QUANTUM MEASUREMENT ACT
AS A SPEECH-ACT

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Abstract: I show that the quantum measurement problem can be understood if the measurement is seen as a “speech act” in the sense of modern language theory. The reduction of the state vector is in this perspective an intersubjective – or better a-subjective – symbolic process. I then give some perspectives on applications to the “Mind-Body problem”.

Keywords: Quantum measurement – Mind-Body problem – Language

1 Introduction: “Realism” is an Idealism

Science, and in particular physics, is a perpetual fight against absolute bases and essences: space, simultaneity, heat as phlogistic, ether, properties of quantum objects. Relativity theory and quantum physics have shown all the benefits of the renouncement of essences such as ether and values of physical quantities. Such essences do not belong to experience and are only the fruit of imagination (more exactly they represent an abstraction constructed out of experience thanks to a priori concepts). In this sense, if by “realism” one means the belief that there is an essence behind experience, realism is an idealism. An “objective underlying reality” is only a word (expressing a desire of reality) and there is nothing behind or beyond it. Since the present meeting is also devoted to “the subjective”, it is worthwhile to point out that the same phenomenological and constructivist approach holds also for the mental world and that for instance “the” mind (as an essence) has also to be renounced.
2 The quantum measurement

2.1 Reminder of the problem

Although the rules of quantum mechanics are well known, it is better, for clarity, to recall them. They rest on primitive notions such as "system", "state of a system", "observable" and can be summarized as follows:

- R1 Every system $S$ is described by a Hilbert space $\text{Hilb}$.
- R2 Any state of the system is described by a $\psi \in \text{Hilb}$.
- R3 In absence of measurement, the system evolves according to the Schrödinger equation $i\hbar \partial \psi / \partial t = H \psi$, where $H$ is the hamiltonian of the system.
- R4 A physical quantity (observable) is described by an operator $A$ on $\text{Hilb}$.
- R5 The only possible outcomes of a measurement of the observable represented by $A$ are the proper values $a_i$ of $A$, with the corresponding proper vectors: $A\psi_i = a_i \psi_i$.
- R6 The result of the measurement of $A$ on the system in a state $\psi$ is random with a probability given by $p_i = | < \psi_i | \psi > |^2$.
- R7 After the measurement the system is in the state $\psi_i$ ("state vector collapse").

There is a kind of duality in these fundamental concepts and rules, since rules R1 - R3 deal with the description of the system, while rules R4 - R6 deal with observables which appear heterogeneous with respect to the system. In this sense, the observables do not belong to the system.

It is natural for a physicist to try to describe the measurement as an interaction between the system and the apparatus and therefore the latter as another system, i.e. by a state vector $\psi_A$ of $\text{Hilb}$. But then, when this approach is translated into the quantum formalism, a contradiction appears. Indeed, let $\psi_{SA}$ be the vector describing the meta-system "system + apparatus" and $H_{SA}$ the interaction operator system-apparatus. Then:

- from (R3), after the measurement, the meta-system is in the (unique and predictable) state $\psi_{SA}(t) = e^{-i/\hbar H_{SA}t} \psi_{SA}(0)$.
- from (R7), after the measurement, the system is, at random, in one of the states $\psi_i$. 
The two final states are incompatible. That is the problem.

The central question then is: “Why does the process of observation (giving rise to the state vector collapse, that is to a sudden transition between two states of the observed system) escape the normal evolution of the pair system+observer described by the Schrödinger equation?” There is an even more radical question. The knowledge of the state $|\psi\rangle$ of the system is necessary to predict the possible outcomes of the observation. But it is not sufficient since, to describe the set of outcomes, we need to add an heterogeneous element, the operator associated with the observable which is measured. Why is this second level necessary? I shall call it the “question of the concept of observable”.

2.2 Why “decoherence” does not solve the problem.

Several solutions have been proposed during the past years. Some of them modify in a way or another the foundations of quantum mechanics: hidden variables, spontaneous localization, non linear Schrödinger equation, “many worlds” (in fact many observers) interpretation etc.

A different solution, known as the decoherence theory, has been developed by Zeh, Zurek, Omnès and others without any change in the standard postulates. It consists in pointing out that the interaction of the system with the environment diagonalizes very rapidly, with a very short characteristic time $\tau$ and in an irreversible manner, the density matrix of the meta-system formed by the system, the observer and the environment, thus leading to an apparent quasi-collapse of the state vector. This explanation has become popular since the occurrence of decoherence has been experimentally demonstrated (Davidovich, Brune, Raimond et al., 1996).

Unfortunately the explanation based on decoherence is not satisfying for the following reasons. First, decoherence is a statistical notion based on the statistical matrix representing statistical ensembles of systems. But in a given experiment one does not deal with statistical ensembles but with an individual system (and an apparatus). In other words, the unicity of the result of a given experiment is not expressed by a diagonal matrix. In mathematical terms, decoherence leads to a diagonalized matrix, while in a single experiment all the diagonal elements of the matrix are all zero except one. In other words, the expression

\[
\rho = \begin{pmatrix} 1/2 & 0 \\ 0 & 1/2 \end{pmatrix}
\]

is not the same as

\[
\rho = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}
\] or \[
\rho = \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}
\].
Supporters of decoherence often reply that quantum physics makes only statistical predictions. That statement is contradicted by predictions like “the measurement of any component of the spin of a photon in a single experiment will give an integer result”. In addition, the very concept of “ensemble” presupposes that there are single individuals of the ensemble. If quantum theory only deals with statistical predictions, it is an incomplete theory since individual experiments escape it. A second problem with decoherence refers to the question of the concept of observable (end of section 2.1). This question is in fact addressed to any attempt to describe the measurement as a system-apparatus interaction. If this interaction was a good model, it should be able to describe several aspects of a measurement with, as only primitive concepts, those of state vectors $\psi_S$, $\psi_A$ of the system and the apparatus and the system-apparatus interaction hamiltonian. Namely:

- What is the meaning of an “observable”?
- What means “the value” of an observable?
- Why is the outcome of an experiment random, while the interaction is deterministic?
- After the interaction why is the system precisely in one of the states $|a_i>$?
- Why are the only possible outcomes one of the proper values of an operator $A$ (that the model should construct)?

J.-S. Bell was well aware of all these difficulties when he wrote his paper “Against measurement” (1990) where he proposed to replace observables by “beables”.

2.3 What is really a measurement?

To be performed, a measurement needs two ingredients:

- an apparatus, object of perceptions and manipulations
- (pre-existing) mathematical symbols to express the result.

There is indeed no measurement without (or before) the expression (in mathematical terms, for instance “$A = a_i$”) of its result. This is not a philosophical point of view, it is an empirical fact. In this respect, $A = a_i$ does not reflect or translate a reality outside itself. It creates, by its own declaration, this reality. It is this (symbolic) reality. As a matter of fact, a
symbol is its own actualization. It means that, as a mathematical symbol, the outcome of a measurement is not the (quantum) state of the screen of an apparatus and, thus, cannot be described by a state vector. In pre-quantal terms, a symbol, \( e.g. \) 1, is different from its pixelized image and from its physical support, since the symbol 1 is required \textit{a priori} before any pixelisation (Figure 1). In terms of interaction, a measurement is thus not a physical interaction (i.e. described by an Hamiltonian) between two systems (described by state vectors), but an “interaction” between language (discourse) and a perception.

Figure 1. The pixelisation of the symbol “1” is different from the symbol itself.

These remarks lead in a natural way to the solution I propose (Schneider 1994): the measurement act is not a physical transition or phenomenon, but a purely \textit{semantic} act, in the same line as the \textit{speech acts} \( ^a \), well known in language theory. A speech act does not describe a situation independent of itself, it creates what at the same time it describes. The measurement act has more precisely the structure of a \textit{declaration}. The question whether this process is of psychological nature or takes places in some mind is not relevant. A semantic process is exterior to any individual, it is existing only as shared by the community of locutors and in this sense is objective. It just takes place in a symbolic universe, the universe of discourse in which all physicists live. It is the universe studied by linguistics and semiotics. It has nothing to do with psychology. It is not the “consciousness” of the observer which operates the state vector collapse, as was proposed by London and Bauer (1983). It is the result of an impersonal, non psychological but em-

\( ^a \)For a general introduction to these notions, see J. Austin 1982
pirically ascertainable, production of a signifier which exists only as shared by the community of physicists. In other words it is not a passive registration, it is an active semantic process. The subjectivity of one observer is to be replaced by the intersubjectivity of the discourse, with no psychological subject, where the impersonal semantic collapse of the state vector takes place. To express it in another way, the measurement act, as giving an attribute to a system, is an act of attribution, a declarative act. The judicial domain can help us for an analogy: a judgement does not register afterward a pre-existing reality, it does create it by its verdict. The judgement “guilty” creates, in the judicial universe, guilt. The result of that act is of course random and has a probability of occurrence $|\langle a_i|\psi \rangle|^2$. This conception sheds a new light on causality in the quantum measurement: the result of a measurement act has no other cause than itself, it is its own cause. It is in this respect that there is no quantum causality.

The “classical” character of the measurement apparatus lies in the semantic nature of its description, not in its complex atomic structure (as could naturally but erroneously be inferred from the Ehrenfest theorem). A system is a measurement apparatus only insofar as it is described by a set of signifiers; otherwise it is nothing but a quantum system. As for the observer, it is most certainly decomposable in atoms, but it is an observer only as a support of semantems. In a measurement, the so-called interaction with the measuring apparatus (which would be described by an Hamiltonian) is an encounter, an interaction if one may say so, between the observed system and the universe of discourse. Because this encounter is not describable by an Hamiltonian the measurement process escapes the Schrödinger equation. It was N. Bohr (1983) who was among the first authors pointing out the role of language in the measurement. But for him language was just a collection of words, the vocabulary of classical physics. Here the point of view is different: what is important is not so much the content, but the auto-productive nature of a signifier and it is this auto-production which gives rise to the state vector collapse.

The idea that a measurement does not result from an interaction between a system and an apparatus has been also recently expressed by O. Ulfbeck and A. Bohr (2001). For these authors, quantum physics does only deal with clicks of an apparatus. But they do not address the essential

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According to modern views, consciousness is on the contrary defined as being the cross-rads of different signifier.
question: "What is a click?". For instance when a click is recorded in a
movie, what is the real click? The click or the movie of the click? The
present paper explicitly claims that the objective (intersubjective) click is
the declaration: "There is/was a click".

We can now apply this constructivist approach to the notion of subject
and to the Mind-Body problem.

3 Mind-Body
3.1 General principles

We have seen that a measurement is the (random) emergence of a symbol
detached from (the appearance of) an apparatus. If the symbol is mathemat-
cal, it is a scientific (physical) measurement.

But there can be “pre-scientific” measurements when the symbol is
vague or fuzzy such as a colour, a sound, a smale etc. There is then (at
least up to now) no mathematical representation of these vague symbols by
hermitian operators. But they do nevertheless exist (i.e. are experienced)
as symbols. All these vague symbols are not systems and have no state
vector.

A first application of vague symbols in the context of quantum physics
is the answer they provide to an argument often opposed (in particular by
J.-S. Bell) to the point of view defended here that the state vector collapse
is operated by an observer. The argument is formulated in ironic terms:
“Only physicists having their PhD can operate a state vector collapse”.
In other words, observations or experiments made without the support
of elaborated mathematics would not exist. The notion of vague symbol
provides an answer: every experience, whatever its vagueness, is legitimate
at its own level. It is a scientific measurement when it is expressed in
scientific symbols.

Vague symbols lead to a more general notion of symbol, introduced
progressively along all the XXth century by semiotics (the science of sym-
bols). Indeed, words and mathematical symbols are special types of sym-
blems. Symbols are what Cassirer calls symbolic forms. They are, like Kan-
tian concepts, a priori symbols. They belong to an unlimited variety of
registers: acoustic, graphical, gestual, conceptual, judicial, institutional,
esthetical, emotional, affective, ethical etc. They are all structured as de-
clarations designating what they construct. To be less elliptic, this structure
means that in a first step, as a declarative gesture, they produce themselves
and in a second (timeless) step they present themselves as designating from
the outside, as an objective reality, what they have just created. Toillustrate this approach by a concrete example, the symbol “a” is, in a first
time, just a given letter which, in second time, designates the notion of
“symbol a”. It represents a kind of self-distanciation of symbols.

As mentioned in the introduction, no genuine “consciouinosness” nor “subject” is needed. They are not genuine instances, they are constructed
objects out of two primitive instances: subject-less sensations and (declar-
ative) symbols. This construction, also called symbolization, detaches a
symbolic object from the sensation. To be more precise, there is a primit-
ive instance, the so called “object-relation” (equivalent to a sensation)
which is a complex made of a relation and its “to be” object, entangled
together. At this point, it is not relevant to ask if the object-relation is one
or two instances, since the concept of number does not apply: we are in
the realm of a “proto-arithmetic” (Schneider 1994). More exactly, sym-
bolization creates attributes and an object is in a second step the synthesis
of different attributes.

3.2 Tentative quantum modelization of the Mind-Body relation

To address this question, Mind and Body have first to be defined and
characterized in the framework of the concepts presented here (Schneider
1997).

“The” mind, or the subject, as things are bad primitive concepts. They
have to be replaced by a-subjective symbols, i.e. symbols by their own,
source-less. In the present view, the “subjective” is then a particular object:
an object constructed out of ethical symbolic forms.

The physical body is not the source of sensations. As a physiological
object, it is an abstraction constructed by a bio-physical theorization out
of primitive and source-less sensations.

In other words, the primitive concepts are no more Mind and Body,
but sensations and symbols out of which Mind and Body are constructed
abstract objects. In particular, the body is an abstract synthesis of physi-
ological attributes resulting from symbolization.

In quantum theory, symbolic attributes (i.e. values of observables)
emerge randomly and are cause-less. By extending the notion of symbol as

\footnote{This process leads to the notion of “afterwardness”, a non linear notion of time, de-
scribed by J. Lacan in his work (passim)}

\footnote{The processes by which the subjective is constructed are very complex, they involve
parental and social discourses, words like “I” which precede the subject, identification etc; rigorously speaking, the sentance “I speak” means something like “The word “I”
speaks”. That is why the traditional subjective is in reality a-subjective.}
in section 3.1, there are two types of bodies created by symbolization out of sensations:

- the physical, or physiological body, i.e. the bio-physical description of the body created by the conceptualization of physics

- the emotional body created by emotional symbols (words of pain, joy, anxiety etc).

Emotional symbols are genuine, not constructible from physiological instances. This conception is generalizable to non verbal symptoms (I refer here to the psycho-analytical conception of symptoms as symbols).

Take for instance as physiological observables skin colour, cardiac rhythm, blood pressure. The emotional observables are for instance an exchange of words (with or without an emotional content with an interlocutor). A complete discussion should include unconscious aspects, always emotional, of symbols. The two types of observables do not “commute”, they are complementary in the quantum mechanical sense: it means that an individual cannot at the same time be subject to a physiological observation and have emotional relationships. It is interesting to note that C. Bohr (father of N. Bohr and biologist) wrote:

“An organism cannot at the same time be subject to a chemical analysis and be declared as living”.

We then can have a succession of non commutative events to describe how an emotion can make a face blushing: white skin $\rightarrow$ expression of emotion $\rightarrow$ pink skin. It is similar to the quantum measurements of non commutative components of the spin: $S_X = +1/2 \rightarrow S_Z = +1/2 \rightarrow S_X = -1/2$. We so have a simplified scheme for quantum modelization of the undeterministic evolution of the body.

4 Perspectives

The main stream in current cognitive sciences is to seek a “naturalization” of consciousness. It is an attempt to treat Mind and consciousness as objects (however immaterial they are). An essential prediction of the present approach is that these attempts of naturalization will certainly improve our knowledge of the physical brain but not of the mind.

Secondly, many authors attempt to reconstruct, essentially thanks to decoherence, the classical world out of the quantum level. In the present approach, it is the classical world which precedes the quantum level: the latter is constructed from the behavior of macroscopic apparatuses.
With the concept of afterwardness briefly discussed in section 3.1 (and formalized in Schneider (1994)) it becomes possible to reformulate the notion of consistent history (e.g. Omnès 1994) and the transform it into a notion of “afterward history” (Schneider 2000).

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