely by that configuration. Obviously it cannot be recorded in full: the state of the system as a whole is always contextual to any records, and there is no separate 'backup volume'. A cut in the von Neumann chain at the level of the sensorium, however, naturally resolves this problem. Machine configuration is represented in the sensorium, as physical body sensations, feelings, emotions and thoughts, all of which are observations, and are thus recorded in memory. This gives rise to a self-concept accessible to the conscious observer.

The body-mind produces dense and highly information-loaded 'reports' of the machine configuration, which are known to the observer as proprioception, enteroception, feelings, emotions and thoughts, all of the experiences of oneself

with which the conscious observer is familiar. These observations of machine configuration are integrated to form the self-identity, the central component of the world hologram.

Cutting the von Neumann chain at the final point, conscious awareness, gives rise to a purely experiential definition of the observer. Everett's concepts apply seamlessly to this cut, defining the process of conscious observation in the human observer. The functional identity of the observer is defined at the operational level of subjective experience, meaning the experience itself and the record of experiences, as distinct from all the processes which go to make up subjective experience. Each of us has direct experiential evidence for this divide: the sensorium is the field of inner awareness, conscious observation. From this experiential perspective, the sensory information from the body's sensors is the input to the neural system, while the five-sensory image experienced is the output. The world hologram is the integration over time of this output, corresponding to the contents of the memory of the recording automaton in Everett's formulation. The output of internal computations in the neural system is experienced in this sensorium, in the same way as the output of the neural system representing images of sensory data.[4]

Naturally, some observations are taken in subliminally, thus aspects of the world are represented in the sensorium, although not consciously noticed. Therefore, observation will here be taken to mean any sensory formulation of external or internal processes in the sensorium, defined as the experiential output of the neural system, a purely functional definition.

5 The Reality

The world hologram is the known world of the observer. Due to multiple realisability in the no-collapse universe, it is also the definition of the determinacy of the effective physical environment. Every possible physical environment in which this observer has this record of observations is included in the effective physical environment. The result is that every aspect of the environment is determinate only to the level of resolution of those observations. For example, if an observer observes a red pen on a black desk, every possible physical configuration of the environment with that appearance is included in the effective superposition. Therefore, in the quantum mechanical frame of reference of the functional identity of the observer, the micro-physical structure of pen and desk is indeterminate, since all possible structures with that appearance are

4 Again, this is a purely functional distinction, and can be implemented in a number of different ways. For instance, it can be seen as the net effect of a multiplicity of activities in the neural network such as the Multiple Drafts proposed by Dennett (1991).

effectively superimposed. Thus the determinacy of the environment is defined solely by the record of sensory observations, the world hologram. Somewhat remarkably, the known world, which is also the record of correlations formed with the environment, is the definition of the determinacy of the effective physical environment of this observer, 'the real world'.

5.1 Virtual Reality

As Deutsch states, the subjective concept of reality is in fact a virtual reality:

> Imagination is a straightforward form of virtual reality. What may not be so obvious is that our 'direct' experience of the world through our senses is virtual reality too. (1997, p. 120)

The world hologram is a virtual reality defined by observations, and as Deutsch states, the immediate view of reality is a view of this virtual reality also. This 'direct' experience of the world, the immediate view of reality, is the sensorium, the experiential output of the neural system. Objectively, the world hologram is solely a personal construct, a virtual reality in the body-mind of the physical observer. It is also, however, the definition of the determinacy of the effective physical environment of the functional identity, the quantum mechanical frame of reference.

Additionally, as the world hologram is updated by new observations of the physical environment, this causes change to the effective physical environment: a new version of the world hologram defines a new version of the universe superposition, a new quantum mechanical frame of reference. Subjectively, therefore, meaning on the inside view of the quantum mechanical frame of reference of this observer, this so-called virtual reality effectively is the reality for this observer. One tends to assume that the world one knows is the real world, making no distinction between the virtual reality and the physical environment 'out there'. Given multiple realisability of the functional identity, the two are essentially equivalent. This can be understood as considering the body-mind of the observer to be simply the final measuring device, the output being the contents of the sensorium. The state of the physical environment is measured, and the measurement result is a five-sensory image, the structure of information defined in the sensorium.

5.2 The Holographic Principle

Not only is this all the definition this effective physical environment has, it is only the surface of the world facing the observer that becomes part of the definition. There is thus an interface with the rest of the universe, the observed surface of the physical environment, behind which everything is indeterminate, except where defined by the interface. This is strikingly similar to the holographic

principle of t'Hooft's Dimensional Reduction in Quantum Gravity (1993),[5] according to which there can be no more definition to the region beyond the interface than defined by the interface itself. This is a puzzling result in our ordinary accustomed concept of the universe, but in a reality defined by the state of the memory, such an interface is exactly what is defined by the correlations record. This is a description of the Everettian universe, in the reality of an individual observer, defined by the state of the memory. The holographic principle defines the same physical environment as is implicitly defined by Everett's functional definition of the observer, here the world hologram.

6 Identity

While only the surface of the surrounding environment is defined, the observer is defined in some detail. The physical self-image, the mental picture one holds of one's physical self, is built up from observations of oneself, and as such it is part of the world hologram.[6] This self-image is the integrated sum of all of the observations one has made of oneself, Everett's records of machine configuration. One observes the body not only externally in mirrors but also internally through proprioception and enteroception, and all these observations are added to the avatar self-concept figure in the world hologram, the self-identity. These observations, however, are all one actually knows of one's body. Just as the world hologram is the known world, the self-image is the known physical self, a mental construct formed from observations. Conceptually, one identifies with the body as a whole, but one knows only that much of the body that one has observed.

In the same way, the self-image holds a representation of one's mental nature and characteristics, and this is all part of the self-concept figure in the world hologram also. As with the body, while one is aware of being a thinking, feeling entity, a mind in a body, one does not know the whole of one's mind. Neural network patterns are altered with each neural impulse, and associations and ingrained responses are built up as a result. The vast majority of this information is unknown by the individual. What one knows are all the mental properties one experiences, such as thoughts, feelings, memories and expectations, all of which are observations and are added to the self-identity in the world hologram.

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5 A consequence of the second law of dynamics (Smolin, 2000, p. 174).

6 Naturally enough, it is the central figure in this concept of the world, but this central figure is far more immediately obvious to some individuals than to others. Some people have a full and precise view of their appearance and 'see themselves in the picture' of their experience of reality a all times, while others just see the reality in front of them. All individuals, however, have a detailed body image in the subconscious: this physical sense of self is fundamental to self-identity.

6.1 The Body Determinate

In the quantum mechanical frame of reference of the world hologram, the physical world is highly indeterminate, and this applies even to the body of the observer. This is because a specific world hologram exists not only in bodies which are identical, but also in bodies which are slightly different, and the net result is indeterminacy.

In the effective multiverse of the no-collapse universe, there are inevitably a large number of identical copies of the body of the observer. As Deutsch states:

> If, aside from variants of me in other universes, there are also multiple identical copies of me, which one am I? I am, of course, all of them. Each of them has just asked that question, 'which one am I?', and any true way of answering that question must give each one of them the same answer. (1997, p. 279)

Naturally, the same identical world hologram must necessarily exist in all of these identical copies of the body of this observer, in all the different versions of the world in which such a body exists. However, the same identical world hologram exists not only in all of the identical copies of the body of the observer. It exists also in the bodies of observers where the structure of the body is slightly different, but that difference does not impact the definition of the world hologram.

The layout of the specific pathways of minor blood vessels interior to the body of a given observer, for instance, could be in any number of different configurations. In the universe of the unitary wave function, every different variation of this observer exists. Thus, variations with the same world hologram but different configurations of these blood vessels exist. The same is true for every physical variation of the body possible with the same world hologram: variations embodying physical distinctions of aspects of the body which have not been experienced, and thus have not impacted the world hologram.

Given the Everettian no-collapse universe, a simultaneity of all possible physical environments, the effective physical environment of the world hologram is a simultaneity of all of the versions of the environment in which this world hologram exists, a universe superposition. In this environment, the physical body of the observer is the simultaneity of all of the bodies in which this world hologram exists. Since the world hologram is the record of observations, and this is the only commonality, only those aspects of the body observed are identically the same in all these environments. Thus only those aspects of the body observed are determinate, while all other aspects of the body are indeterminate. Not only is the majority of the physical world indeterminate, but the majority of the fine detail of the structure of the body is indeterminate also. Everything about the physical body not observed, and thus defined in the world hologram, is indeterminate. There is nonetheless a real and specific physical body of the observer: the superimposed sum of all of the bodies in which this world hologram exists.

While this might seem deeply counter-intuitive, and unrealistic, the body is not 'not there' where not observed; it is a simultaneity of all possible bodies commensurate with this world hologram. Naturally, decoherence produces a high degree of determinacy in the physical environment, including the physical body, but all such decoherent determinate environments in which a specific record of observations exists are included in the universe superposition. Thus, that much of this body which is known from observations, and thus defined in the self-image, is determinate, and it is only this which is determinate. The self-image in the world hologram defines the full definition of the determinacy of the physical body. Just as the world one knows defines the determinacy of the effective physical environment, the self-image defines the determinacy of the body in reality.

6.2 The Effective Mind

Yet more curiously, this same principle applies to the mind. The world hologram exists not only in all the bodies of observers which have the same identical mind. It exists also in the bodies of observers in which the mind is slightly different, but the world hologram is identically the same: having the same record of observations, both of the physical world, and of the output of all the mental processes of the body-mind. As before, the effective physical environment is the simultaneity of all of the worlds containing this world hologram. Thus, from the experiential perspective, the perspective of the observer as defined by the world hologram, only those mental properties which have been observed are determinate. Defining the state of the mind as the state of the neural network, one is aware of only the tiniest fraction of this complex system in operation. In the reality of Everett's functional identity of the observer, only the state of the mind represented in the sensory observations formulated in the sensorium, thus forming part of the world hologram, is determinate, and all else is indeterminate.

Given multiple realisability, even the psychological identity is determinate only where it has been implied as a certain way by observations. If I find myself to have a specific psychological pattern, then every effective physical environment in which I exist, is one in which this identity has that psychological pattern: the reality, the effective physical environment, can only be such as to necessarily give rise to that observation. Everything else about my psychological patterning is not just unknown, defined in the unconscious; it is indeterminate. Like all other aspects of this reality, it becomes determinate only when observations define the body-mind system as having a specific property.

6.3 Machine Configuration

Naturally, the world hologram is an aspect of the machine configuration, the physical definition of the state of the body-mind of the observer. Nonetheless, in the effective physical environment of the world hologram, the machine

configuration itself is largely indeterminate. This is the result of making the cut in the von Neumann chain at the level of the sensorium. The world hologram is the record of correlations not only with the world at large, but also with the body-mind. Naturally, machine configuration is recorded in the system even where not observed. However, here the view is taken that this information is not part of the functional identity. As defined in Everett's formulation, the physical observer is a measuring device. The state of the body-mind, the machine configuration, is also measured by observations formulated in the sensorium, specifically, the familiar processes of proprioception, enteroception, thoughts, feelings and emotions. Machine configuration is therefore recorded where observed, as with all aspects of the environment. Thus, with regard to machine configuration, Everett's functional identity defines both the physical self-image and the psychological self-concept. The structure of information defining the body-mind known to the observer is the self-identity built up from observations of oneself, external and internal, and represents the cumulative record of machine configuration, which is thus a perfect fit with the accustomed experiential sense of identity in the human observer.

6.4 The Unconscious

The record of observations of body and mind defines the state of the body-mind, the machine configuration, to the degree it is defined, and it is otherwise indeterminate. This raises a fascinating point. The operation of the neuro-endocrinal system is the mind as a whole. This can be considered as the computational entity running the body and giving rise to cognitive processes: effectively, the operating system managing the hardware, and hosting higher functionality such as cognition. That much of this system unknown to the observer is the unconscious mind, originally noted by Paracelsus in 1567 (Ernest, 1967, p. 20). As long established in psychology, it is an active information processing structure, which carries out high level prioritising and many other functions, including displaying a type of intelligence (Lewicki *et al.* 1992), outside of conscious awareness.[7] Recently, this has even been demonstrated in neuroscience (Hirsch *et al.* 2004), Naturally, in the no-collapse universe, there are many different minds, neuro-endocrinal systems, which instantiate a specific world hologram. From the perspective of that entity, in the quantum mechanical frame of reference of that structure of information, they are all superimposed. From this perspective, the perspective of the observer as defined by the world hologram, only those mental properties which have been observed are determinate. By definition, the unconscious is the sum of those aspects of the mind unknown to this observer: unobserved. Thus the unconscious is the simultaneity of all such definitions of the unconscious, and highly indeterminate.

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7 One of the aims in psychotherapy is to understand enough of how one's unconscious works that one can stop 'pressing the wrong buttons': triggering unconscious psychological patterns into activity which are the opposite of what one wants.

This explains another puzzle seemingly insuperable in a physics without quantum mechanics. As Atmanspacher states:

> In Jung's depth psychology it is crucial that the unconscious has a *collective* component, unseparated between individuals and consisting of the so-called *archetypes*. They are regarded as constituting the psychophysically neutral level covering both the collective unconscious and the holistic reality of quantum theory. At the same time they operate as "ordering factors", being responsible for the arrangement of their psychical and physical manifestations in the epistemically distinguished domains of mind and matter. (2004; his italics)

In an ordinary universe, the concept of a collective unconscious is at best mysterious. It seems to require some non-physical connection between the individual observer and all other human observers. However, if the unconscious in each individual observer is indeterminate, this provides the strange properties Jung's framework describes. The unconscious has a collective quality, since all possible properties of the mind are present, except where specifics have been observed. Although there is no connection between different observers, observers are inherently separate, there is an inherent commonality: with regard to the unconscious, we are all identically the same, encompassing all possibilities, except where self-observed. Since all possible psychological patterns are present, all the archetypes are automatically present in each observer. In addition, the unconscious is held to connect to, or even encompass, the whole of the wider universal reality, and this aspect of Jung's analytic framework is upheld also. Indeterminate, the unconscious is simply one logical aspect of the universal reality lying the other side of the interface between the observer and the rest of the no-collapse universe.

6.5 Self-Identity

The only determinacy in the quantum mechanical frame of reference of the functional identity of the observer is the world hologram, and the only determinacy of the body-mind is the self-identity. The latter nonetheless defines a fully operational observer as a dynamic cybernetic entity. The definition of my identity is not just 'flat' data, it is logically akin to a highly sophisticated computer program. It defines not just objectives, but strategies and methodologies. It contains the principles directing the way I do all the things I do, all the mental and physical activity which I carry out, my traits, habits and decision making processes: in so far as these are derived from observations, and thus determinate. In this way, the world hologram is truly a functional identity. Functionally, this is who and what I am.

Although, objectively, the self-identity is simply an avatar figure at the centre of the virtual reality generated by the mind of the observer, in the quantum mechanical frame of reference of the world hologram, it is the full and complete definition of the determinacy of the body-mind of this observer, including the

psychological make up, the character. Of the physical and mental entity one ordinarily identifies with, only that defined by the self-identity, the self-concept including the self-image, is determinate. Just as only the known world is determinate in this quantum mechanical frame of reference, only that much of oneself defined by the self-identity is determinate also. This is nonetheless commensurate with every aspect of the experience of a conscious observer.

6.6 Summary

Objectively, Everett's functional identity of the observer is solely an epiphenomenon of the body-mind of the physical observer. Subjectively, however, meaning within the idiosyncratic quantum mechanical frame of reference of this identity, it is the sole determinant, not only of the effective physical environment, but also the body-mind itself. Objectively, on Tegmark's outside view, the observer is a body-mind. Subjectively, on the inside view, the observer is the functional identity Everett defines, the world hologram. In the light of this unexpected implication it is not difficult to see why full comprehension of the concept has been elusive. A world determinate only where observed is a well-aired idea, though none the less counter-intuitive for that. That one's very body-mind should be determinate only where observed, is a natural extension of this concept, but certainly a significant degree stranger. However, it helps to note that the body-mind, like the world, is not 'not there' where not observed. Like the reality, it is all possibilities, except where observed. It is a fullness not an emptiness. Thus, despite the fact that this definition of identity is vague about the details of the body and the specifics of much of the mind, the individual is a person who does have all these properties, even if they are not precisely defined and determinate in the world hologram. Just as the physical environment effectively collapses and acquires determinacy where observed, so too does the body-mind of the observer, acquiring specificity where observed. There is a real physical body-mind, just as there is a real physical world. It is simply that only those aspects which have been observed are determinate. The rest is all physical possibilities at once.

Everett accounts for the appearance of collapse to observers, an experiential phenomenon. What is shown here is that the inside view inherently defined by his formulation, the subjective reality of the functional identity, corresponds precisely to the experiential reality the conscious human observer is directly familiar with. What is remarkable is that his mechanical and comprehensive solution defines precisely not only the experiential reality of the observer, but also the nature of the observer as an experiential entity. Moreover, as Everett (1973, p. 10) demonstrates, only with respect to the functional identity, defined as the state of the memory, is there the appearance of collapse. Thus, all conscious observers experiencing the appearance of collapse, in other words making observations, are necessarily of this type. We are world holograms, and physical reality, including the body-mind, is determinate only where observed.

7 Inside and Outside

Central to understanding Everett's formulation is the radical difference between the inside and outside views of a mathematical structure as described by Tegmark. In reference to quantum mechanics, Tegmark declares:

> Here one choice of outside view is that of a Hilbert space where a wave function evolves deterministically, whereas the inside view is that of a world where things happen seemingly at random, with probability distributions that can be computed to great accuracy from the wave function. It took over 30 years from the birth of quantum mechanics until Everett showed how the inside view could be related with this outside view. (1998, p. 10)

Everett's formulation defines the inside view of the effective physical environment. This is the 'Relative State' in the title of his thesis, here the quantum mechanical frame of reference. The reason full comprehension of his formulation has been so challenging is that it defines something totally unexpected, which is, nonetheless, the full and complete explanation of the meaning of quantum theory: different dynamics effective for the inside view to the outside view. Only on the inside view is there collapse. As Everett states, after observation:

> It is then an inescapable consequence that after the interaction has taken place there will not, generally, exist a single observer state. There will, however, be a superposition ... each element of which contains a definite observer state (1973, p. 10)

On the outside view, there is no collapse, simply a continuation of the time evolution of the linear dynamics, hence a superposition of all of the possible outcomes, subsequently decohering to a mixture. On the inside view, as each observation is made, a new correlation is added to the quantum mechanical frame of reference. As Everett states:

> *… the observer-system state describes the observer as definitely perceiving that particular system state*. This correlation is what allows one to maintain the interpretation that a measurement has been performed. (1957, p. 459; his italics)

Thus, as he says:

> ... the formal theory is objectively continuous and causal, while subjectively discontinuous and probabilistic. (1973, p. 9)

The time evolution of the linear dynamics progresses until an observation is made. This changes the record of observations, which changes the quantum mechanical frame of reference, and thus the linear dynamics. The time evolution of the new version of the linear dynamics progresses until an observation is

made, and the cycle continues. Thus, on the inside view, from the perspective of the functional identity of the observer, 'subjectively', the cyclical nature of the standard formulation is effected: progression in the linear dynamics causes the exercise of the collapse dynamics, the collapse causes the change in the effective linear dynamics, and the cycle begins again. Thus, on the inside view, there is the appearance of the exercise of the standard von Neumann - Dirac formulation of quantum mechanics (1955). As Everett states:

> ... we were able to show that all phenomena will *seem* to follow the predictions of this scheme to any observer. (1973, p. 110)

8 The Nature of the Observer

It seems clear that Everett intends to model the functional level of sensory experiencing, the sensorium:

> For any interpretation it is necessary … to deduce the changes that occur in an observer as a consequence of interaction with the surrounding subsystems, and to interpret the changes in the familiar language of experience. (1957, p. 457)

> The mathematical model seeks to treat the interaction of such observer systems with other physical systems (observations), … and to deduce the resulting memory configurations, which are then to be interpreted as records of the past experiences of the observers. (p. 457)

Clearly, the resulting memory configurations are to comprise the record of the *experienced* sensory formulations, and this implies a cut in the von Neumann chain at the level of the sensorium, At the functional level of sensory experiencing, the body-mind is simply the final measuring device.

The nature of the observer is very different on the inside and outside views. On the outside view, the observer is a body-mind, a physical entity housing a highly complex computational capability. The inside view appears to be just the inside view of this 10^{14} cell real world object, which, of course, it is. However, on the inside view, in a universe superposition, from the point of view of the functional identity, this real world object is a simultaneity of all such objects housing this functional identity. Thus it is only determinate where observed, as is all of the effective physical environment.

Everett's formulation defines the operational dynamics of the inner view, experiential reality. Each observation is added to the record of observations, the world hologram, which is exactly the experiential entity one finds oneself to be. On the outside view, objectively, we are body-minds. Subjectively, on the inside view, we are world holograms, virtual realities.

This is very difficult to grasp without understanding that the body-mind is a measuring device, something one has, while the world hologram is the identity, something one is. Objectively, on the outside view, the human observer is the physical observer, the body-mind, just as in Everett's formulation the observer is the automatically functioning machine. Subjectively, on the inside view, in terms of experiences, and the resulting memory configurations, the observer is the functional identity. As Everett states, there are some language difficulties here, since both are 'the observer':

> At this point we encounter a language difficulty. Whereas before the observation we had a single observer state afterwards there were a number of different states for the observer, all occurring in a superposition. Each of these separate states is a state for an observer, so that we can speak of the different observers On the other hand, the same physical system described by the different states. is involved, and from this viewpoint it is the same observer, which is in different states for different elements of the superposition (i.e., has had different experiences in the separate elements of the superposition). In this situation we shall use the singular when we wish to emphasize that a single physical system is involved, and the plural when we wish to emphasize the different experiences for the separate elements of the superposition. (e.g., "The observer performs an observation of the quantity A, after which each of the observers of the resulting superposition has perceived an eigenvalue.") (1973, 68, footnote)

Thus Everett defines 'observer' as denoting the outside view and 'observers' as denoting the inside view.

Each observer is two things at once, different on outside and inside views. As Bitbol asserts, the only thing required to make sense of quantum mechanics is a dual view of ourselves as observers, the outside view, on which one is an ordinary body-mind, and the inside view, on which one is the determinant of the quantum mechanical frame of reference:

> ... we only have to acquire a double view of ourselves: ourselves as one part among many others of the chain of relations which constitute the world, and ourselves as privileged beings ... for ourselves; ourselves as naturalized entities, and ourselves as transcendental backgrounds. (2008, p. 10; his ellipses)

By making the cut in the von Neumann chain at the very end of the chain, at the level of the sensorium, one is according special status only to the point where the quantum state is defined by a structure of information, the record of observations, this being also the record of correlations with the physical environment. With respect to the functional identity, this is the determinant of the effective physical environment, the quantum mechanical frame of reference. And it is 'here', at the end of the von Neumann chain, that experiential reality exists. Thus the observer

experiencing this structure is 'here' in this situation. This is the fundamental 'situatedness' Bitbol draws our attention to (2008). The inside view is the experiential reality, and it is here, and only here, that Everett shows us there is any collapse phenomenon, as indicated by the plural:

> ... it develops that the probabilistic aspects of Process 1 reappear at the subjective level, as relative phenomena to observers. (1973, p. 115)

If we are experiencing collapse, making observations, we are entities of this nature.

As an experiential entity of this nature, one exists only on the inside view. Thus the functional identity Everett defines is the true identity of each conscious, meaning simply experiencing, operational, observing entity. What makes this an even bigger step of comprehension is twofold. The functional identity does not define as determinate all of the body-mind one customarily identifies with, only that much of it which is observed and thus known. Additionally, the functional identity defines the determinacy of all of the quantum mechanical frame of reference. In other words, in terms of information, the functional identity of the observer is the quantum mechanical frame of reference. In the final analysis, not only is the view of the world very different on the inside view, the identity of the observer is very different also. Given this understanding, it is clear that Everett's insight is highly significant, not only for the revelation of the true nature of quantum mechanics, but of the true nature of observers in the no-collapse universe also.

9 The Process of Information

On the inside view, the appearance of collapse in the subjective reality is an information process: the addition of the observations, structures of sensory information, to the world hologram. This is the operational dynamics of the virtual reality experienced by the observer. Whenever more than one such world hologram is instantiated in a single physical environment, due to superposition, this information process fissions, as does the effective environment. This is directly borne out by an example given by Mitra:

> If an initial state
>
> $$|\psi \text{ initial}\rangle = |O_1\rangle\,|U_1\rangle \qquad (4)$$
>
> evolves in time to become a superposition of the form
>
> $$|\psi \text{ a while later}\rangle = |O_2\rangle\,|U_2\rangle + |O_3\rangle\,|U_3\rangle \qquad (5)$$
>
> We then interpret this as two parallel universes, one containing the observer in state $|O_2\rangle$, the other containing the observer in the state $|O_3\rangle$. (2008, p. 2)

As he describes, $|O_1\rangle$ is the classically describable macrostate corresponding to the experiential state of the observer, and $|U_1\rangle$ is the state of the rest of the universe concomitant with the existence of this observer.

In the human observer, this superposition is a very short-lived phenomenon. Decoherence rapidly produces determinate versions of all possible specific outcomes. The inside view of each decoherent, determinate version of events is unique and idiosyncratic in every case: it is the inside view of a specific version of the physical environment.[8] At the same time, since the specific structure of information defining each inside view, the world hologram, exists in every physically possible decoherent environment in which it is instantiated, the effective physical environment is the simultaneity of all such physical environments.

The sensorium is the net product of all the processes of information operating in the mind that take the information from the body's sensory devices and give rise to the contents of awareness. In computational terms, these processes are in the position of operational applications running on the hardware and operating system of the body and mind, and the net result of this system of information precessing is the human measuring device. The measurement is the sensory data representation of the immediate view of the physical environment, along with the dense and highly specialised reports of internal physical and psychological state, Everett's machine configuration. The latter, in logical terms, are the diagnostic and status reports of the hardware, operating system, and cognitive processes. Altogether this defines the virtual reality that Deutsch points out is in operation in all conscious human observers. This is the inside view of the quantum mechanical frame of reference, Everett's relative state. This is the experiential reality of the observer.

The central point is that on the inside view, in the experiential reality, there is the collapse of the probabilistic quantum state, while on the outside view there is not. It appears an oxy-moron to say that there is a quantum mechanical process which applies on the inside view, but does not apply on the outside view. It seems somewhat obvious that the linear dynamics subsumes every possible aspect of the time evolution of the physical system, and the observer is a physical system. However, this is the source of all the difficulty in comprehending Everett's solution to the measurement problem. At the logical level of the observer as a physical system, there is no collapse. As he states, there is no actual physical collapse, only the appearance of collapse, meaning only on the inside view, experientially, is there collapse. In other words, the collapse dynamics is an information process; the collapse dynamics is the process of observation.

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8 Decoherence, however, does not solve the measurement problem, it simply explains the transition of the system to a mixture of states, in which, each, singly, is a determinate reality. As Donald states: “Decoherence by itself does not break symmetry; only decoherence plus collapse or observation.” (1999, p. 53)

The collapse dynamics is not a physical process, in the ordinary sense of the phrase. This is why there is only the appearance of collapse. It is the change of the quantum state effective for the observer, and hence the change of the linear dynamics effective for the observer. In physical terms it is a 'jump' to a 'parallel reality'. As Everett states:

> The "quantum-jumps" exist in our theory as relative phenomena (i.e., the states of an object-system relative to chosen observer states show this effect), while the absolute states change quite continuously. (1973, p. 115)

The collapse dynamics is essentially a process meta to the physical, as Everett states:

> ... [our theory] can be said to form a *metatheory* for the standard theory. (1957, p. 462; his italics)

The collapse dynamics is a purely subjective process, but this does not mean it is something happening in the brain of an observer. It is a process that renews the subjective definition, not only of the whole brain, and the whole body-mind, but of the whole effective physical environment. Subjectively, in the experiential reality of the observer, the definition of the effective physical environment of one moment is replaced by that of the next moment; objectively all are pre-existing and unchanging.

Collapse can only take place at the experiential level. At the physical level, all possible outcomes happen, more correctly, exist. At the experiential level, collapse is the experience of the change of the quantum mechanical frame of reference, as each observation is made, and the effective quantum state of the environment, defined by the correlations record, changes. Only at this level, the level of structures of information, on the inside view, can there be a 'collapse' of this nature. As the linear dynamics progresses, the next observation is formulated in the neural network of the observer. As the formulation is completed, and this observation is added to memory, the correlations record changes. Subjectively, on the inside view, possibilities collapse to certainty, for each and every version of certainty. Objectively, on the outside view, there is a simultaneity of all of the possibilities. Subjectively, each possibility is not only a specific idiosyncratic identity, a specific world hologram, but one that exists, on the inside view, in a specific idiosyncratic effective physical environment, the quantum mechanical frame of reference, determinate only where observed by this observer and thus defined in the world hologram. On the outside view, Everett's formulation appears to make no sense. On the inside view, it is simply the way the standard formulation is effected.

10 Conclusion

The concept of the world hologram clearly illustrates the nature of Everett's functional identity. It is the precise definition of the virtual reality Deutsch states to be present in every observer of our type. This is the overall process in which the integrated synthesis of the recorded observations of the environment is interpreted as the spatially distributed known world, thus forming a virtual reality out of the record of observations. At the centre of this virtual reality is represented the self-image avatar, the concept of self, established from observations of one's internal state, Everett's machine configuration. The world hologram as a whole, the experiential reality the observer is aware of, is the functional identity of Everett's formulation.

This identity, however, is highly counter-intuitive. Firstly, it is the whole known world which forms the functional identity, the accustomed self-identity avatar being only a small part, however important. Secondly, this identity defines the determinacy of the effective physical environment, the quantum mechanical frame of reference. Given the cut in the von Neumann chain made at the level of the sensorium, Everett's functional identity is both the definition of the experiential entity of which conscious observers are aware, and at the same time, the determinacy of the effective physical environment, here the quantum mechanical frame of reference. Consequently, individually, each functional identity is literally the determinant of the effective physical environment, the quantum mechanical frame of reference, effective for that observer.

Thirdly, the inside and outside views of the mathematical structure of information defining the effective physical environment of the observer are radically different, as explained by Tegmark (1997, 1998, 2007, 2008). The two different views define, on the inside view, the experiential life of the observer, and on the outside view, the body-mind instantiating it. On the objective outside view, the observer is the body-mind. On the subjective inside view, the observer is the world hologram, with the self-identity avatar at the centre. Objectively we are body-minds, subjectively we are world holograms. While extraordinary, this radical difference between the inside and outside views should perhaps not be entirely unexpected. While on the outside view of the situation, the time evolution of a physical object must follow the linear dynamics, on the inside view, there is never a superposition or mixture in experience, because the definition of the functional identity is a structure of information.

In Everett's formulation, the functional identity of each conscious individual inherently defines a world, an effective physical environment, an idiosyncratic quantum mechanical frame of reference, determinate in experience: hence many worlds. Given universe superposition, Everett's formulation demonstrates a functional frame of reference, which is a subjectively determinate, discrete,

personal, idiosyncratic, transtemporal, physical, quantum mechanical frame of reference. The time evolution of this quantum mechanical frame of reference follows the logical form of the standard von Neumann-Dirac formulation precisely. Thus subjective, determinate, discrete, transtemporal, physical realities are defined by the quantum formalism, within the context of the objectively all-subsuming unitary linear dynamics. The universe is a unitary linear system, which produces subjective, meaning simply experiential, transtemporal physical realities. Each one is a quantum mechanical frame of reference, which is subjectively, meaning from the inside view, logically segregated from the unitary whole, while being at the same time quantum mechanically part of it. Each individual reality is defined by the record of observations, the world hologram, the world one knows, and all else is indeterminate. This is the meaning of Everett's 'Relative State' Formulation of Quantum Mechanics.

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