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# ON QUANTUM MECHANICS, PHENOMENOLOGY, AND METAPHYSICAL UNDERDETERMINATION

RAONI WOHNRATH ARROYO
*Federal University of Santa Catarina,* BRAZIL
raoniarroyo@gmail.com

LAURO DE MATOS NUNES FILHO
*Federal University of Santa Catarina,* BRAZIL
laurodematosnunesfilho@yahoo.com.br

**Abstract.** Metaphysical underdetermination arises when we are not able to decide, through purely theoretical criteria, between competing interpretations of scientific theories with different metaphysical commitments. This is the case in which non-relativistic quantum mechanics (QM) finds itself in. Among several available interpretations, there is the one that states that the interaction with the conscious mind of a human observer causes a change in the dynamics of quantum objects undergoing from indefinite to definite states. In this paper, we argue that there seems to be also a metaphysical underdetermination concerning London and Bauer's theory of measurement between two methods of phenomenological reduction: the eidetic and the transcendental approaches. Recently, Steven French argued that both methods can be combined in order to interpret London and Bauer's formalism. However, in this paper we argue that the eidetic one is the only viable phenomenological way to interpret this particular theory of measurement in QM based on the formalism presented by London and Bauer, hence breaking this phenomenological underdetermination.

**Keywords:** Metaphysical underdetermination • interpretation of non-relativistic quantum mechanics • consciousness • phenomenological reduction

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## Introduction: interpreting quantum mechanics

Non-relativistic quantum mechanics (QM) works. It is, at the present, one of the best scientific theories in terms of the precision of predictions with empirical data. One can say in Bell's (2004) terms that, *for all practical purposes*, the mathematical formalism and its empirical counterparts of QM[1] does not represent a matter of disagreement in the physics community. Its meaning, however, is rather controversial. Since its early foundations in the 1920's, scientists and philosophers struggle to find out precisely what QM tells us about the world (and *if* it does such a thing as well). So if we want a scientific realist approach to QM, that is, if we want for QM to *tell us about the real world*, then we ought to inquire about its meaning. As soon as we get into the debate of the *meaning* of the theory's operational features, we are dealing with QM's domain of *interpretation*.[2]

It is widely known that QM is *compatible* with many different interpretations, and there is no consensus about which is the *right* one (or whether there is a right one). So we know QM works but we don't know how to interpret it. For instance, the well-known measurement problem is addressed in different ways by many-worlds interpretations (Everett 1957), hidden-variables interpretations (Bohm 1952), and consciousness interpretations (von Neumann 1955). At the present, the matters concerning the choice of an interpretation of QM are not strictly objective, so one may voluntarily choose one. So, suppose we pick one of these interpretations above as the right one. We will not discuss whether there are good reasons or not to pick a single interpretation as the right one based on an objective evaluation, but let us pick the consciousness-based interpretation (CBI)[3] just to get our point across. Even if it is asserted that "CBI is *the* most correct interpretation of QM", we will still not know how to interpret it in metaphysical terms: one can associate different metaphysical commitments to the concept of "consciousness", from a dualist view (that we call the "*received view* on consciousness")—put forth by von Neumann (1955)—to a phenomenological view—put forth by London and Bauer (1983) (see French (2002) for this detailed characterization and references therein). Because CBI is compatible with more than one metaphysical thesis, we argue that it is subject to the problem of metaphysical underdetermination. However, it is distinct from the metaphysical underdetermination that the one concerning the general framework of interpretations of QM, because they are developed upon a common hypothesis, namely that the consciousness has a role in the measurement process.[4]

But suppose even further that we are able to pick a single approach to be the right one, and we still don't know how to interpret in (*even further*) metaphysical terms. The crux of the matter is this: at the present, we are in no position to choose objectively between different interpretations of QM as the *right* one—maybe this is a matter of physics rather than philosophy, as some suggests (Cf. Ćirković 2005); however, a careful study on metaphysics may tell us what are (or aren't) the available metaphysical options to interpret QM *within* a particular domain of interpretations of QM. In this paper, we put forth a case study on the phenomenological approach to CBI, as proposed by London and Bauer (1983). Again, we will not discuss this kind of evaluation between interpretations of QM here, but suppose that we pick the phenomenological approach to CBI. There are at least two metaphysically incompatible phenomenological approaches to phenomenology, the *eidetic* and the *transcendental*, and it is not clear which one is at stake in the phenomenological approach to CBI. So the phenomenological approach to CBI raises the same problem within itself, as it does not determine its own metaphysics.

A milestone of the phenomenological approach to CBI is Steven French's (2002) paper, whose account shows clearly that the CBI proposed by London and Bauer (1983) is to be understood, in metaphysical terms, within a phenomenological framework—thus, radically different from von Neumann's (1955) dualist approach. In this paper, we distinguish between two phenomenological approaches, the eidetic and the transcendental one; we argue that French (2002) conflates both approaches, and we also argue in favor of the eidetic approach only. In order to do so, we structure the paper as follows. In the first section, we show how the phenomenological CBI responds to the measurement problem in QM. In the second session, we analyze the phenomenological approach of CBI in more detail, emphasizing the two metaphysical possibilities of interpreting it. In the third and last session, offer an evaluation of phenomenological interpretations of CBI, and how well they make sense of the formalism of QM. We conclude that the eidetic approach is compatible with London and Bauer's (1983) formalism, whereas the transcendental approach is not, thus the most viable way to read the CBI interpretation of QM is, among these choices, through the lens of an eidetic phenomenological metaphysics (which is the less problematic metaphysical option until now). With such efforts, we seem to be able to understand what indeed are the available options for interpreting QM in the case of CBI.

## 1. Consciousness and the measurement problem

It is well-acknowledged that QM can be formulated in several mathematically-equivalent ways.[5] Here, we take into account the standard formulation via Hilbert space and Schrödinger equation, an idea first put forth by von Neumann (1955). In his framework of quantum measurement, von Neumann uses two distinct dynamical laws of movement. The use of two apparently incompatible dynamic laws, however, originates the measurement problem, which can be briefly defined as their problematic conjunction. Remarkably, von Neumann's approach to the measurement problem was to consider that both dynamics operates within different ontological domains of reality, being one mental and other material, and, thus, replacing the solution of the measurement problem with the solution of the mind-body problem. Similarly, London and Bauer (1983) pushers further the *rationale* in von Neumann's framework of quantum measurement, stating that the transition from one (linear) dynamics from another (non-linear) one—*i.e.*, the *collapse*—can only occur due the interaction with the conscious mind of a human observer.

We label this response for the measurement problem as CBI. It came to be the *received view* about the concept of "consciousness", when related to QM. We make the point here that the CBI is not an unitary interpretation of QM, but in fact is a basis for a "*family* of interpretations"—a term that we borrow from Shimony (Shimony and Malin 2006)—which is a set of interpretations that share this common hypothesis about the measuring process. Jammer 1974, §11.2–11.4, labeled the received view as the "subjectivistic interpretations" of QM.

However, compared to von Neumann (and the received view of CBI), London and Bauer had very different assumptions about the ontological status of each dynamic law. As we argue, this would form a divergence of interpretations *within* the CBI: a dualist one due to von Neumann and the received view on CBI, and a phenomenological one due to London and Bauer. In the present section we briefly outline both approaches to quantum measurement theory, emphasising their differences in its background metaphysical assumptions. As French (2002) argues, the critiques that these authors put forward upon CBI affects only the *received view* of CBI; rather, those critiques *misses the point* when one interprets London and Bauer's (1983) framework through a phenomenological (rather than dualist/subjetivistic) approach. We deal with this issue in the next sections.

## 1.1. The measurement problem

We mentioned that von Neumann's (1955) framework takes into account two different dynamic laws for quantum systems. Let us first discuss the dynamics that accounts for undisturbed systems, named "process 2" after von Neumann (1955), or "process of the second kind". Consider for simplicity an observable $O$ to be measured in a Hilbert space $\mathscr{H}$ as a Hermitian operator $\hat{O}$ whose state, prior to measurement, is $|\psi\rangle = \sum_i^n a_i |\psi_i\rangle$. When this system is leaved undisturbed, its states will evolve deterministically according to the Shrödinger (where '**H**' is the Hamiltonian, which gives the energy of the system):

$$i\hbar \frac{\partial |\psi\rangle}{\partial t} = \mathbf{H}|\psi\rangle \tag{1}$$

In this standard formulation of QM, the evolution in time of quantum systems in equation (1) is ruled by linearity, which implies that if $|\psi_1\rangle$ evolves to $\left|\psi_1'\right\rangle$ and $|\psi_2\rangle$ evolves to $\left|\psi_2'\right\rangle$, then $a|\psi_1\rangle + b|\psi_2\rangle$ evolves to

$$a\left|\psi_1'\right\rangle + b\left|\psi_2'\right\rangle. \tag{2}$$

But the vector sum in (2) is *not* a measurement outcome, in the sense that it is not an eigenvector of the observable in question. In the same vein, if QM should hold true for *all* physical systems, then there seems to be no reasons to preclude that any macroscopic measurement apparatus is treatable within QM—and so von Neumann's (1955) argument goes. So the situation of a measurement apparatus $A$ interacting with a quantum system $S$ should be describable by linearity. This means that the macroscopic measurement apparatus is describable by a Hilbert subspace $\mathscr{H}_A$, and its interaction with a quantum system is described by a $\mathscr{H}$ that is factorised into "system" and "apparatus" subsystems with Hilbert spaces $\mathscr{H}_S$ and $\mathscr{H}_A$ respectively, so that: $\mathscr{H} = \mathscr{H}_S \otimes \mathscr{H}_A$.

If this is the case, then it is hard to see how a measurement apparatus plays a causal role in the measurement process (*i.e.*, that it *produces, alone, a single-term measurement outcome*—because its states $|\varphi\rangle$ will become entangled[6] with the states of the operator $\hat{S}$ in the interaction, so that the formalism describes the composite system $\hat{S} + \hat{A}$ in a given $t_{x>0}$ as follows:

(3) $$|\psi\rangle = \sum_{i}^{n} a_i \Big( |\psi_i\rangle \otimes |\varphi_i\rangle \Big)$$

For the present discussion, this is the most relevant issue in von Neumann's measurement theory: it is committed to an infinite regression of measurement apparatuses. That is, at any attempt to reduce the superposition of this composite system with further measurement apparatuses, further superpositions will arise: consider the case of adding the image registered in an observer's eye being represented by $\left|\varphi_i'\right\rangle$, its optical nerve being represented by $\left|\varphi_i''\right\rangle$, its brain by $\left|\varphi_i'''\right\rangle$, and so on infinitely. The case will then be described by:

(4) $$\sum_{i=1}^{n} a_i \Big( |\psi_i\rangle \otimes |\varphi_i\rangle \otimes \left|\varphi_i'\right\rangle \otimes \left|\varphi_i''\right\rangle \otimes \cdots \otimes \left|\varphi_i^{\infty}\right\rangle \Big)$$

No eigenvector of the observable (which characterizes the very idea of measurement) is obtained in this process. Because of that, no matter how many measurement apparatus one might introduce to try to reduce the superposition of the composite system, if the system is described by unitary dynamic laws, it will *always* be described by a superposition. The awkward thing is that we never see a superposition. In fact, the very concept of "superposition" does not have *any* physical referent. Although it is *precisely* the superposed state $|\psi\rangle$ that is subjected to a measurement, it *never* appears as the result of a measurement outcome. Even in limit cases, such as the recent quantum controlling experiments, as the isolation of a single trapped electron done by Haroche and Wineland (Wineland 2013), the measurement outcome *never* is a vector sum, but a definite single state vector.

So it seems that if one wants to connects the mathematical representation with the physical outcomes that scientists actually observe, something must be done. In the standard QM due to von Neumann's framework, a *new dynamic law* is introduced via a postulate to deal precisely with measurement outcomes. The *collapse postulate* is introduced as a way to reduce the infinite superposition of measurement apparatus stated above. This is precisely what "process 1" (or "process of the first kind") does: it collapses the deterministic evolution of the composite system into a new state which is one of the states contained in the superposition:

$$\sum_{i}^{n} a_i\Big(|\psi_i\rangle \otimes |\varphi_i\rangle\Big) \longrightarrow \Big(|\psi_\lambda\rangle \otimes |\varphi_\lambda\rangle\Big)_{\lambda\in i} \tag{5}$$

Such transition occurs with a probability given by the Born rule, which states that the probability of finding $|\psi_\lambda\rangle \otimes |\varphi_\lambda\rangle$ is $|a|^2$, but it is fundamentally an *indeterministic* process. As we mentioned earlier, the attempts to reconcile these two dynamics is known as the "measurement problem".

## 1.2. The phenomenological response

Let us now examine London and Bauer's (1983, pp.251–2) account for the process of quantum measurement, which pushes further the rationale put forth by von Neumann (1955), by defining "measurement" as an act with epistemic charge: "[a] measurement is achieved only when the position of the pointer has been observed. It is precisely this increase of knowledge, acquired by observation [...]"; and the referred "knowledge" would be responsible to the choice of one among several other possible states within a superposition such as in equation (3).

The composite system $\hat{S} + \hat{A}$ should then be treated with the addition of the consciousness of the observer $C$ in a Hilbert space $\mathscr{H}_C$ as a self-adjoint operator $\hat{C}$. Let $\{|\chi_1\rangle, \ldots, |\chi_i\rangle, \ldots, |\chi_n\rangle\}$ be the eigenvectors of its observables, whose possible values (*e.g.*, a definite state of mind at a time $t$) are given by the sum of all possible states of $|\chi\rangle$. The state of this new composite system $\hat{S} + \hat{A} + \hat{C}$, represented by the vector $|\psi\rangle$, is described in a subspace $\mathscr{H}_S \otimes \mathscr{H}_A \otimes \mathscr{H}_C$ as follows.

$$|\psi\rangle = \sum_{i}^{n} a_i\Big(\,|\psi_i\rangle \otimes |\varphi_i\rangle \otimes |\chi_i\rangle\,\Big) \longrightarrow \Big(\,|\psi_\lambda\rangle \otimes |\varphi_\lambda\rangle \otimes |\chi_\lambda\rangle\Big)_{\lambda\in i} \tag{6}$$

As acknowledged by London and Bauer (1983 p.251), from an *objective* point of view, the addition of $C$ in the composite system doesn't seem to solve the problem in comparison with von Neumann's chain, as expressed in equation (3). The state of its objective components remains indeterminate; but the subjective component, by possessing a so-called "faculty of introspection" (that is, a subjectivity that distinguishes the *kind* of states of $\hat{C}$ in comparison with the objective states of $\hat{S}$ and $\hat{A}$), has the ability to recognize its own states at any time in virtue of some kind of "immanent knowledge", which enables the creation of its own objectivity and thus break the chain of superpositions by simple stating "I am in the state $|\chi_\lambda\rangle$" or "I perceive the pointer in $|\varphi_\lambda\rangle$" or even "$\hat{S} = |\psi_\lambda\rangle$". So the transition in equation (5) occurs in virtue of a property of $C$ that is not shared by the other—objective–parts, *e.g.*, subjectivity.

This feature presents a *significant difference* between the metaphysics associated with von Neumann's and London and Bauer's use of the notion of "consciousness" in the role of quantum measurement: the former is committed to some kind of *dualist ontology* which places the role of the observer[7] outside the domain of physics, suggesting that it has to be a different substance, other than the material, in a substance-dualist fashion, while the latter is committed to a different kind of ontology where mental and material systems occur and interact *in the same ontological level*. Within London and Bauer's (1983) formalism, the consciousness of the observer is treated as another Hilbert space $\mathscr{H}$ that interacts with the "objective" parts.

It should be mentioned that it was London and Bauer (1983, p.259) themselves who acknowledged the phenomenological implications of their interpretation, specifically the one regarding Edmund Husserl. Also, London's biographer, Gavroglu (2005), had stressed that point too. More recently, French (2002) argued that the concepts involved in London and Bauer's proposal suggest that these should be understood within a phenomenological, particularly Husserlian, phenomenological framework.

If London and Bauer's (1983) monograph is to be understood within a (general) phenomenological framework, then consciousness should not be regarded as the *cause* of the collapse, but rather as a *relational act* between the so-called "immanent knowledge", which can separate itself from the superposition and keep constantly tracking its own states undoubtedly, and the objective parts. Interpreted phenomenologically as a relational act, consciousness would, through collapse, set a *new objectivity* by stating definite properties of the whole composite system. In this sense, to the phenomenological approach, the objectivity is not given *a priori*, neither resides in some subjectivity that is separated from the whole process of measurement; rather, objectivity is *constituted* by a creative act of observation in which the observer separates itself and the object that is being observed. In this approach, a superposition such as equation (6) describes correctly the situation *externally*, but it is only consciousness that would be able to describe it *internally* through the separation of its "I" from the composite system and gaining the right to choose one component of the superposition among many others, as described by the formalism of QM.[8] It is worth to mention that this act constitutes a new objectivity, and because of that we can avoid further reference to the internal aspects in judging it.

## 2. Phenomenological underdetermination

Phenomenology, as it is known, is a philosophical investigation demarcated by the so-called "method of phenomenological reduction", which is divided into two main groups: one about intentional objects called "eidetic reduction", and another more radical about ego or pure consciousness called "transcendental reduction". The phenomenological approach to CBI seems to be underdetermined by both metaphysical possibilities, but French (2002) conflates those two. We will deal with these issues in this section.

## 2.1. Two methods of phenomenological reduction

According to Husserl (2012, §65–6; 1964, pp.18–19), phenomenology is a descriptive science about phenomena. The main function of phenomenology is to provide an explanation of how phenomena are constituted and how they are possible. Phenomenology is not about the discovery or passive receipt of information about something, it is about constituting meaning. In this sense, in phenomenology we do not inquire about *after* or *before* the phenomena. Likewise, it is not a question of interacting with a passive and hidden world that hopes to be discovered, as it is sometimes presupposed in dualism. Unlike the dualist approach, in phenomenology subject and object are considered to be poles of the same process of meaningfulness. In the phenomenological approach, then, there is no real difference between observer and observed. In this sense, a measurement outcome is not to be considered something previously available, waiting for its discovery by a neutral observer. There are several phenomenological approaches, but a singular feature is common to all of them: there is no external (transcendent) reality and there is no internal reality (immanent), the reality is which appears for us at any moment (Husserl 1964, §6). All we can get is the actual phenomenon in each observation. This is not so different from the dualist view about the measurement, but in the phenomenological approach there is no ontological difference between observer and observed: just observation in order to obtain meaning. Different from dualism, with the phenomenological approach is possible to have a philosophical explanation to London and Bauer's (1983) process of measurement without state different ontological levels for each term in the equation (6).

So, the formalism for quantum measurement in equation (6), as presented by London and Bauer (1983) seems to require an interpretation within a phenomenological metaphysical framework instead of a dualist one. As we have said, French (2002) has shown it; however, where he sees a single option within this general phenomenological approach, we argue that there is more than one. We agree with him in the main point: until now the phenomenological approach seems to be the better option to interpret London and Bauer's (1983) account for quantum measurement in metaphysical terms; however, we disagree with his view about how Husserlian phenomenology works in this explanation. Here is why: there are two main metaphysically distinct paths *within* the phenomenological approach. The first is the *eidetic reduction* which deals with intentional objects and the domains where such objects are disposed; the second one is the *transcendental reduction*, which deals with the transcendental ego, where there is no interest in intentional acts and objects. This is precisely where metaphysical underdetermination kicks in: between the eidetic and the transcendental reduction within the phenomenological approach.

The eidetic reduction is a method by which someone moves from the consciousness of individual and concrete objects to the domain of pure essences and thus achieves an intuition of the essence of a thing, *i.e.*, of what it is in its invariable and essential structure, apart from all that is contingent to it. These essences are the principle or necessary structure of the thing. Being a science of essences, phenomenology finds this reduction important for its methodology. Apparently, in London and Bauer's case, the eidetic method arise as the best philosophical interpretation in order to understand its philosophical approach to quantum measurement process. On the other hand, the transcendental approach in phenomenology consider only the pure consciousness, the eidetic reduction is seen to be like an intermediary method. Properly, the use of the transcendental approach for understand London and Bauer's proposal is unreasonable because it is not about object and subjects, such elements instead being previously presupposed are now put from apart in the transcendental reduction. In London and Bauer's (1983) proposal, the quantum object (*i.e.*, the intentional object) is maintained as an intentional correlate of the subject, which is not the point when one works with the transcendental reduction. Unlike the French's (2002) approach, which considers the transcendental method, we believe that the approach of London and Bauer (1983) is compatible with the eidetic reduction but not with the transcendental reduction.

When French (2002) takes the whole Husserlian project (both eidetic *and* transcendental) as a background for London and Bauer's proposal, we believe that he makes a mistake. Necessarily the Husserlian project goes far beyond London and Bauer's conceptual needs. In most cases Husserl are not dealing with intentional objects directly, which is a seminal characteristic of London and Bauer's formalism. In particular, the transcendental reduction pressuposed by French (2002) is useless in London and Bauer's case.

## 2.2. A dangerous conflation

French's (2002) paper was seminal for the debate between the dualist and the phenomenological approaches. However, we argue that there is a misconception in his final position about how to interpret London and Bauer's (1983) proposal, as he conflates both the eidetic and the transcendental reduction within Husserl's whole phenomomenological project. It became clear when French (2002, p.484) interpret London and Bauer's formalism as including different stages of Husserl's philosophy, which includes eidetic and transcendental reduction:

> Such an account is useful in the present context since it enables us to situate London's dissertation, for example, in the Husserlian first stage, whereas, as we shall see, the considerations of consciousness and objectivity that we find in the monograph with Bauer span the second and third stages.

For us, it seems that French (2002, p.484) is correct when he uses the eidetic reduction in order to interpret the phenomenological CBI, making reference to the ego-object structure:

> "Note, first of all, that at the beginning of this characterization, the observer is not set outside of the domain of quantum mechanics. She too is represented by a wave function within the superposition. But she, as an 'I' or ego, possessing this characteristic faculty of introspection, has 'immanent knowledge'—that is, absolute and indubitable knowledge—of her own state by virtue of which she can, on the one hand (namely that of the ego), separate herself from the superposition and, on the other (namely that of the object in question), create or set up (in the French, it is '*constituer*' or '*constitute*') a 'new objectivity'. This separation should not be thought of in terms of consciousness 'causing', in whatever sense, the wave function to collapse, but rather in Husserlian terms, as that of a mutual separation of both an Ego-pole and an object-pole through a characteristic act of reflection."

However, French (2002, p.480) makes use of the concept of *pure consciousness* (or *pure ego*), which is a concept of the *transcendental* phenomenological reduction, making use of all of Husserl's philosophy. However, it is hard to see how London and Bauer's proposal is connected with the last stages of Husserl's philosophy. As we know, such connection is not possible because it is not compatible with the scheme object-apparatus-subject presupposed in London and Bauer's formalism.

> "Hence, the perception of something immanent is indubitable, in the sense that there can be no failure of reference. This is not so for something transcendent, of course. This then leads to a further difference between the physical and mental, that bears on the apparent retention of the pure ego: the positing of things in the world is always a contingent positing, but the positing of my 'pure ego', as—crucially—the subject of mental acts, is necessary and absolute [. . . ]."

Although French (2002) pointed out that the phenomenological approach is the best way to understand London and Bauer's (1983) formalism in metaphysical terms, he ends up committing himself with a much broader philosophical position. French (2002) makes use of the eidetic and the transcendental reduction in order to explain how London and Bauer's (1983) proposal works.

In London and Bauer's (1983) formalism, as equation (6) shows, the quantum object, the measurement apparatus *and* the observer are included in the same mathematical level. But, in some sense, the observer has a privileged status in the measurement process (*i.e.*, it is capable of reducting superpositions and stopping the chain effect). So how is it possible for the observer to be on the same mathematical level, but on a different ontological level? For dualist-oriented interpreters of QM, this is not a real problem: it is just the way it is! However, for the phenomenologist, it is possible that the observer and the observer be in the same ontological level, because in phenomenology when there is an observation and an observer, they are always *codependents*. As it can be said, there is no observer without something which is observed and there is no observed without an observer. If there is some object of our actual knowledge it is present for us in some kind of relation. For instance, if we are looking to the Sun, there is the intentional act of seeing something and there is the intentional object which is presented in each relation. Seeing, perceiving, thinking about an object is always a new way to perceive such object, but it is not possible that the object is a source of meaning without being in that relation.

This is why London and Bauer (1983) chose the phenomenological approach to explain their formalism in a metaphysical way. Let us focus in this point. In phenomenology, the "same" object can be part of different kinds of relations. Such change in the relation implies a new meaning for such object, so we can observe a mountain and perceive something beautiful or sad, or have an impression about the past or future, we can hate or love that place. The object itself is the same in all instances, but the kind of meaning (or *information*) is always different in each of them. The same goes to the process of measurement in QM: we can obtain different kinds of information in each measurement—we just need modify the type of observation. The object is the same, but the information provided by it is always different.

However, when French (2002) accepts the phenomenological project as a whole, which includes the transcendental reduction, he ends up with a problematic conflation between two distinct methods of phenomenological reduction—which, as we argue, is very problematic in the specific case of interpreting London and Bauer's (1983) CBI. In the next section, we will demonstrate how the phenomenological approach for CBI is better understood by means of the eidetic reduction.

## 3. One less metaphysical underdetermination

So we wish to break a metaphysical underdetermination which concerns both the *eidetic* and the *transcendental* phenomenological approaches to CBI. We will engage such problem in a further analysis of the formalism presented by London and Bauer (1983, pp.251–2).

There are in fact historical reasons to believe that London and Bauer (1983) were considering *only* in the eidetic approach, specifically if one concerns the philosophical roots of Fritz London. Max Jammer (1974, p. 482–3) pointed out that London became deeply interested in philosophy in the 1920's. He earned his Ph.D. degree for a thesis in philosophy which was a study on phenomenology under a Husserl's follower, Alexander Pfänder. A main key of the historical reasons to support our argument argument is precisely London's relation with Pfänder: as many others disciples, Pfänder was a controversial follower of Husserl's ideas, and had defended that just the eidetic approach was a viable path in phenomenology because the investigations about the ego were some kind of idealist turn inside the Husserlian project. Moreover, still following Jammer (1974, p.482–3), both Pfänder and London were also influencied by Theodor Lipps, who also was very critique in relation of the idealist turn in phenomenology. Gavroglu (2005 p.179), however, states that at the time of the discussions between London and Pfänder, Pfänder (2009) had published already his critique on philosophical psychologism, such as that put forth by Lipps, in his book entitled "*Logik*"; nevertheless, Pfänder himself, in this very book, endorses the eidetic phenomenological approach. So it is very unlikely that London, who, according to Jammer (1974, p.483) and Gavroglu (2005), primarily wrote the philosophy part of their monograph, could possibly endorse a transcendental reduction within the phenomenological approach. We might conceive that London was referring to a specific kind of phenomenological approach, namely the eidetic one. However, from London and Bauer's (1983) monograph, we can only define the phenomenological insight, but nothing in specific, then we cannot ground our thesis only in this hystorical argument.

In the next subsection, then, we will justify our position by comparing both phenomenological approaches and identifying which is more compatible with the formalism presented by London and Bauer (1983). In some sense, even if London and Bauer have said that their position were that exposed by French (2002), our defense of an eidetic approach is much more coherent with their formalism, precisely in equation (6).

### 3.1. A *coup de grâce* through the formalism

There is a natural relationship between the transcendental ego and other intentional structures. But it does not make sense to resort to the transcendental reduction to interpret the formalism of quantum measurement put forth by London and Bauer (1983); such method of phenomenological reduction cannot make any clarification over their formalism. This becomes clear if we are conscious that London and Bauer presuppose at least three instances in its formalism, the object, the apparatus and the consciousness of observer: it matches perfectly with the eidetic reduction, which examines the intentional structures that enable the formation of phenomena. In eidetic reduction it is examined the intentional acts and its intentional correlates (intentional objects). In contrast, in the transcendental reduction those structures are put aside of the investigation by demand of the method itself. This why London and Bauer's

(1983) formalism becomes meaningless in the transcendental reduction.

Let us push this point a little further. The whole endeavour put forth by London and Bauer (1983), as we understand it, had two main objectives: first, to explain the chain reaction when a measurement is operate without recurs to an infinite chain of observations as in equation (4); second, explain how consciousness operates in the measurement process without committing oneself with the problems of dualism. As we see it, there is indeed no metaphysical underdetermination problem in this case, for the transcendental phenomenological reduction is not really compatible with the formalism presented by London and Bauer (1983). Take, for instance, London and Bauer's (1983) description for a quantum superposition, as in equation (6), and let us rewrite it with the concepts of the eidetic phenomenological approach to CBI.

$$\sum_{i=1}^{n} a_i\Big(\underbrace{|\psi_i\rangle \otimes |\varphi_i\rangle}_{\text{intentional objects}} \otimes \overbrace{|\chi_i\rangle}^{\text{intentional act}}\Big) \tag{7}$$

This notation aligns nicely with the eidetic approach when takes into account intentional objects and intentional acts: it is consciousness ($|\chi_i\rangle$), as an *intentional act* that states the contents (*i.e.* the states) of its own *and* the content (the states) of the intentional objects. Notice that this distinction between intentional acts and intentional objects *only* makes sense in the eidetic phenomenological reduction; in the transcendental phenomenological reduction, on the other hand, such division would not be possible. Thus, it seems that the transcendental approach to London and Bauer's (1983) CBI is not possible. And, as we argued in the previous section, if this is so, then French's (2002) conflation between the eidetic and transcendental phenomenological reduction is indeed misleading because of the concepts involved in the *transcendental* reduction. Schematically, our criticism of the transcendental approach to the phenomenological CBI goes as follows:

- The transcendental reduction is not about an act and its correlates, it is about the reduction of the natural ego in order to describe a pure ego. As Husserl (1989, §24) himself says, the "[...] pure Ego it does not harbor any hidden inner richness; it is absolutely simple and it lies there absolutely clear [...] all richness lies in the cogito and in the mode of the function which can be adequately grasped therein";

- As such, the transcendental reduction does not consider mathematical constructions, inasmuch such constructions are taken to be just abstractions over pre-scientific experiences of the world. Different from other stages of Husserl's philosophy, in the transcendental reduction there is no interest in ideal objects, as mathematical ones like those pressuposed by London and Bauer;

- The transcendental reduction is a radical position inside the Husserlian phenomenological project, which is considered, even for his most known followers, as impracticable.[9] Without a reference to a more concrete conceptual apparatus several philosophers discredit an effective use for the transcendental reduction, which is directed for the investigations about the pure ego;

- The transcendental approach do not deal with mathematical constructions as London and Bauer's formalism. On the other hand, the eidetic approach consider such constructions in the object-subject schema by considering mathematical objects as intentional objects. So, among the these two (apparently) available phenomenological approaches to CBI, the eidetic phenomenological approaches, the eidetic is the *only* viable one to interpret London and Bauer's (1983) formalism.

This occurs because the thesis about the transcendental ego represents a return to the idealism (Husserl 1970, §65–67), which gives special attention to the pure ego, an instance without reference to intentional structures as intentional acts and objects. When French (2002) makes use of a such radical instance of Husserl's phenomenology he ends up by abandoning the explicit correlation between London and Bauer's (1983) formalism and the intentional structures presupposed by the eidetic reduction. Thus, for us just the eidetic path is a real option for interpreting the phenomenological CBI, because the second do not deal with the quantum objects, and quantum objects *do appear* in London and Bauer's (1983) formalism through equation (6). So the transcendental reduction is not a phenomenological approach that is compatible with their interpretation of QM. There is no obvious way in which the formalism in equation (7) can be understood in a transcendental phenomenological approach to CBI: so it was never really an option to interpreting it *ipso facto*. Hence, *if* the phenomenological CBI is a meaningful option to interpret QM (as it seems to be, at least in empirical and mathematical grounds), until now the only way to understand it in metaphysical terms is through the *eidetic* phenomenological approach. Hence, there was never a metaphysical underdetermination in this case.

## 4. Final remarks

The matters of interpreting QM are far from obvious, and far from being over in sense of the settlement of an unitary, single scientific image of the world *modulo* QM. Nevertheless, we argued that philosophy may indeed helps us to better understand the available options for interpreting QM in the sense that we could offer some (vague) criteria for "ruling out" out some alternatives for the interpretation of QM using metaphysics, even though we could not do it empirically nor mathematically—which is a nice achievement for philosophy as a discipline.

In this paper, we presented some motivations for the abandonment the transcendental reading of the phenomenological approach to CBI, inasmuch as it does not conforms with the formalism of QM. Thus, we showed that the most reasonable way to understand the phenomenological approach to CBI is via the eidetic reduction.

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## Notes

[1]There are many mathematical formulations for QM (Styer et al. 2002). We will focus here on the standard formulation of QM, which is the Hilbert-space formulation of QM.

[2]At least this is the standard approach of the domain of the "interpretation" of QM, as opposed to QM as a quantum "theory" (see, for instance, Jammer 1974, §1). As problematic as it may be, we will keep this distinction only in the intuitive level, following the standard approaches in the literature. It should be clear that the so-called instrumentalist approaches will not be considered here as well, to whom there is no meaning in the effort of interpreting QM in the sense described above.

[3]This is a highly controversial interpretation of QM and, of course, one may argue that QM "does not *need* consciousness". This is a claim which we completely agree. Nevertheless, it should be mentioned that QM is at least *compatible* with such an interpretation (in the same way that it is compatible with various versions of no-collapse interpretations). Because of this large variety of compatibility of interpretations with distinct metaphysical commitments for each one of them, one can state that QM is *underdetermined* by its (metaphysical) interpretations. In this way, each interpretation remains consistent with QM, and the theory itself does not give the ingredients necessary to the choice of a single, final, interpretation. Based on the underdetermination argument, we think that no interpretation, as controversial as it is, should be dismissed *prima facie*, as if one already knew what is the *right* interpretation for QM—if this even makes sense at all.

[4]It is worth mentioning that Bub (1999) acknowledges a similar distinction between the metaphysical outcomes of various interpretations *within* the relative-state interpretation, first put forth by Everett (1957), as one can assign to it a meaning that the branching processes are "many worlds" (DeWitt 1970) or "many minds" (Lockwood 1989).

[5]For an account of several formulations of QM, the reader should be referred to Styer et al. (2002).

[6]Although von Neumann did not mentioned the term "entanglement" (as the term is coined by Schrödinger in 1935, and von Neumann's seminal book dates from 1932), it is clearly an entanglement situation because both subsystems $\mathscr{H}_S$ and $\mathscr{H}_A$ are *correlated*, and not just the values of observables within the same system.

[7]It should be acknowledged that von Neumann's (1955 p.421) use of the term "abstract ego" is conventionally understood as "consciousness". For a historical account on this matter, the reader should be referred to Jammer (1974).

[8]As such, the phenomenological approach to CBI avoids the standard criticisms directed to von Neumann's (1955) dualist approach, such as the paradox of Wigner's friend (see Wigner (1983), Shimony (1963), Jammer (1974)), because, in it, there is no such thing as *a mental process acting as causal agent in the reduction of superpositions*. Nevertheless, as we already said, we will not engage here the evaluation between the dualist and the phenomenological approaches to CBI; rather, we are taking for granted the phenomenological approach by inference.

[9]Martin Heidegger (1996, p.210, §644) was one of the main opponents of Husserl's late work. "The idea of a 'pure ego' and a 'consciousness in general' are so far from including the a priori character of a 'real' subjectivity [. . . ]".

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