

The Phenomenological Role of Consciousness in Measurement

Patrick A. Heelan

Department of Philosophy

Georgetown University, Washington D.C., USA

Abstract

A structural analogy is pointed out between a hermeneutically developed phenomenological description, based on Husserl, of the process of perceptual cognition on the one hand and quantum mechanical measurement on the other hand. In Husserl's analytic phase of the cognition process, the "intentionality-structure" of the subject/object union prior to predication of a local object is an entangled symmetry-making state, and this entanglement is broken in the synthetic phase when the particular local object is constituted under the influence of an $\epsilon\iota\delta\omicron\varsigma$ ("inner horizon") and the "facticity" of the local world ("outer horizon"). Replacing "perceptual cognition" by "measurement" and "subject" by "expert subject using a measuring device" the analogy of a formal quantum structure is extended to the conscious structure of all empirical cognition. This is laid out in three theses: about perception, about classical measurement, and about quantum measurement. The results point to the need for research into the quantum structure of the physical embodiment of human cognition.

1. Introduction

A formal structural analogy between quantum mechanics and human embodied cognition will be shown in this paper. This claim is based on a developed Husserlian phenomenological analysis of the *first-person* and *third-person* aspects of both perception and scientific measurement. Ordinary perception, on the one hand, and scientific measurement, whether classical or quantum, on the other hand, intend – aim to know – empirical data. I will show that the phenomenological analysis of the conscious intentionality of empirical data is structured by fundamental principles among which are *complementarity* (and *uncertainty principles*), *symmetry-making* and *symmetry-breaking*, all of which can be modeled mathematically with the help of the same kind of formalism as that employed by quantum mechanics.

Within the context of phenomenology, the terms familiar to us from quantum mechanics will be shown in this paper to have extended meanings beyond the immediate context of quantum mechanics that describe

the functions of human empirical cognition. As a consequence, the philosophical signposts point, on the one hand, towards a re-interpretation of perception and classical science in terms of quantum science and, on the other hand, towards a re-interpretation of quantum science more as Bohr originally saw it than as the subsequent tradition chose to present it. The same signposts also point toward the possibility that the physically embodied mind, capable of both first-person and third-person empirical cognition, has the structure of something like a quantum macro-system. This last point will not be developed in this paper.

1.1 Phenomenology

Though the phenomenological tradition is not well received by philosophers of science or philosophers of mind in the USA, Husserl's eidetic, formal, genetic, historical, and transcendental phenomenology¹ turns out to be a powerful tool for investigating both matter and mind, since both are mutually engaged in the empirical activities of both ordinary perception and scientific inquiry. I take my cues from Husserl's "analysis" and "synthesis" of perception in a life-long series of works that stretch from the *Logical Investigations* (Husserl 2001a) to his posthumous *Crisis of European Sciences* (Husserl 1976).²

Husserl, like most speculative philosophers, continued to think and re-think his phenomenology while he was living, and we honor him best by continuing this process of re-thinking phenomenology in the light of new and newly relevant questions. Such questions have come, for instance, from natural and social scientists, philosophers of science, and interdisciplinary students of science.

¹My work in the philosophy of science has been much influenced by what is lacking in the "received view" of logical empiricism, highlighted by its current critics in what is called "science studies". For the group-theoretic structures of observational data see Heelan (1988, 1989a); for the praxis-ladenness rather than the theory-ladenness of scientific data see Heelan (1989b, 1997, 1998, 2002a,b, 2003) and Heelan and Schulkin (2003). For quantum logic see Heelan (1983). This paper attempts to look at roughly the same core range of problems as do Atmanspacher and Primas (2003), but I believe from a more coherent point of view inspired by Husserl.

²Phenomenology is the tradition, beginning with Hume and Kant, that eventually wended its way through Hegel, Schleiermacher, Dilthey, to Husserl, the so-called modern founder of *phenomenology*, and later to Heidegger, the founder of *hermeneutic phenomenology* (for the history of phenomenology see, e.g., Spiegelberg 1982). Of many excellent critical expositions of Husserl's work in English, I have found the work of Cobb-Stevens (2002), Drummond and Embree (1992), Sokolowski (2000) and Welton (2000) among the best commentators for the purposes of this paper.

1.2 Husserl and the Mathematics of Group Transformations

Though not explicit in Husserl's writings, it is plausible to believe that the mathematical theory of group transformations was involved in Husserl's thinking. Husserl taught philosophy at the University of Göttingen from 1901–1916. During this time the notion of physics in Germany was being transformed from a predominantly experimental one to one that was predominantly theoretical. The radical center of this change was Göttingen. Husserl had been trained in mathematics at Halle before moving to Göttingen as an *Extraordinarius*. There he found himself lodged together with the “natural philosophers” (as scientists were then called) in the same faculty of philosophy. What characterized the Göttingen spirit of science was the use of methods based on the symmetries and invariants of group-theoretical transformations. Among his mathematical and physicist colleagues there were, to name a few, David Hilbert, Felix Klein, Richard Courant, Emmy Noether (see Heelan 1988, 1989a). Others powerfully influenced by this same orientation were Einstein, Heisenberg, and the physical chemist and later Nobel laureate Wigner.

I will claim that Husserl's eidetic phenomenology is “group-theoretic”. By this I mean that, though the phenomenological essence or *εἶδος* of any phenomenon is the (experienced) invariant among the manifold of its different exemplifications or subject-related *profiles*, this is explained – modeled mathematically – as the symmetry of the transformation group that mutually transforms the exemplifications of the phenomenon among themselves. Thus, though the *εἶδος* of a rigid body is *experienced* size and shape invariance among the manifold of its possible spatial presentations, this *experienced* size/shape invariance is *theoretically explained* as the symmetry of the transformation group of rotations and translations of the rigid body.³ Looked at in this way, a perceptual *εἶδος* can be defined as the symmetry of such a group of transformations. If the functional transformation group is given, then all profiles can in principle be re-constituted provided that only a small sample of profiles – perhaps no more than a single one – is presented.

1.3 Technical Terms

By “scientific objects” I mean *data* or *phenomena*; these are particular, local, observed, and recorded events, described in scientific terms. By the terms *complementarity*, *uncertainty principle*, *entanglement*, *symmetry-making*, and *symmetry-breaking*, I mean to refer to functions within empirical consciousness that are analogous (and perhaps more than analo-

³These functional transformations must be taken both *actively* (as re-locations of the rigid body in a fixed coordinate frame) and *passively* (as transformations of the coordinate frame). For an excellent discussion of the group-theoretic structure of perception see Cassirer (1944).

gous) in structure to the way those terms are used in quantum theory.⁴ Their functions, as I will show, can for instance be represented (theoretically) by operators on a Hilbert space of conscious states in the way “observables” are represented by measurement operators in a quantum mechanical Hilbert space.

Complementary descriptive predicates P and Q “can be formulated without explicit reference to physics, to wit, as two aspects of a description that are mutually exclusive yet both necessary for a full understanding of what is to be described” (Pais 1991, p. 24). When applied successively, the sequential ordering PQ gives a different outcome from the outcome of the reverse ordering QP , that is P and Q do not commute, $PQ \neq QP$, implying an *uncertainty relation* between them.⁵ Bohr writes, “... the limited commutability of the symbols by which such variables are represented in the quantal formalism corresponds to the mutual exclusion of the experimental arrangements required for their unambiguous definition” (Bohr 1987, Vol. 3, p. 5). Both the *uncertainty principle* and *complementarity* belong to the topic of observation.

By the *entanglement* of two systems, say S and O , I mean that the *entangled* system $S \& O$ is a single system with descriptive predicates P_1, P_2, \dots that are *complementary* to the descriptive predicates Q_1, Q_2, \dots of its separated subsystems S and O . The entangled system $S \& O$ can be seen as an *emergent synthesis* (a function of emergent *symmetry-making*) of S and O . Alternatively, S and O can be seen to be the products of the break-up of such a synthesis (a function of *symmetry-breaking*).⁶ *Symmetry-breaking* as a general term includes but is not limited to the phenomenology of the “reduction of the wave packet” in quantum mechanics.⁷

⁴For a discussion of *complementarity*, *uncertainty principle* etc. as defined by Bohr in his philosophical writings see Bohr (1987) and Pais (1991, p. 24). For a more general history of these terms see Jammer (1966, pp. 360–374) and Plotnitsky (1994).

⁵Heisenberg took the mathematical form of the quantum *uncertainty principle* to be the basic regulative notion of quantum mechanics. Bohr, however, took *wave-particle duality* and its associated intuitive notion of *complementarity* to be more basic. Both notions are connected, see Jammer (1966, pp. 360–374). Plotnitsky (1994, pp. 65–85) addresses philosophical implications that Bohr associated with his more general notion of *complementarity*.

⁶Bohr speaks of such an *entangled* state of observer and observed when he says that “any observation of atomic phenomena will involve an interaction with the agency of observation ... [a]ccordingly, an independent reality in the ordinary sense can neither be ascribed to the phenomena nor to the agencies of observation” (Bohr 1987, Vol. 1, pp. 53–54); see my comments on Bohr’s views in the last section of this paper.

⁷The problem of the “reduction of the wave packet” will not be addressed directly in this paper. It is a central problem of the quantum theory of measurement and was first addressed by von Neumann and later in phenomenological terms by London and Bauer in 1939 (see Heelan 1965, pp. 71–79) and Wigner (1967, pp. 153–170). The history of this much debated problem is presented in Gavroglu (1995) and in French (2002).

2. Phenomenology of Perception

2.1 The Given and Its Profiles

The starting point for my reflection on natural science is an application of Husserl's *eidetic* phenomenology to perception. Husserl's phenomenology differs from the typical *empiricist*, *rationalist*, and *pragmatist* accounts of perception. Husserl's aim is to find the right balance in the *constitution* of a perceptual object between its *essence* – Husserl's term is $\epsilon\iota\delta\omicron\varsigma$ (that is, *what it shows itself in consciousness to be*) – and what Husserl called "*die Sache selbst*," or the "givenness" of the individual object by the world to perception. A brief summary of Husserl's phenomenology follows; Welton (1999) offers a good selection from Husserl's own writings.

Methodologically, phenomenological reflection shifts the attention of the inquirer away from the "given" sensible particular object to the structure of the "givenness" of this object to conscious awareness: *How is it "given"? And by means of what intentional functions⁸ is it "constituted" as an object?* In this kind of reflection, the objectivity of the object is "finessed" in favor of an attentive focus on the functions operating in consciousness to constitute for the perceiving subject a sensible particular of a certain kind. This "finessed" mode is called the mode of *epoché*, the pre-predicative mode, the mode of conscious union between subject and intended object in which each is constituted as a function of the other through a quasi-dialogue of shared "information." This stage of "symmetry-making" is antecedent to the "symmetry-breaking" stage of predication (or judgment) in which is expressed the phenomenologically evident ("apodictic") objective distinction between the "given" object and the subject to whom it is "given", where each finds itself located at a different place in a common space-time world.

In *Experience and Judgment*, Husserl (1973, p. 262) writes about the $\epsilon\iota\delta\omicron\varsigma$, for example, of color:

"When the generic universal which is the essence, e.g., the $\epsilon\iota\delta\omicron\varsigma$ color, is exemplified in a number of colored objects, each of these objects has *its own* individual moment of coloring; we have many individual moments of color and, in contrast to them, the one $\epsilon\iota\delta\omicron\varsigma$ as a generic universal. This $\epsilon\iota\delta\omicron\varsigma$ is capable of being envisioned only because, having been given several individual moments of color, we bring the colored objects into overlapping "coincidence" by comparison and then apprehend the universal, which is given in the

⁸While Frege uses the terms *Sinn* and *Bedeutung* to distinguish between sense (logical meaning) and reference, respectively, it is important to note that Husserl's use of terms is different. For him *Sinn* (sense) adds intentionality to logical meaning so that between logical meaning and reference there is a third, the *noema*, the carrier of sense and object intentionality. See Marbach (1992).

coincidence as what is common to them – but not common in the *reell* sense – and which we separate from what is irrelevant in the exemplifications. This is the intuitive [*schauende*] process of abstraction of a generic universal.”

The *ειδος* or generic universal is, then, not an “abstracted content” derived from the exemplifications in the empiricist, rationalist or pragmatic sense as a part common to each, because its “*irreell*” predicates are *complementary* to those of the sensible particulars which are “*reell*”. (By “*reell*”, Husserl means existing in space-time independently of the subject.) The particular exemplifications, or profiles, can be brought into “overlapping coincidence” only in interiority by actions of the subject or object that have the effect of mapping one profile on another, or exchanging one profile for another. We have identified the *ειδος* with a symmetry that is preserved under group transformations. This common symmetry or *ειδος* is not located in space-time (it is not “*reell*”), nor is it any one of its space-time profiles. It is rather a function (or subsystem) of human consciousness that operates on the field (or subsystem) of sensory exemplifications that are the arguments of this function. Moreover, when these two subsystems enter into a holistic union its properties are *complementary* (see above) both to those of the subject’s functional *ειδος* and to the field of the object’s exemplifications. This suggests that Husserl’s *noetic-noematic union* of subject and object is an *entanglement* between the intentional subject and the emerging object – similar, perhaps, at this stage to Heidegger’s *Dasein*. From this *entanglement* empirical subject and empirical object emerge within consciousness as separate and independent space-time entities, each with its own set of predicates.

2.2 Analytic and Synthetic Phase

Husserl distinguishes in phenomenology an *analytic* phase and a *synthetic* phase (Husserl 2001b). In the *analytic* phase, the focus of the *epoché* is on the temporal structure of what is already “given” as a sensible particular of a certain *ειδος*. In the *synthetic* phase, the focus of the *epoché* is on the process whereby the “givenness” of a sensible particular is *constituted* by the subject.

The analytic phase is chiefly concerned with the way in which the *ειδος* (“generic universal” or concept) that is used descriptively in predication of a sensible particular comes to be structured. The term for a sensible particular as “given” to consciousness is a (concrete) *noema*. It is “given” as a concrete unity under a multiplicity of concrete profiles (*Abshattungen*, exemplifications, adumbrations, appearances, or perspectives – Husserl 1983, Sect. 41). These profiles each exemplify the same sensible particular. They are experienced in the subject’s inner time consciousness as having emerged from a field of sensory flux produced by

movements or actions of the subject, or independently by movements or actions of the object. In this flowing sensory field the profiles are permuted while continuing all the time to belong to a single stable sensible local particular. The generic unity of this multiplicity is the *εἶδος*. The stability of this unity can be understood as an invariant of the flowing sensory field. This phenomenological system can be described as one of *symmetry-recognition* under group-theoretic variations generated by the subject's "giving" and "receiving" in the milieu of the enviring space-time world. There is, then, an identity between *εἶδος* and a symmetry under a group of transformations that generate the coherent multiplicity of profiles of a single local object or phenomenon. This phenomenon is emergent in consciousness through a symmetry-making process that is at the same time transformative of the meaning of flowing sensory inputs, and is objectified in a synthetic symmetry-breaking phase.

This synthetic phase reveals the contingency of empirical facts and data. Though a subject may be in possession of a perceptual *εἶδος*, this possession does no more than provide the subject with an *inner horizon* or conceptual possibility, but not yet with sensible local particulars (facts, data). Facts and data are not just created by the subject or projected at will into the world, but are found in the world only when and where they are "given" by the world. *The inner (conceptual) horizon must then be matched, Gestalt-like, with a suitable outer (worldly) horizon that breaks the symmetry of the inner horizon.* But while the inner horizon is theoretically definable as a symmetry under a discernible group of transformations and emerges from a kind of dialogue – or "information-sharing" – between the *noetic* subject and the sensory flux of the world, the outer empirical horizon is not theoretically definable. It is a field of largely indeterminate cultural and historical possibilities from which much can be learned only on the basis of a familiarity with natural, historical, and cultural settings. What is learned are clues that point in the direction where particulars ("all things being equal") are to be found. Likewise for the laboratory, familiarity with the laboratory world enables scientists to create the circumstances in which scientific data ("all things being equal") are to be found. Only under such circumstances is it possible to break the symmetry of the entangled state of subject and object. Apart from familiarity with the local world, nothing short of a comprehensive moment-to-moment knowledge of the cosmos would be needed to find whether or not particulars are to be found and where, and such a comprehensive account is beyond our powers.

I claim, then, that the defining properties of any object O, whether *quanta* or *qualia*, are representable (theoretically) as symmetries of transformation groups isomorphic with the relevant space-time group. In ordinary perception as well as in science, the transformation groups are typically observational contexts that leave the *quanta* or the *qualia* in-

variant. Observational contexts place the subject either in a *first-person role* (S_1) or in a *third-person role* (S_3). These roles as they affect science will be explained more fully below. They are briefly defined according to the assumed presence or absence of a relevant interpreted purpose. For example, in the role of S_1 a car driver “reads” a traffic signal to “say” “free to go” (relevant interpretation for the driver); the passenger in the role of S_3 sees the color of the traffic light to be amber (relevant interpretation for the passenger). According to (what is perhaps) the prevalent uncritical view, S_1 ’s view is biased by subjective interpretation in contrast with S_3 ’s view which is assumed to be “objective” or free from such a bias. I take the position, however, that S_1 and S_3 both witness in their different interpretative accounts of (what each takes to be) “the (relevant) facts” though responsive to different interests. The basic problem at issue is, whether these two “facts” relate *intentionally* to one another in the situation at hand? Not at all? Deductively? Or complementarily?

Whether or not the intention of the subject is to seek empirical data from the world, there is always an identity of generic meaning in the transition from mere thought object to the recognition of a local fact or datum, even though performance involves the breaking of the *entanglement* between the constituting subject and the constituted object. In this transition the symmetries of thought characteristic of the *noetic-noematic* structure of intentionality are broken. What is meant by mere thought is intentionally non-local, universal, and necessary, but what exists (as *referent*) is intentionally always local, particular, and contingent. What is intentionally meant by a mere thought is time reversible, but what is intentionally meant as *referent* is generally not time reversible. Symmetry breaking is what characterizes the transition from thought to life. This will be taken up again below.

2.3 From Perception to Measurement

Going now to scientific measurement: what is given to consciousness is a possible datum. This is constituted (as has been shown) by a meaning-transformative conversion of group-theoretic sensory inputs into the profiles of an individual local object under a scientific $\epsilon\iota\delta\omicron\varsigma$. In unaided perception, this is usually pre-conscious. For a scientific datum, however, the manifold of profiles is sketched out by the corresponding manifold of different possible measurement procedures that, *all things otherwise being equal*, produce a profile of constant measure, i.e. the datum. Possible data are thus constituted as possible objects of knowledge under the same conditions as perceived objects. Therefore, Husserl’s phenomenological analysis of perception can legitimately be extended to measurement.

However, a cautionary note: to be consistent with the development of phenomenological thinking and also with the phenomenology of contemporary science studies, Husserl’s *eidetic* phenomenology has to become a

hermeneutic science-historical phenomenology in the spirit implicit in his posthumous work, *Crisis of European Science* (Husserl 1976), and explicit in Heidegger’s critique of Husserl’s phenomenology.

Tables 1a and 1b represent *non-objective and objective moments of intentional consciousness*. The left hand side of the tables represents the functional resources of the analytic phase in the pre-predicative phase, antecedent to judgment, and it outlines the constitutional rules implicit in (what Husserl calls) the *noetic-noematic intentionality* analysis of an object of experience (i.e. a concrete *noema*) when under construction.

<p>Non-Objective Moments</p> <p><i>noetic-noematic entanglement</i> (S & O)</p> <p><i>eidetic</i> concept constitution</p> <p>hermeneutic symmetry making</p>	<p>Objective Moments</p> <p><i>disentanglement</i> of S and O</p> <p><i>referential assignment</i> of O</p> <p>symmetry breaking</p>
<p><i>Noetic-noematic intentionality structure</i></p> <p>(<i>noetic</i>) profiles of O being constituted by <i>εἶδος</i></p> <p>(<i>noematic</i>) profiles of O constituted as particular moments</p> <p>generic universal concept</p> <p><i>noema under construction</i></p> <p><i>possibility of uncertainty and complementarity due to entanglement</i></p>	<p><i>Noema as fulfilled in experience</i></p> <p><i>Hyletic</i> sensory flux, hermeneutically transformed into group theoretic profiles of disentangled <i>noema</i> fulfilled in experience as a perceptual object in its <i>horizon</i></p> <p>perceptual phenomenon particular as fulfilled</p> <p><i>objectivity</i></p> <p><i>complementarity, uncertainty, disentanglement and horizontal symmetry breaking</i></p>

Table 1a: Non-objective and objective moments of intentional consciousness in the constitution of a perceptual object.

In the early stage of the process of synthesis the *eidetic* function of the subject is *entangled* in consciousness with the world’s field of sensory

flux. In this *entanglement* samples of the sensory flux generated by the subject's local bodily interaction with the world are surveyed for systems of profiles of an anticipated symmetry in what I have called "information exchanges" with the environment.

<p style="text-align: center;">Non-Objective Moments</p> <p style="text-align: center;"><i>Pre-predicative epoché</i></p> <p style="text-align: center;"><i>intentional sense</i> <i>under construction</i></p>	<p style="text-align: center;">Objective Moments</p> <p style="text-align: center;"><i>predicated horizontal judgments</i></p> <p style="text-align: center;"><i>intentional</i> <i>reference</i></p>
<p style="text-align: center;"><i>Entanglement of S & O</i></p> <ul style="list-style-type: none"> – noetic-noematic intentionality structure – implicit in reception of sensory flux as potentially meaningful – mutuality of S & O – dialogue of 'transmitting and receiving' information <p style="text-align: center;"><i>Uncertainty, complementarity</i></p> <ul style="list-style-type: none"> – many possible complementary $\epsilon\iota\delta\eta$ – many possible complementary <i>noemata under construction</i> <p style="text-align: center;"><i>Symmetry of S & O structure; universally entangled systems</i></p> <ul style="list-style-type: none"> – subsystems not locally embodied in any horizon – time-reversible – operators commute 	<p style="text-align: center;"><i>Disentanglement of S and O</i></p> <ul style="list-style-type: none"> – detachment of S and O in existential judgment – no mutuality of S and O – dialogue ended <p style="text-align: center;"><i>Specificity, Particularity</i></p> <ul style="list-style-type: none"> – single $\epsilon\iota\delta\omicron\varsigma$ by choice – single <i>noema</i> by choice <p style="text-align: center;"><i>Symmetry-breaking into S and O; subsystems disentangled</i></p> <ul style="list-style-type: none"> – subsystems locally embodied in a contingent worldly horizon – (possibly) time-irreversible – (possibly) operators do not commute

Table 1b: Non-objective and objective moments of intentional consciousness in the constitution of a perceptual object (continued).

The right hand side of Tables 1a and 1b represents *objective moments of the lived world*. These are the concrete *noemata* and are the products of *disentanglement*. The process of *disentanglement* occurs when the subject is confronted with the “facticity” of the local empirical world. In quantum mechanics this is the moment of the phenomenology of the “reduction of the wave packet” which culminates in the assertion of a datum. In this assertion subject and object are recognized as present but distinct, each filling its proper place and function in the lived world.

When the constitutional rules are used in synthesis, the synthesis is of a special form that is based on a (usually pre-conscious) hermeneutic meaning-transformative function that converts in inner time selected elements of the streaming sensory flow into profiles of a particular object (i.e. of a *noema*) having an already established essence or $\epsilon\iota\delta\omicron\varsigma$. This synthesis is directed by the *noetic* activity of the subject functioning through an $\epsilon\iota\delta\omicron\varsigma$ presumed to have been acquired from earlier experience, with the aim of constituting a particular *noema* within consciousness. The synthesis is *intentional*, and in this case it seeks to constitute objects of experience that can be affirmed as real and distinct from the empirical subject in space and time. Other characterizing *quanta* and *qualia* are symmetries of their respective subgroups of transformations, each isomorphic with the space-time group of the world of the laboratory.

If, in the search for objects of experience, there is no already established $\epsilon\iota\delta\omicron\varsigma$ available to the subject, one has to be created and appropriated. The tools for such an inquiry are innate in the capacity of the perceiver. These tools permit the seeking and finding of the possibilities of $\epsilon\iota\delta\omicron\varsigma$ from the streaming sensory flow (i.e. from the *hyle* or “matter” to be converted into “profiles” of things) in inner time. A new $\epsilon\iota\delta\omicron\varsigma$, once established, has the power to constitute concrete *noemata* from the sensory field of the local world. This local world must contain, however, local particulars of the new $\epsilon\iota\delta\omicron\varsigma$ so that the appropriate *hyle* can be provided to the perceiver. This process is addressed by Husserl in his work on genetic phenomenology (e.g., Husserl 2001b). In ordinary perception, this synthesis is usually done pre-consciously, but in science, it is done at first with deliberate and conscious skill by a combination of postulated theory and laboratory measurement. When laboratory expertise has been acquired, the acquired skills subside into the pre-conscious, joining the acquired repertory of other pre-conscious skills.

2.4 Perception and Complementarity

I will begin with the analysis of some case studies that will be useful in making the transition from perception to measurement.

Case 1. Compare (a) a dynamic sensory flux produced by, say, a lifesize cardboard photo of Einstein with (b) the static sensory field of

the imagined bodily presence of Einstein depicted in the image. Also compare (c) the dynamic sensory flux of Einstein's real bodily presence with (d) a partial sensory flux of Einstein glimpsed as moving in a crowd. The horizon of (a) is constituted by a real sensory flux from a piece of cardboard with a printed image of a single profile of Einstein.⁹ There is a sense of the reality of the cardboard photo, but not of the real bodily presence of Einstein. The horizon of (b) is experienced as a picture of a static, imagined but nevertheless unreal Einstein.

The two horizons (a) and (b) cannot be seen together at the same time by the same viewer. They are *complementary* presentations. It will be shown below in the case of measurement that they are formally related by *uncertainty relations*, and that in each case a form of shared meaning, *entanglement*, is presupposed between observer and observed prior to the moment when a judgment is made; this is the *symmetry-making phase*. The judgment performs the function of detaching or *disentangling* the subject from the intended object of choice, publicly asserting the presence of what the viewer has chosen to see; this is the *symmetry-breaking phase*.

Consider now the horizon of (c), constituted by a real sensory flux out of which Einstein's full bodied presence can be recognized. Compare this with the fourth option (d): a partial sensory flux of Einstein glimpsed as moving in a crowd. Though one receives in this case just a partial sampling of the total sensory flux, one also sees Einstein in full bodied presence. In order for full bodied presence to be perceived, some flux is necessary in order that the law of the whole can be discovered and recognized. In actuality, sensory flux is exceedingly redundant and in practice we need no more than a small sampling (exemplified in this case) to achieve clear and accurate perception, evidence that the functional $\epsilon\iota\delta\omicron\varsigma$ has the capacity to constitute a concrete *noema* from a very limited number of "given" profiles used as objectifying resources. This result reminds us of the use of Gabor functions to minimize redundancy in communication by compressing signal fields (see Pribram 1991, pp. 70–73, and Gabor 1946).

Case 2. The second case study is the viewing of a familiar perceptual illusion, the Necker cube, where the element of conscious choice is absent. In this case one is presented with an ambiguous sketch that can be seen either as a top view of a cube or a bottom view. The two views cannot be seen simultaneously. The viewings are unstable and flip from one to the other, sometimes according to prescribed rhythms. The *entanglement* is between the sensory form of the sketch and the viewer's $\epsilon\iota\delta\omicron\varsigma$ of a cube.¹⁰

⁹Husserl addresses the viewing of images in Husserl (1981, §9). See also Heelan (1983, pp. 98–128), Brough (1992), and Marbach (1992, pp. 144–155).

¹⁰Whether or not the two viewings of the Necker cube are superposition states or emergent states is a matter for further discussion. I think they are probably superposition states of the entangled system and emergent states of the disentangled subsystems. A more generalized and detailed treatment of the Necker cube has been done by At-

Case 3. A third illustration of complementary perceptions is found in the geometry of visual spaces. I have shown (Heelan 1983) that vision unaided by instruments generally sees the environment as Euclidean only within a limited zone directly in front of the viewer and probably only in the domain within reach, for only in this zone is an otherwise hyperbolic Riemannian visual space close to being Euclidean. When, however, the environment is “carpentered” with streets, buildings, and other spatial markers that embody Euclidean measures, people such as engineers and architects can learn to see this more expansive environment as close to Euclidean. I have used van Gogh’s *Bedroom at Arles* to point to a family of visual geometries varying from hyperbolic Riemannian to Euclidean. As in the Necker cube illustration above, we are faced in this case with a kind of “double vision” of complementary – Euclidean and non-Euclidean – visual geometries. These geometries are of variable curvatures, adjusting to the different tasks that compete for visual attention; the competition is resolved in the pre-predicative entanglement phase of visual perception.

Guided by the discussed case studies, a formal analogy linking perception and quantum physics can now be stated.

Thesis I: Phenomenology of Perception

Perception entails complementarity and uncertainty relations, also entanglement (symmetry-making) and disentanglement (symmetry-breaking), formally equivalent to the situation in quantum theory.

In addressing perception, all cases illustrated above used some medium in the perceptual performance; a *photograph* of Einstein, a *sketch* of the Necker cube, and a *painting* by van Gogh. The presence of a medium created in each case the possibility of seeing now one, then another of two complementary possibilities: either the image or the imaged in case of Einstein, either the top view or the bottom view of the Necker cube, either the Riemannian bedroom of van Gogh with closed shutters (as originally portrayed) or the Euclidean bedroom when the closed shutters are replaced by open shutters, leaving everything else unchanged.

In some of the cases discussed above the viewer could choose what to see, for example in case 1. In the other cases, the visual system takes charge, whether in case 2 looking at the Necker cube or in case 3 viewing van Gogh’s bedroom. In each case the two visual possibilities are *complementary*.

Taking Bohr’s statement that “an adequate tool for a *complementary* way of description is offered precisely by the quantum-mechanical formalism” (Bohr 1987, Vol. 2, p. 40), let me now construct a Hilbert space model of perception and measurement.

manspacher *et al.* (2004).

Let Φ be a Hilbert space, that represents (or models) the set of ideal pre-predicative states, and let the perceptual “functions” of an observer be functions on this Hilbert space. Consider the two observer roles mentioned above: S_1 , the first-person role, and S_3 , the third-person role. Let P_1 and P_3 be projection operators representing the perceptual functions of S_1 and S_3 , respectively; and let the states of Φ be the arguments of these operators. Let P_1 and P_3 generate subspaces $P_1\Phi$ and $P_3\Phi$ of Φ representing the pre-perceptual horizons of S_1 and S_3 , respectively.

The subspaces $P_1\Phi$ and $P_3\Phi$ are representations of the *noetic-noematic* pre-perceptual horizons of S_1 and S_3 , respectively, i.e. they represent the possibilities of particulars (*noemata*) perceivable by an observer taking the role of S_1 or S_3 , respectively. The subspace $P_1\Phi$ contains the possibility of O as *noema*, but not of M. The subspace $P_3\Phi$ contains the possibility of M as *noema*, but not of O.

Since P_1 , operating on the possibility of the *noema* of M, gives the possibility of the *noema* of O, the subspace $P_1P_3\Phi$ contains the possibility of the *noema* of O, but it does not contain the possibility of the *noema* of M. By contrast, subspace $P_3P_1\Phi$ contains neither the possibility of the *noema* of M nor the possibility of the *noema* of O. Forming the commutation relation of the projection operators P_1 and P_3 , we find

$$[P_1P_3 - P_3P_1] \neq 0.$$

This completes the proof of the thesis that *perception entails complementarity and uncertainty relations, entanglement (symmetry-making) and disentanglement (symmetry-breaking), formally equivalent to those notions in quantum physics.*

3. Measurement

Scientific phenomena, like perceptual phenomena, exhibit, on the one hand, the non-locality, necessity and universality of their $\epsilon\iota\delta\omicron\varsigma$ or essence. This condition is easy to satisfy – any scientific theory will fulfill it. On the other hand, however, the process of data recognition exhibits the factual dependency of $\epsilon\iota\delta\omicron\varsigma$ on the sensory flux and the contingency of the viewer’s – in this case, the scientist’s – performance. But to fulfill the latter, the $\epsilon\iota\delta\omicron\varsigma$ has to have an intrinsic linkage to sensory appearances, real or imagined. A group-theoretic mathematical model does this only on the presupposition that each term of the model has its own $\epsilon\iota\delta\omicron\varsigma$ that functions to synthesize a common empirical meaning for that term from the multiplicity of sensory profiles. The inner dependency of the $\epsilon\iota\delta\omicron\varsigma$ on sensory experience is evident in the pre-predicative stage when subject and object are meaningfully *entangled* with each other. Judgments, insofar as they break the meaningful *entanglement* phase, stabilize this

constitutional form by expressing its outcome as a public fact. This constitutional form depends on an uncertainty of choice by the viewer as to what is intended by the viewing of the sensory flow and whether the choice is deliberate as in case 1, or stochastic as in case 2, or possibly sometimes one and sometimes the other as in case 3. Also involved is uncertainty about the correctness of the viewer's choice and performance; here the criteria are set by the culture of the laboratory. These uncertainties have their origin in the *complementarity* of *symmetry-making* and *symmetry-breaking*, the former opening exclusive choices and the latter limiting the datum to locality, particularity, and contingency when the system is confronted with the worldly horizon of the laboratory.

Despite the often perplexing obscurity of cognitive functioning, it might be useful to point out some important consequences that flow from this account for a better understanding of the historicity of human development, culture, and science. *Complementarity* and *symmetry-breaking* in perception as well as the possibility of subsuming measurement under the structures of perception help us to understand emergent insights, and how learning takes place *via* new perceptions. Emergent insights and new perceptions have their sources, for example, in nature, art, laboratory measurement, or "readable technologies" (see Heelan 1983, p. 206). *Complementarity* and *symmetry-breaking* in perception are, then, some of the functions that give shape to human historical and cultural development.

3.1 Measurement in Classical Physics

Using the above analysis of scientific phenomena and data, I will briefly summarize two fascinating but somewhat paradoxical philosophical principles about the natural sciences to which it leads. I have called these the "paradoxes of measurement" (Heelan 2003).

Thesis II: Classical Uncertainty Principles

There are basic uncertainty principles for phenomena in classical physics and classical natural science that are analogous to those of quantum physics. These are due to the meaningful entanglement of the observer and the observed in the intentional constitution of possible empirical data, and possible complementarities in the dynamic play of noesis and noema in relation to the use of measuring instruments.

To explain what this thesis means, consider the *first-person role* S_1 and the *third-person role* S_3 . Each observational role is directed – though directed differently – toward the same instrumental response M . Seen from each of these different roles, the measurement event will appear differently.

S_1 is skilled in experimental measurement, intending by observation to experience the "given" datum which is O (exemplified by or under

the profile of O_M), and to make a first-person report about this datum. The third-person role S_3 , however, observes S_1 's engagement with the instrument as just a physical interaction but does not have access to S_1 's interpretive act. If the same observer were to attempt to play both roles, it would become clear that they cannot be played simultaneously, but only sequentially. If, however, there are two observers, say, both skilled experimentalists, the second observer (given proper scientific instrumentation) would be in a position to observe – in the role of S_3 – the neurological response of the first observer. This second observer would not have experimental access to the interpretive part of the first observer's observational act. We can reflect on the phenomenology of these two roles in order to compare and contrast the intentional structures characteristic of these two roles. Whether or not such reflection has – or should have – a place in a strictly scientific inquiry is a matter for further discussion.

Figure 1 provides a schema for understanding the contrast between *first-* and *third-person reductions*. It shows by horizontal and vertical lines the observational connections of M and O to S_1 and S_3 . When S_1 observes O, the instrumental response M is *noetically* a functional part of the operating subject S_1 , while *noematically* it specifies and is specified by the profile O_M under which O is “dressed” for its appearance in the laboratory. Figure 1 says that, when S_3 observes M, it observes it under the profile M_i . M_i and O_M are not the same for, though S_1 and S_3 involve M, they involve M differently. M_i is seen as the effect of a physical engagement with S_1 , while O_M is the outcome of a group-theoretical meaning-transformational conversion of M_i . M_i then is nothing but the presence of – the exemplification of – the instrumental response M to S_3 , while O_M is nothing but the manifestation of the presence of – the exemplification of – O to S_1 . The reasoning is much the same as that given in the illustrations used above.

From the phenomenological stance of S_1 , an object is perceived only if the entire range of its connected appearances is virtually present through the dynamic *noetic-noematic* schema in which mutually objectifying information is virtually exchanged (“giving” and “receiving”) between the observer and the world. This relationship is a kind of dynamic hermeneutic entanglement of meanings between the observer as a *noetic* agency and the observed as a *noematic* responder to a set of meaning-generating group-theoretic interactions with the world made present through the particular profile O_M . Both subject and object are fulfilled by this *entanglement* of meanings in which the subject has found in the sensory flux of the measuring act enough fulfillment of O's $\epsilon\iota\delta\omicron\varsigma$ to authenticate the presence of an instance of O as “given” under the profile O_M . Only in this *meaning-entangled* union can the knower be in possession of the intuitive evidence “given” (by the world) and “received” (by the subject) on the basis of which S_1 can make public assertions. S_1 can make three

public assertions: “As an empirical object, O exists”; “As an empirical subject, I exist”; and “I am not O”. With these assertions the symmetry of the pre-predicative *entangled* stage of subject and object is broken. As a consequence the subject and the object are placed separately and independently in the public sphere of the lived world of the community, that is, of the “real” world.

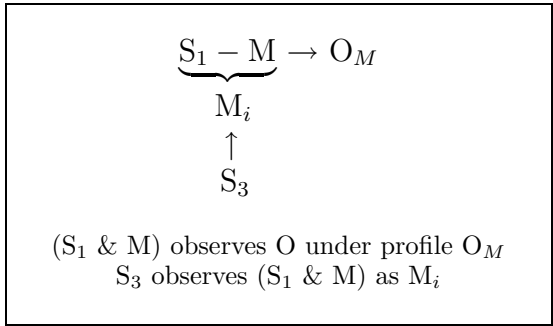


Figure 1: Observational roles of S_1 (first-person perspective) and S_3 (third-person perspective). In terms of S_1 's analysis of entangled intentional consciousness, M is not an object on its own but is absorbed into the functioning subject S_1 . Its function is to provide the profile O_M with which O is “dressed” for its appearance in the laboratory. In terms of S_3 's analysis of entangled intentional consciousness, M is an object given under a profile M_i , but O is not an object.

How are spatiality and temporality involved in the “real” world? The usual assumption made in classical physics is that two objects are “real” and ‘distinct’ only when they are separated by strictly non-overlapping spatial boundaries. The above analysis is silent about spatial-temporal boundaries. Spatiality and temporality are involved, of course, but only because in some way yet to be studied it is among the conditions for the possibility of perceptual and scientific consciousness.

Where does this thesis lead? The holistic *entangled* phase of consciousness is shared both by the act of viewing and by the active response from what is being viewed. In this phase, neither the sense of the subject as potential knower nor the sense of the object as potentially known can exist apart from the virtual back-and-forth flow of meaningful information between the environment on the one hand and the *noetic* intentionality on the other. The latter includes the resources of memory and imagination. This establishes that S_1 and O are functioning together in the shaping of perceptual meaning. The back and forth flow of meaningful information must be sufficient to provide evidence of the existence of the object. Sufficient evidence seems, in some cases, to be provided by less

than comprehensive evidence. I have pointed out that a compressed evident sample can be sufficient, something, say, of the form of a Gabor function reduction of a comprehensive set of profiles.

Any scientific theory comprises a set of (so-called) “theoretically defined” entities, each with its own $\varepsilon\iota\delta\omicron\varsigma$ and each with a characteristic manifold of measurement processes of which the $\varepsilon\iota\delta\omicron\varsigma$ is the proper symmetry. The elements of this manifold are connected by a transformation-group isomorphic with the space-time group. When sufficiently tested, this combination of theoretical laws and empirical praxes guarantees the reality of the “theoretical entities.” But the guaranteed reality is conferred on the “theoretical entity”, not in virtue of its theoretical meaning, but only in virtue of the meaning generated by the group of measurement instruments and the associated praxes. When this is so, instruments can be standardized, constructed, and bought off the shelf. Around this a scientific tradition can be built. Scientific entities can then become a kind of “second nature” mediated by the culturally defined instrumentation of “readable technologies” (cf. Heelan 1983, pp. 209–213). This “second nature” joins the “first nature” of things given by unaided perception. Within this tradition measurement enhances and extends perception since both are built on the same foundation of the innate capacity of natural perception to find and “constitute” stable perceptual objects in the sensory worldly flow.

The quantum features of classical science occur because every measurement event has the possibility of intending two different *noemata*, represented by non-commuting operators in a Hilbert space; one represented by the *first-person operator* $P_1 = P(S_1)$ that “reads” the event as a datum O (under profile O_M), and the other by the *third-person operator* $P_3 = P(S_3)$ that “reads” the event as a datum M (under profile M_i). The conditions within the *entangled* phase of intentionality permit both. Which one of the two is observed depends on how the external symmetry-breaking horizon functions. In a purely physical quantum system the outcome is ruled by strict probabilities. In the case of a human observer the outcome is also affected by the observer’s ability to choose which horizon to attend to. It is clear that over time learning takes place and the likelihood of choices changes and becomes stabilized.

How is the choice of horizon made? It seems to be made by attending to one of the horizons to the exclusion of the other and by operating on the environment so as to generate a confirmatory sample of the horizontal flux. Observation then breaks the symmetry for this horizon, at first as a local event, and then descriptively using the terms of the scientific theory. What happens to the unfulfilled complementary symmetry? It may be erased in time as a consequence of the environmental changes made to generate the confirmatory flux. The paper on which an image is printed may be used for other purposes and the image incidentally lost; or the

image may be retained by transferring it to another medium and the paper incidentally lost. What are the differences between a physical quantum system and a consciousness quantum system relative to the possibilities of choice? A non-deterministic physical system permitting choice is always merely stochastic. Consciousness seems to enjoy a limited freedom to choose which among the possible horizons of the world it will actively attend to.

3.2 Measurement in Quantum Theory

Quantum physics provides an especially interesting case for phenomenological analysis.

Thesis III: Quantum Measurement

An elementary quantum system exists and functions prior to and in some way independently of the phenomenological constitution of classical scientific laboratory space-time. The reason for this is that it is not an embodied physical object, that is, it does not have a definite location or spatial boundary in its own right. It is intuitively given to an observer only by the actual and isolated “footprints” it leaves in the perceptual world of the laboratory. These are the record of individual measurements. However, insofar as it leaves “footprints” in the laboratory world, a quantum object is a physical, not an immaterial, object.

I take “embodied” to mean having a location and a stable bounded extension in the perceptual space-time of everyday life or the laboratory. Scientific objects disclosed by measurement would normally be displayed with the anticipation of having a localized and classically bounded physical body, the latter being a symmetry of the space-time group. Elementary quantum systems turn out not to have such “bodies”. They have, however, properties, such as mass, charge, spin, etc., which are usually defined relative to classical (or relativistic) space-time even though they lack an embodied presence in the laboratory space-time. They acquire an empirical relationship to this space-time only by measurement, and these relationships are episodic because quantized and isolated from the dynamic ordering of things in this space-time. Each measurement is like a single snapshot. Or each is like an isolated “footprint” left by a passing and momentary presence in the laboratory world during an actual measurement. The momentary and passing presence of an elementary quantum system is more than just a sign of an abstract or non-physical presence, for it does have a physical presence in the world in the place where and at the time when the footprints appear. Since it does not fulfill the appropriate Husserlian protocol, it cannot be an embodied symmetry

of the space-time group, that is, it does not have a “physical body” in any ordinary sense of the term.

Many physicists and many philosophers of science have contributed to the discussion of the problem of complementarity and uncertainty and their connection with observation and measurement in quantum mechanics. Principal among them are Heisenberg, Bohr, and Wigner (cf. Jammer 1966, pp. 360–374).

When interviewed for the *Archive for the History of Quantum Physics*, Heisenberg said “... physics has to confine itself to the formal description of the relations among perceptions ...” (cited by Jammer 1966, p. 349).

In an essay on “The Role of Invariance Principles in Natural Philosophy” (Wigner 1967, pp. 28–37), Wigner noted that the concepts and idealizations of mathematics have been well explicated by intuitionist accounts, but no such clarity has been obtained so far for physics. He comments (Wigner 1967, p. 37, emphasis added) “*that the basic concept in the epistemological structure of physics is the concept of observation, and that psychology is not yet ready for providing concepts and idealizations of such precision as are expected in ... physics.*” (emphasis added).

Bohr wrote even more extensively on the necessity of re-thinking the classical epistemological tradition, explaining his reasons for doing so. A single citation is hardly enough, but it will suffice to provide a key to his way of thinking (Bohr 1987, Vol. 1, pp. 53–54, emphasis added):

“Now, the quantum postulate implies that any observation of atomic phenomena will involve *an interaction with the agency of observation not to be neglected. Accordingly, an independent reality in the ordinary physical sense can neither be ascribed to the phenomena nor to the agencies of observation. After all, the concept of observation is so far arbitrary as it depends upon which objects are included in the system to be observed. [...]* This situation has far-reaching consequences. [...] *If in order to make observation possible we permit certain interactions with suitable agencies of measurement, not belonging to the system, an unambiguous definition of the state of the system is naturally no longer possible, and there can be no question of causality in the ordinary sense of the word.*”

In this quotation Bohr refers to the “quantum postulate” stating that the *agencies of observation cause a physical disturbance* when they interact with the observed object. Since this has been, as it were, the canonical view among many physicists and philosophers of science, it should be clear from the phenomenological analysis laid out in this paper that a physical disturbance cannot be the reason for the peculiar phenomenology of *uncertainty relations* or *complementarity*. Phenomena and their definitions involve the relevant symmetries of the space-time transformation groups. These fall into two sets: the first contains the space-time transformation

group which defines the space and time of the laboratory world where the instrumental “agencies of observation” reside, and the second contains the measurement transformation groups which define *observables as group-theoretic symmetries*; these groups are isomorphic representations of the space-time group. I have shown that the reason for *complementarity* is the *dual entanglement* relationship between *first-person* and *third-person* use of theory-guided instruments or other media aids such as images or “readable technologies” (cf. Heelan 1983, pp. 197–201) extending our perceptual faculties. These modulate the relevant sensory flux present to the natural human observer from which dual complementary symmetries can be constituted that use the same *hyle* (material) and are rivals (see above) for recognition by human perception when faced with a symmetry-breaking empirical world.

One final word about the importance of the thesis that consciousness has, on phenomenological grounds, a similar structure to quantum mechanics: there is need for research into the quantum structure of the kind of physical embodiment in the world that makes consciousness and cognition possible.

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