

# The Role of the Observer in the Collapse of the Wave Function: A Cognitive and Linguistic Analysis of the Double Slits Experiment

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## Abstract

The goals of this paper are to analyze cognitively and linguistically the Double Slit Experiment, trying to understand what the functions of the observer in the collapse function wave are. To do it, a didactic video that explains the experiment in great detail was selected, and the audio (Brazilian Portuguese) was transcribed and rigorously analyzed. The theory that enabled to do this analysis was the Conceptual Metaphor, a central theory in the Cognitive Linguistics field. The results were: DOUBLE SLIT EXPERIMENT was conceptualized and understood in terms of TRAVEL; ELECTRON was conceptualized sometimes in terms of OBJECT (PARTICLE); ELECTRON was another time conceptualized in terms of FLUID (WAVE). How a TRAVELER is an OBJECT and not a FLUID, the particular ELECTRON properties are highlighted during the measurement whereas wave properties keep hiding in cognition. As a conclusion, the Description Prescription Principle was proposed in this paper trying to solve the problems between the realism of Natural Sciences and the idealism of Social Sciences.

**Key Words:** Double Slit Experiment, epistemology, quantum physics, linguistics, psychology

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## Introduction

In this section, the literature review will be presented with reference to the observer problem in Quantum Mechanics since the wave collapse depends on an observer, that is, someone concrete (Dugald, 1987). However, before presenting this problem of the observer, the history of contemporary physics will be presented due to the paradoxical nature of light. Light, as it is known today, has paradoxical properties, because it is able to behave like a wave as well as a corpuscle, depending on the

experimental context (Tipler, 1995). The waves have properties of diffraction and interference, whereas the particles have properties of reflection and refraction (Figure 1). These physical properties are seen as contradictory by classical physics, since a moving car cannot cross another with nothing happening; they would clash as particles reflect. It's important to do a brief review about corpuscular and wave properties, which will make the paradox more comprehensive.

It's important to consider that this introduction, at least in the first part, is based on old discussion in quantum mechanics, since the goals of this paper is working with language and cognition, which are always supported by cultural models. Then, it's very important to do a brief

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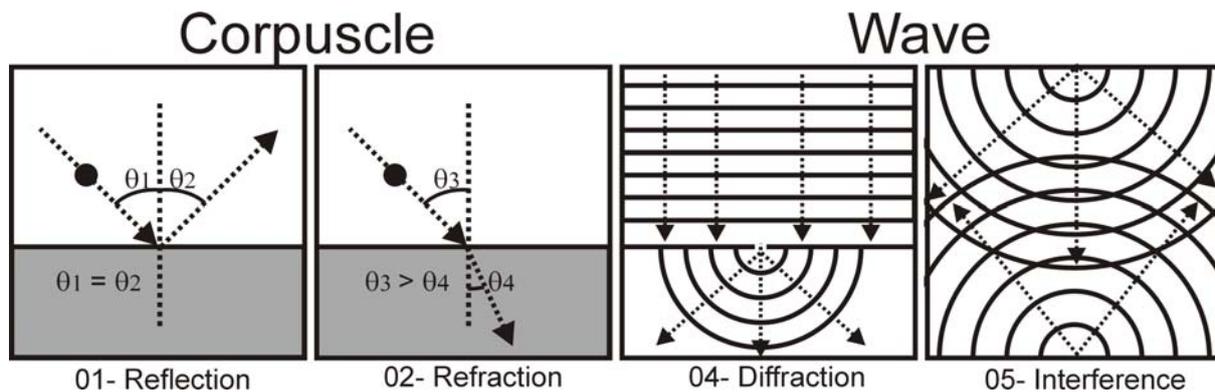
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recapitulation of this discussion, which came from of the dichotomy between classical mechanics and wave studies, since the great problem that researchers, thinkers and philosopher had in the past was to integrate the corpuscular properties (reflection and diffraction) and wave properties (diffraction and interference). We know that this dichotomy division is not absolutely correct

or exact according to quantum mechanics today. However, this didactic division was indispensable to explain the results. For example, a simple experiment using a ball and a bathtub full of water is enough to explain the wave properties and the corpuscular properties in a classical way (Figure 1).



**Figure 1.** Wave and corpuscle properties. 01: the ball is reflecting; 02: the ball is refracting; 03: the water is diffracting; 04: the water is interfering.

From a certain point of view, reflection may be considered as a corpuscular phenomenon and occurs when an object or a light touches on a surface, changing its direction, but without changing the medium (Halliday *et al.*, 2009). When a person, a woman, for example, is standing in front of a mirror, dressing up to go a party, she is experiencing the phenomenon of reflection (Figure 1; 01). The light is emitted by a lamp (or sun) and focuses on the person's body, and some of these reflected rays go on toward the mirror, where they are reflected again. The ray that touches on the surface is called an incident ray, whereas the other, which is reflected, is considered a reflected ray. These rays make, each one, an identical angle with the normal line, which is an imaginary perpendicular line on the surface. They can be understood like "billiard balls" (Figure 1), because the light is reflected according to these laws, that are widely used by engineers from different areas.

Refraction may be also considered as a corpuscular phenomenon and occurs when an object or a light changes from one medium to another, changing its direction and speed, according to the properties of the medium (Tipler, 1995). For example, when

someone dips a stick into full glass water, he or she notes that the object apparently bends because of refraction. The light ray that focuses on water is called the incident ray, while the ray that penetrates the water and changes its direction and velocity is called the refracted ray. The stick apparently bends because the light in water has a lower speed than the light in the air, and then the refraction angle is smaller than the angle of incidence. Situation like this occurs when a person fires shot into a pond, because the bullet loses speed and changes its direction when it penetrates the water. The angle of refraction, as in the case of light, is less than the angle of incidence, when the bullet passes from the air to the water. They can be perceived like "billiard balls", the light loses speed and changes its direction when moving from one medium to another, characterizing the phenomenon of refraction.

On the other hand, interference is a wave phenomenon, and occurs when two or more waves, when crossed, superimposed constructively or destructively at one point (Halliday *et al.*, 2009). When two people produce with their hands two waves in a bathtub full of water, these waves propagate

and interfere with each other. Constructive interferences occur when two crests (high points of the waves) or two valleys (low points) overlap, whereas the destructive interferences occur when the valleys and crests are subtracted. The wavelength is the distance between two crests (or valleys) in succession, while the frequency concerns just the oscillations per second. The frequency of a wave is dependent only on its source (in the example, it would be the speed with which the person touches the water), while its wavelength may increase or decrease according to the environment (water, oil etc.). Since the wave intensity concerns its amplitude, that is, how tall it is, and corresponds to the distance between the resting state of the wave, without any disturbance, and its crest or valley. In order to be understood like a wave, light rays can be seen to pass each other (interfering constructively or destructively) without anything to happen.

Like interference, diffraction is also a wave phenomenon and occurs when a wave passes through one slit or circumvents an object whose size is of the same order of magnitude of the wavelength (Tipler, 1995). If a wave in the sea has a wavelength in the same order of the magnitude of an object, like a rock, the wave can get around it. If the object were larger than the wavelength, the wave of the sea would be reflected as a "billiard ball", and not circumvent the object. If a wave goes toward a loophole that has the same order of magnitude as the wavelength, it will be diffracted when passing through the hole. If the gap is too large, outside of the magnitude order, the wave is not diffracted and passes straight through the hole. For to be perceived like a wave, but as an electromagnetic wave, the light can diffract according to the principles mentioned before.

In nineteenth and early twentieth century, the wave- corpuscle duality was questioned by many researchers, who often adopt postures exclusionary (Hussein and Salinas, 2001). While some proved by experiments that light behaved as a corpuscle, others proved that it behaved like a wave, and that is the source of the paradox. For example, Thomas Young, in the first half of the nineteenth century, by his famous

Double Slit Experiment, proved that the light is diffracted and interfered in passing through two tiny holes (Hewitt, 2002). It was an empirical and experimental evidence that light behaved like a wave, not as a corpuscle. On the other hand, Albert Einstein, in the first half of the twentieth century, also proved that an electron could be torn from a metal plate from the emission of an electromagnetic wave such as light. This Photoelectric Effect, as it became known, was also empirical and experimental evidence that light consists of photons (packets of energy), and behave like a corpuscle.

How to solve this wave-corpuscle paradox, since both hypotheses were tested and proved by important research theories, yet in different experimental contexts. The researcher who gave an answer to this paradox was Niels Bohr, which said that the corpuscular and wave properties are not exclusive, but complementary (Dugald, 1987). This became known as the Principle of Complementarity. In a given experimental context, as in the case of the Double Slit Experiment, light behaves like waves, since these properties are mobilized. However, in another experimental context, as in the case of the Photoelectric Effect, light behaves as a corpuscle, as the wave properties are not being mobilized. Therefore, the wave-corpuscle duality is similar to the definitions of yin and yang presents in Chinese Philosophy, and there is evidence that it inspiring Bohr (Capra, 2006).

The wave-corpuscle paradox has become more bizarre with the experimental evidence that larger particles, like electrons, protons and neutrons also behave like waves (Tipler, 1995). De Broglie was the one who said that all matter, including macroscopic, behaved as a wave-corpuscle, and it would depend on the so-called "Wavelength of De Broglie" (Oliveira, 2005). It means that all objects in the world, despite the apparent corpuscles principles, also have wave properties associated with, but do not manifest themselves in everyday life. When a person goes through a door, the person does not diffract like waves do, because its Wavelength of De Broglie is infinitely smaller than the doorway. However, there was a big problem in reconciling the

corpuscular and wave properties, because the question of the equations that describe these waves of matter. It was studied by Erwin Schrödinger, who solved this problem developing the so-called Schrödinger equation, which is a mathematical function that describes a distribution of matter (Nagasawa, 1993).

The Schrödinger equation, despite describing the distribution of matter, brought new problems to the physics of his time, because it was such a wave function of complex quantity, not measured directly by any physical instrument (Oliveira, 2005). It means that the Schrödinger equation was a mathematical abstraction, which used to represent just the state of a given system. It was solved by Max Born, who reformed some aspects of the Schrödinger equation, enabling the interpretation of quantum phenomena in terms of probabilities. However, this quantum probability is not similar to the one already studied by Classical Physics, like flipping a coin and waiting head or tail probabilities. For classical physics, the probability is related to the control of all variables, because if the researcher knows the weight, the speed and the angle of the hand, he would be able to predict the results. The probability that quantum physics, set forth in the center of its mathematical formalism, is a kind of uncertainty inherent in nature (Dugald, 1987).

Now, the physics cannot be further treated in a deterministic way, because obtaining information of the measurement beforehand does not provide subsidies to forecast results. The Uncertainty Principle of Heisenberg had already made it clear that the momentum and position of a particle could not be described with exact precision at the same time (Oliveira, 2005). If the researcher wants to measure the velocity of a particle, it necessarily loses information about its position in the space, or vice versa. The best thing that physics is able to do, from a repetitive series of experiments, is describe the properties of a system in terms of these probabilities: (1) the probability of a particle being in a position X; (2) the probability of it having the trajectory Y, and (3) probability of the particle having the energy Z in a given moment. Niels Bohr was

a defender of this intrinsic randomness of quantum nature, while Albert Einstein, a determinist, used to say that "God does not play dice" (Whitaker, 2006).

This problem about free will and determinism, which incorporates the Greek philosophers, put the indetermination as central to quantum mechanics, especially from the Copenhagen Conference (Petruccioli, 1993; Dugald, 1987). In the Copenhagen interpretation, Bohr, Born, Heisenberg and others have defined as intrinsically paradoxical quantum phenomena, emphasizing the importance of the [perception of the] observer in the measurement process. Before the researcher performs the measurement on his equipment, the quantum properties staying in a superpositional state of self-states, thus, indefinable. When the researcher, someone concrete, interacts with the object-experiment by his equipment, the wave function collapses into one of the possible states, according to the laws of quantum mechanics. For example, if an electron has a probability in a given experiment to go through four different paths, it does not present a given state before the measurement. It's not possible, according to Quantum Mechanics, to acquire information about the electron (such as position and speed) in an instant before the measurement, and predict its future behavior. The presence of the observer is indispensable for the wave function collapse into one state possible (position, speed, path, energy and so on), and the goals of this paper are understand it in terms of cognition and language.

Recently, Conte (2010) has finally demonstrated some results about this discussion, proving that the brain works not in a deterministic way, but in a quantum probabilistic manner. His conclusions can be summarized, but not exhaustively, as:

- 1) Quantum wave function collapse is demonstrated and no more assumed as a postulate in quantum mechanics;
- 2) A quantum measurement is a semantic act, that is to say, a cognitive act;
- 3) The entities of quantum mechanics are conceptual entities interfaced with matter;
- 4) There are quantum interferences effects in mental states.

His works were specially based on physics, mathematics and neuroscience, that is, from natural sciences' point of view, and not from a social science framework. However, this work, proposed here, seeks to analyze the Double Slit Experiment, trying to understand what the importance of the observer in the collapse of the wave function in a cognitive and linguistics paradigm. Is the observer able to create the reality? Or observer only knows the world "out there"? Is the observer external to the experiment? Or is the observer also part of the experiment? Why the mathematic language says one thing and experiential reality says another? What is the nature of cognitive and linguistic paradox of wave-corpucle? These are some questions that may or may not be answered from the analysis of Double Slit Experiment. For the analysis of the Double Slit Experiment, we used the Cognitive Linguistics, a subarea of Cognitive Sciences, which considers language as a manifestation of the conceptual system.

## Methodology

### **Step 1- The choice of the experiment**

The experiment that was selected for linguistics and cognitive analysis was the famous Double Slit Experiment<sup>2</sup>, conducted initially by Thomas Young in the first half of nineteenth century (Hewitt, 2002). This experiment was initially conducted with light, and later, by other researchers, with an electron, proving its wave-corpucle duality (Tipler, 1995). With the purpose of making this work more comprehensible, a cartoon of Dr. Quantum, which aims to explain the Double Slit Experiment, was selected (Experimento da Fenda Dupla, 2010). Its

<sup>2</sup> The Double Slit Experiment was select to analyze, instead of another simplest experiment, because its conceptualization depends on complexes cognitive schemas. For example, in the results of this paper, the metaphor QUANTUM PHENOMENA ARE UNKNOWN AND MYSTERIOUS LANDS (CONTAINER) explains the old dichotomy: classic phenomena *versus* quantum phenomena. Because, If a "macroscopic thing" (researcher) is in a "container" (quantum phenomena), it (he or she) is not able to be out of the "container" (classic phenomena) at the same time. Then, a simple experiment could have been less productive than the analyses of the Double Slit Experiment, which requires high level of cognition and language, and explains that nobody is discovering the world "out there", like defends ingenuous realism.

audio (Brazilian Portuguese) was transcribed into a document, and then rigorously analyzed from the theoretical framework of Cognitive Linguistics. This theory will be more fully explained below, in the next sub-chapter, after a detailed explanation of the Double Slit Experiment.

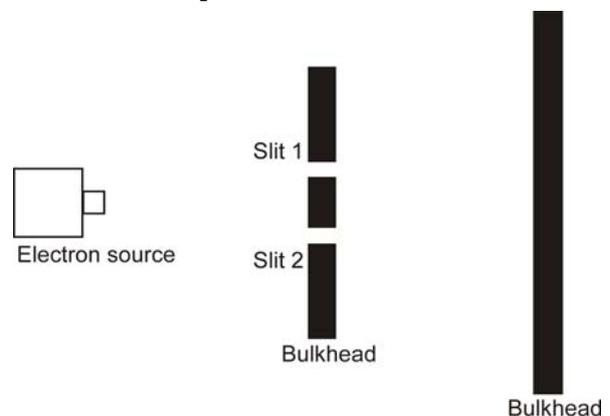


Figure 2. Double Slit Experiment

The experiment (Figure 2) consists in throwing electrons toward a bulkhead that has two slits, and the electrons that pass through can make a design in the back bulkhead (Hewitt, 2002). When slit 1 (one) is covered, the electrons are able to pass through slit 2 (two), or vice versa, and it makes a design of corpuscles in the back bulkhead. The electrons are behaving as well as corpuscles, yet they make just two lines in the back of the bulkhead in this case. However, when the two slits are simultaneously uncovered, that electrons don't behave anymore like corpuscles, but instead of, they behave like waves. A lot of lines made in the back bulkhead are parallel, yet the electrons are behaving as well as waves on water. In sum, the electron leaves the source, passes through a slit (while the other remains closed), or both in the same time, and hits the bulkhead behind.

With the aim of discovering which of the two slits the electron has passed in the bulkhead, the researchers put a measuring instrument behind of the slit. According to the mathematics of Quantum Mechanics, the electron has 4 options for passing through: (1) slit 1 (one); (2) slit 2 (two); (3) both slits; and (4) neither slit. When the researchers tried to figure out which of the two slits the electron passed, they became even more shocked, because the electron has returned

to form a pattern of corpuscle in the bulkhead behind. This means that before measuring, the four options were vague, in a superposition state of self-states. The presence of the observer, someone concrete, caused the collapse of the wave function, that is, the manifestation of just one empirical reality.

### **Step 2 - Referential Theory**

The referential theory that was used in this study was the Cognitive Linguistics theory (Evans and Green, 2006; Geeraerts and Cuyckens, 2007), that understands the language as a manifestation of the conceptual system embodied. The theory that allowed a detailed analysis of the Double Slit Experiment was the Conceptual Metaphor Theory (Lakoff and Johnson, 1980; Kövecses, 2002; 2006), which considers the cognitive processes in terms of conceptualization. Conceptualizing is understand and organizing a domain in terms of another domain, establishing conceptual mapping between the corresponding elements. These processes occur in the mind of the speaker or the writer when they are living in the world through their bodies, and manifest in their speech, gestures and behaviors. Analyzing the video “O Experimento da Fenda Dupla” (Double Slit Experiment), the cultural models and cognitive schemas were much better understood during the collapse of the wave function.

For instance, when someone says “Christmas *is coming*”, “the New Year *is after* Christmas”, “Easter has *passed*”, he/she is conceptualizing the TIME in terms of a MOVING OBJECT. Although TIME is an abstract thing, it can be understood in terms of a MOVING OBJECT, since the time is able to come and to pass by the speaker. When a person says “don’t *waste* your time”, “*invest* your time in good things”, “don’t *rob* my time”, now he/she understands the TIME in terms of MONEY. The source domain (the one that is used to understand something) is usually more concrete and less complex, while the target domain (the one that is comprehended by another domain) is more abstract and complex. In these examples above, the target domain is TIME, whereas the source domains are the MOVING

OBJECT domain and the MONEY domain respectively.

A phenomenon that occurs during this process of conceptualization and needs to be mentioned is the phenomenon called highlighting and hiding (Evans and Green, 2006). When someone understands a domain in terms of another, the source domain puts some elements in evidence on the target domain, while others remain in the background. For example, when a person understands the LIFE in terms of WAR, she/he puts some source domain elements (enemy, battle field, borders, weapons, etc.) in evidence on the target domain LIFE (competition, hard work etc). As a consequence, loves, peace, cooperation, which are also parts of the LIFE domain, remain during the process of the conceptualization in the background. That person wouldn't be able to experience good feelings and good relationships in his or her life, because he or she is used to understanding LIFE in terms of WAR.

### **Results**

The results were organized into two parts: (1) the cognitive metaphor DOUBLE SLIT EXPERIMENT IS TRAVEL (EXPERIMENTO DA FENDA DUPLA É VIAGEM) will be presented; and then (2) the metaphors ELECTRON IS OBJECT (ELÉTRON É OBJETO) and ELECTRON IS FLUID (ELECTRON É FLUIDO). This division is only didactic, because, in fact, all these results are essential to understand the experiment as a whole. The results will be presented in English translation and also its original version, Brazilian Portuguese.

The first result was that the DOUBLE SLIT EXPERIMENT (EXPERIMENTO DA FENDA DUPLA É VIAGEM – target domain) was being understood and conceptualized in terms of TRAVEL (VIAGEM – source domain). Although it is imperceptible to human senses, the quantum phenomena were being understood by the sensor motor experiences of the body in the world. Below there are the cognitive metaphors and some examples, underscores, in both languages, of metaphorical expressions in language.

DOUBLE SLIT EXPERIMENT IS TRAVEL

**(EXPERIMENTO DA FENDA DUPLA É VIAGEM)**

**ELECTRON SOURCE IS JOURNEY ORIGIN (FONTE [DE ONDE SAEM OS ELÉTRONS] É ORIGEM)**

[A1] (...) the electron leaves [from the source] as a particle (...).

[A2] (...) o elétron sozinho sai [da fonte] como uma partícula (...).

The emission source of electrons is being understood metaphorically in terms of travel origin; that is, the electron can leave the electron font as well as a traveler can leave a city X and go to another city Y.

**BULKHEAD IN THE BACK IS DESTINE (PAREDE DE TRAZ [AONDE CHEGAM OS ELÉTRONS] É DESTINO)**

[B1] If by chance we throw a little object through the slit, maybe a marble for example, we can see a model *on the back bulkhead*.

[B2] Se por acaso lançarmos um pequeno objeto pela fenda que pode ser uma bolinha de gude podemos ver um modelo *na parede de trás*.

The bulkhead in the back is being understood in terms of the travel destination; that is, the electron leaves the font, goes ahead on a path, passes through a slit, and arrives at the bulkhead. At the same time, a traveler leaves a city X and arrives at another city Y by a path Z.

**POSSIBILITIES ARE DIFFERENT PATHS (POSSIBILIDADES SÃO CAMINHOS NA ESTRADA)**

[C1] All *these possibilities* are in superposition with one another.

[C2] Todas *essas possibilidades* estão em superposição uma com a outra.

The possible trajectories of an electron are being understood in terms of different paths in the journey; that is, between origin/font and destination/bulkhead in the back there are a lot of possible paths.

**SLITS ARE PASSAGES ON THE ROAD (FENDAS SÃO PASSAGENS NA ESTRADA)**

[D1] (...) *passes* through two slits and by neither and *passes* through just one and *passes* only through the other.

[D2] (...) *passa* por duas fendas e por nenhuma e *passa* por uma só e *passa* só pela outra.

The slits on the bulkhead in the middle of the path are being understood metaphorically in terms of passages; that is, a traveler can pass through a passage on a wall as well as an electron can pass through a slit.

**BULKHEADS ARE IMPEDIMENTS ON THE JOURNEY (ANTEPAROS SÃO IMPEDIMENTOS NA ESTRADA)**

[E1] Thus the balls have passed through the slot and *hit* there [on the back wall].

[E2] Pois as bolinhas passaram pela fenda e *bateram* lá [na parede de trás].

The bulkheads are being understood in terms of impediments on the journey; that is, an electron can't go ahead because of the bulkheads on the way as well as a traveler can't go on the journey because the impediments are like a wall.

**ELECTRON IS HUMAN TRAVELER (ELÉTRON É VIAJANTE HUMANO)**

[F1] The electron *decided to act* because it *knew* it was being observed.

[F2] O elétron *decidiu agir* já que ele *sabia* que estava sendo observado.

The electron is understood metaphorically in terms of a human traveler, that is, there is a process of anthropomorphizing the electron, which is regarded as a thing that thinks, knows and behaves.

**THE PAST IS THE ROAD TAKEN (PASSADO É CAMINHO PERCORRIDO)**

**THE FUTURE IS THE ROAD NOT YET TAKEN**

**(FUTURO É CAMINHO A SE PERCORRER) THE PRESENT IS THE PLACE OF THE BODY ON THE ROAD**

**(PRESENTE É LOCAL ONDE SE ENCONTRA O VIAJANTE NA ESTRADA)**

[G1] When they observed, the electron *went back* to behaving like a marble.

[G2] Quando eles observaram, o elétron *voltou* a se comportar como uma bolinha de gude

Time is being comprehended in terms of space; that is, the past corresponds to the back space behind the traveler, the future corresponds to the front space not yet known, and the present (here and now)

corresponds to the traveler's position on the journey.

#### MEASUREMENT INSTRUMENT IS OBSERVER (INSTRUMENTO DE MEDIDA É OBSERVADOR)

[H 1] The *observer* ended the wave function simply by *observing*.

[H 2] O *observador* acabou com a função de onda simplesmente por *observar*.

Measurement is being understood in terms of the observer apart from the journey; that is, a traveler can cross curious observers out on the road as well as an electron can pass through a slit being observed by equipment.

#### QUANTUM PHENOMENA ARE UNKNOWN AND MYSTERIOUS LANDS (CONTAINER) (FENÔMENOS QUÂNTICOS SÃO TERRAS DESCONHECIDAS E MISTERIOSAS [CONTÊINER])

[I 1] And so physicists have *got in that strange and mysterious land* of quantum events.

[I 2] É foi assim que os físicos *entraram nessa terra estranha e misteriosa* dos eventos quânticos.

Quantum phenomena are being understood metaphorically in terms of unknown and mysterious lands; that is, a traveler is able to get in or get out a land as well as researchers can get in or get out quantum phenomena.

The other results which complement those presented results above were that ELECTRON (target area) was being understood metaphorically sometimes as OBJECT (field source) and sometimes as FLUID (source domain). Below, there're the metaphors ELECTRON IS OBJECT and ELECTRON IS FLUID, as well as their respective metaphors hyponymy, which contains all the features.

#### ELECTRON IS OBJECT (ELÉTRON É OBJETO) ELECTRON IS SMALL BALL (ELÉTRON É BOLINHA)

[J 1] They [physics] thought "maybe these *little balls* are jumping on each other and making this model."

[J 2] Eles [os físicos] pensaram "talvez essas *bolinhas* estejam pulando umas nas outras e criando este modelo".

#### ELECTRON IS A PIECE OF MATTER

#### (ELÉTRON É PEDAÇO DE MATÉRIA)

[L 1] How *piece of matter* can create a model of wave's interference?

[L 2] Como *pedaços de matéria* podem criar um modelo de interferência como o das ondas?

The electron, although it has never been directly observed by researchers, is understood metaphorically in terms of an object in space; that is, the same way that a marble has content, form, size, speed and position, an electron is understood as a spherical ball of matter and very small.

#### ELECTRON IS FLUID (ELÉTRON É FLUIDO) ELECTRON IS WAVE (ELÉTRON É ONDA)

[M 1] (...) [Electron] *interferes* with itself (...).

[M2] (...) [o elétron] *interfere* consigo mesmo (...).

An electron, although it's not a mechanical wave, is being understood metaphorically in terms of fluid; that is, the same way as a water wave has a frequency, amplitude, interference, wavelength etc., an electron is regarded as a fluid wave that spreads through space indefinitely.

#### Discussion

In this section, the discussions of results will be presented, seeking to deepen the importance of the observer, an embodied observer, on the co-construction of phenomenological reality.<sup>3</sup>

First, the differences between language and *parole* will be explained, because mathematics language and verbal language have very different characteristics (Fiorin, 2002). Mathematics, like music and plates of traffic, is a form of language, a system of signs, socially shared. The sign is an entity composed of two indivisible parts, the signifier (concrete in nature) and significance (abstract in nature). For example, the significant "+" means addition, the significant "-" means subtraction, the signifier "8" means eight units, and so on. In order to be a kind of language, mathematics

<sup>3</sup> It is important to consider that the phenomenological reality is being used here in the sense of the embodied thesis - embodied experience, embodied cognition and embodied realism (Varela, Thompson and Rosch 2003; Lakoff and Johnson, 1999) - where there are a structural and functional coupling between body and environment.

are a socio-historical convention, which allows researcher to formalize their observations and experiments. The mathematical formalism, although it has a series of rules, algorithms, doesn't have the same rules of verbal language, the grammar, it has defined characteristics.

**Table 1.** The cognitive metaphor DOUBLE SLIT EXPERIMENT IS TRAVEL (EXPERIMENTO DA FENDA DUPLA É VIAGEM) in English (translated version) and Brazilian Portuguese (original version).<sup>4</sup>

DOUBLE SLIT EXPERIMENT IS TRAVEL (EXPERIMENTO DA FENDA DUPLA É VIAGEM)	
Source domain	Target domain
TRAVEL (VIAGEM)	DOUBLE SLIT EXPERIMENT (EXPERIMENTO DA FENDA DUPLA)
Journey origin (Origem)	Electron source (Fonte - de onde saem os elétrons)
Journey destine (Destino)	Bulkhead in the back (Parede de trás - aonde chegam os elétrons)
Path 01 (Caminho 01 - passar pela passagem 01)	Probability 01 (Probabilidade 01)
Path 02 (Caminho 02 - passar pela passagem 02)	Probability 02 (Probabilidade 02)
Path 03 (Caminho 03 - passar pelas 02 passagens)	Probability 03 (Probabilidade 03)
Path 04 (Caminho 04 - passar por nenhuma passagem)	Probability 04 (Probabilidade 04)
Passages on the wall 01 (Passagem 01)	Slit 01 (Fenda 01)
Passages on the wall 02 (Passagem 02)	Slit 02 (Fenda 02)
Impediments on the road (Impedimento no caminho)	Bulkhead with two slits (Anteparo com as 02 fendas)
Human traveler (Viajante - humano)	Electron (Elétron)
The road taken (Caminho percorrido)	Past (Passado)
The road not yet taken (Caminho a se percorrer)	Future (Futuro)
The place of the body on the road (Local onde se encontra o viajante na estrada)	Present (Presente)
Observer on the roadside (Observador na passagem)	Measurement instrument (Instrumento de medida)
Unknown and mysterious lands (Terras desconhecidas e misteriosas)	Quantum phenomena (Fenômenos quânticos)
Macroscopic object (Objeto)	Electron (Elétron)
Small ball - form (Bolinha - forma)	Spherical - form (Esférico)
A piece of glass - contend. (Vidro - conteúdo)	A piece of matter - contend (Matéria)
Macroscopic fluid (Fluido)	Electron (Elétron)
Water waves (Onda na água)	Matter waves (Onda de matéria)

The verbal language, although it is also a system of signs, has its own properties, as articulation and hierarchy of constituents (Fiorin, 2002). When an American speaker says "The boy threw the ball at the window," the competent listener understands, because this sentence is grammatical; build a

hierarchy of constituents. If someone says "threw the ball in the window boy", the listener does not understand anything, because this sentence is ungrammatical; not building any hierarchy. Besides being organized hierarchically, the verbal language is articulated morphologically and phonologically, which ensures greater retention and convenience in communication. When an American speaker says "boy and boys", he or she needs just put "-s" in the end, because this morpheme "-s" means plural. When he or she put "-s" in the end of the word "boy", it is not necessary to give all the information again, two times, as human being, small, young and male, because "boy" means it already.

This articulatory property and that hierarchy of constituents are not present in mathematical language, but only in the verbal language, both verbal and written. Mathematically, when a researcher says that the electron passes through a slit one (25% chance) and passes through slit two (25%) and passes through the slits one and two simultaneously (25%) and do not pass through any slits (25%), it is absolutely consistent. Physicists do not see problems in the mathematical equations used in quantum mechanics. Statisticians, like physicist, are always "cutting off" people in fractions, as in government research, when they use rational numbers. For example, when statisticians say that three point four people (3.4) die every minute is mathematically consistent, although it is not possible to kill just four tenths of a person. Therefore, the paradox is not in the relation between mathematical language and world, but only in the relation between verbal language and world. It's important to remember that mind, according to Linguistic Relativism (Evans and Green, 2006), works with verbal language, words and grammar, and the perception of the reality is mediated by them.

The metaphor DOUBLE SLIT EXPERIMENT IS TRAVEL means that the domain of the TRIP is projected onto the domain of DOUBLE SLIT EXPERIMENT, trying to comprehend it. This conceptual mapping between these two domains highlights some elements in DOUBLE SLIT EXPERIMENT domain, while other

<sup>4</sup> Portuguese language, the grammar, is very different from English language, and no generalization can be made, because grammar can change thought process according to the Linguistic Relativity Principle.

elements remain hiding in cognition. This means that TRAVEL domain constricts the conceptualization of DOUBLE SLIT EXPERIMENT domain, putting in evidence the corpuscular properties, while wave properties remain obscure. That is why the electron behaves like a corpuscle at the same time of measurement, because the researcher uses the domain of the TRAVEL to understand in conceptualizing the DOUBLE SLIT EXPERIMENT. The researcher's cognition is habituated to see travelers passing

through a hole in the wall or another hole, or neither ones, but never through two holes simultaneously. This sensory motor experience (travel) was learned from the macroscopic world, and it is being projected onto DOUBLE SLIT EXPERIMENT. How the ELECTRON is conceptualized and understood in terms of the TRAVELER (A DEFINED OBJECT IN SPACE), then corpuscular properties are manifested in phenomenological reality.

**Table 2. Highlighting and hiding processes in cognition**

Source domain	Mapping	Target domain
The traveler passes through two passages and by no one and passes just one and pass through another. (superficial structure)	→	The electron passes through two passages and by no one and passes just one and pass through another. (superficial structure)
“O viajante passa por duas passagens e por nenhuma e passa por uma só e passa só pela outra”.	→	“O elétron passa por duas fendas e por nenhuma e passa por uma só e passa só pela outra”.
Syntactically consistent, but semantically impossible.	→	Else, syntactically consistent, but semantically impossible.

The metaphors ELECTRON IS OBJECT and ELECTRON IS WAVE reinforce the previously stated arguments, because the source domain always constricts the conceptualization of the target domain (Evans and Green, 2006). The ELECTRON, though invisible, was being understood sometimes in terms of the OBJECT, and sometimes in terms of the WAVE (FLUID), but never both ways simultaneously. Why? It so happens that there is a lot of cognitive details, which put some properties in evidence, while others necessarily do not. For instance: if a traveler is in a place (x, y and Z), he necessarily can't be in other places. If a traveler is moving, he can't be stopped, and vice versa. If a traveler passes by a path X, he necessarily has not passed by other paths (Y, K, and so on). If a traveler is facing two holes on a wall, he is able to decide to pass through one, and necessarily can't pass through another, and vice versa. If someone says “the traveler is moving and stopped”, it is a semantic contradiction, because these two things don't occur simultaneously in the world. When these relations in TRAVEL domain are mapping

onto the ELECTRON domain, they put the corpuscular properties in evidence (highlighting), while the wave properties remain hiding in cognition (Table 02). As a result, the electron will not behave like a wave, because a traveler is not a fluid in source domain, but an object in a defined space-time. Then, the researcher watches a phenomenological reality where electron behaves like a corpuscle, not like a wave<sup>5</sup>.

When Democritus, a pre-Socratic philosopher, started to say that everything in the world came from atoms (infinitesimal and indivisible pieces of matter), he was not just describing the world “out there”, but also prescribing a phenomenological world for the future generations. It was rescued by Newton and, more after, by Dalton, Thompson, Rutherford and other chemists that reformulated that idea, which was

<sup>5</sup> It explains why nobody is able to watch, at the same time, an electron behaving like corpuscle and wave in a phenomenological reality, because, in the course of history, the electron has been conceptualized in terms of very different elements: macroscopic objects and macroscopic fluids.

sanctioned by culture along the time. Today, everyone experiences a world where everything is made from atoms, and working as particles, although nobody has never seen directly any electron. Based on observations, mathematical formalism and experiments, General Relativity, Quantum Physics, Ecology and other knowledge areas understand the world more in terms of systems, processes and complex fields. It means that the description of reality (the thing in itself) is, at the same time, a prescription of a phenomenological reality, based on cultural models, which can be formalized as:

Description-prescription principle:

The description of A in terms of B is, necessarily, a prescription of C; where, A is a target domain, B a source domain and C a cultural model.

When Isaac Newton described the universe in terms of forces and mechanisms, he was not describing the universe "out there", but also prescribing the cultural model UNIVERSE IS MACHINE, which was gradually sanctioned throughout history. If the machines had not been invented during the Industrial Revolution, according to economical and political interest, the MACHINE domain would not have had existed, and then the phenomenological reality would be quite different today. There would be no metaphors like BODY IS MACHINE, DEPARTMENT IS MACHINE, HARD WORK IS A PRODUCTIVE MACHINE, UNIVERSE IS MACHINE and others. Then, nobody would be able to experience the world and say "the kidneys *filter* blood", "the department *doesn't work* so much", "the hard worker is a good *producer*" and so on. When astronomers say the stars "are born", "grow" and "die", they are not only describing the stars "out there", but also prescribing a cultural model STARS ARE HUMAN BEINGS. If a researcher discovers by his mathematical equations that a given star "dies" even before "born", the astronomical community would feel trapped in a paradox.

These simple examples make it clear that nobody has direct access to the reality "out there", since it is mediated by his or her language, cognition and culture that are embodied. What is the universe? Is it a

machine, like defended René Descartes in the beginning of the modern age? Or, is it a hologram, like defended David Bohm more recently? Because, UNIVERSE IS A MACHINE and UNIVERSE IS A HOLOGRAM are not reality in itself, but just embodied metaphors, that is, a way to conceptualize a thing in terms of another thing. What is an electron? Is it a corpuscle? Is it a wave? Is it a piece of matter? Is it a traveler? What is the double slits experiment? Is it a travel? Because, everything that has been presented until here are not realities about the world "out there", but just conventionalized and entrenched embodied metaphors. What are the new true and reality which will give up in the future of the natural science? Cognitive linguistics is not based on ingenuous realism (analytic philosophy, positivism and so on), but supported by Kant, Husserl, Merleau-Ponty, Sapir, Whorf, Humboldt, and others.

Traditional cognitive science (TCS) defends that reality is "out there", and it has its own inherent properties, that can be known by researcher, that have his or her own brain. Then, the researcher needs just to have a good methodology, a very neutral method, to describe the world "out there", and needs to leave his or her own opinions and interests out. The concept "observer", very common in traditional epistemology, makes clear that the function of the subject is just knows, observer, the reality "out there", not building the reality. However, it is absolutely wrong, because (as it was exemplified before) nobody has direct access to the reality in itself, and there is not such thing as absolute neutrality. Every researcher needs to use a domain to conceptualize another domain, and it is a cognitive process, based on cultural models, that can be observed in language. There are, according our searches, two ways of co-building<sup>5</sup> the phenomenological reality, that makes the human being a little different from plants and animals: the ability of working and the ability to language. These two properties, "work" and "language," were based on Vygotsky (1984).

The ability of Working: 1) Human being act on the world, using his or her body, and makes things and culture (cars, computer, pants, sun glass and so on); 2) the world changed by human being

reaction, gives a feedback on the human being, that will watch the world in a new way, including his or her body, mind, emotions, thought and so on. It is a dialectic interaction!

Computers, machines, pants, pencil and holograms are not found in nature as well as plants, rocks, rivers, animals and so on can be found since prehistoric age. Prehistoric human beings are not able to use those complex domains to conceptualize the world, because they had not such a complex culture as we have today. Metaphors like MIND IS A CONTAINER, SELF IS AN OBJECT IN THE SPACE, EMOTIONS ARE TEMPERATURES, BODY IS A PLANT and CONSCIOUSNESS IS LIGHT are very old. Because prehistoric man already had experiences with rocks, containers, plants, animals, temperatures, light and dark. On the other hands, metaphors like MIND IS A COMPUTER, MIND IS AN HOLOGRAM, CONSCIOUSNESS IS ELECTRON MAGNETIC FREQUENCY and BODY IS A MACHINE are very new. It is obvious, because nobody is able to conceptualize a thing in terms of another thing, whether a domain, like computers, doesn't exist in environment. It explains why the metaphor DOUBLE SLITS EXPERIMENT IS TRAVEL is experienced by all researchers around the world as real, true and universal, because the travel domain is very old, and it's entrenched and conventionalized in many cultures. Human beings have traveled on the world since they used to have a nomadic life, yet computers, machines and others domains are very new, when they are compared with travel domain.

It means that "work ability" has a central role in ontology, because human being co-builds the phenomenological reality using his or her body (many time using instruments) at the same time that co-builds him or her-self. A person that makes shoes is not just a person in commonsense, but actuality a "shoemaker", that is, a human being more complex, and he or she is able to say happy "I'm a shoemaker!". When a researcher makes an experiment he or she is altering the world at the same time that he or she is altering him or her-self, in a dialect interaction, because there's no any dichotomy division between creator and creation. What are the evidences in

language? "I'm a psychologist" (co-building "myself" and "psychologist classes"); "I am from UFMG University" (co-building "myself" and the "UFMG university classes"); "I'm a Brazilian scientist" (co-building "myself" and the "Brazilians scientists' classes") and so on. If someone says "Brazilians researchers are bad researchers", I can feel bad, because there is a part-whole schema between "Brazilian researcher's class" and "myself". There's no dichotomy division between object and object, body and environment, individual and society, because the part-whole schema are involved in many metonymic processes.

The ability of language: 1) Human being act on the world, using his or her language (speak, gestures and so on), not just describing, narrating or arguing about the world "out there", but also make thing and culture (ideology, scientific theory, myths, lies, and so on); 2) the world changed by human being action, gives a feedback on the human being, that will watch the world in a new way, including his or her body, mind, emotions, thought and so on. It is a dialectic interaction too!

Formal semantics (FS), which has a strong influence on classical cognitive science, defend the thesis that language has the properties of referring the objects on the world "out there". The word "electron" is a language expression that referring an object on the world and the object has its own properties, that is independent of language, cognition and culture. If someone says "an electron is a ball", it can be false or true, independently if the researcher is an American, a Brazilian or Japanese, because the electron is "there" and has its own properties. This kind of sentence ("electron is a ball", "electron is a wave" and so on) is a constative sentence, because it depends on just contacting the true conditions. If the electron was a visible object, the researcher must just watch the electron and says "it is true" or "it is false", confirming or refuting his or her hypothesis experimentally. Is formal semantics right? No! Because, formal semantics has considered mind disembodied, and FS has been separated semantic process from pragmatic process.

There're a lot of sentences that can't be put in this traditional true conditions, and

Austin (1962), a pragmatic philosopher, called this sentences of performative utterance. For example, the sentences “I declare he and she married” and “I name this particle of Pity” are not true or false, but in fact happy or unhappy. A police probably would be not happy in says “I declare he and she married”, but a renamed scientist (in this case, a physicist) probably would be happy when he says “I name this particle of Pity”. Thus, there is a conventional and cultural context, where a speech act occurs, and has more or less probabilities to be happy. Not just performative sentences works in this way, but also constative sentences, which are not true or false, but actuality happy or unhappy. It means that if a language expression is used in culture for a long time, this happy language expression in use can be turn in a conventionalized expression, that will be experienced as true and real by people. An example will be present in the next paragraph, about the sky color. It is a manner of doing things with words, as argued Austin, because speech has the same effect on the reality that arms and legs.

If someone says “the sky is blue”, it is a constative sentence, because everybody are able to look up and prove or disapprove it, but it is actuality a speech act, that can be happy or unhappy. In commonsense language, this sentence has great probability to be true (happy) in Brazil, because many people have listened “the sky is blue” since childhood. However, if someone says “the sky is blue” in front of a neuroscientist, it can be considered false (unhappy), because the scientist may say “no, the universe is non-color, indoor, insipid, hence the sky is not blue”. Actuality, these constative sentences can be also considered in its deeps structures, in language and cognition, like a performative sentence: “I am arguing/believing/defending that ‘the sky is blue’”. It means that describing things in the world “out there” is also a manner of prescribing phenomenological realities. This same idea can be generalized for all expressions that have been presented in this paper, because “electron is a corpuscle”, “electron is a wave” and so on, are not true or false, but happy or unhappy. Commonsense is a kind of knowledge, that has its properties, and scientific theories are another kind of knowledge, that also has its

own vantages and advantages. This paper defends no radical dichotomy division between science and others knowledge, but supports the idea of paradigm (Kuhn, 1971) and the principles proposed by Karl Popper (1972).

It means that “language ability” has a central role in ontology too, because human being co-builds the phenomenological reality using his or her language abilities, at the same time that co-builds him or her-self. When Americans insists in say “Arabs are terrorists”, “Arabs are fundamentalists”, “Arabs are crazy”, Americans are not just describing the Arab in the world “out there”, but also prescribing a cultural model. It is not true or false, but happy or unhappy, because the rest of the world will not behave in relation with the Arabs in the world “out there”, but behaves in relation with these cultural models. It is the genesis of the prejudice and ideology! When Isaac Newton started to describe the world in terms of forces and rules, he was not just describing but at the same time prescribing a cultural model. It is as Newton was saying unconsciously “hey people, a have a model to the world, and you need to believe in me, because I am an intelligent thinker, and I know what the best for the world is”. The society, especially bourgeoisie, in its turns, unconsciously answered “ok, Newton, we believe in you, and we will support your ideas, because Industrials Revolutions are important for us, and we need to take it for the rest of the world”. Then, the iluminism, the humanism, the industrial revolution, the imperialism, the classicism and others Europeans knowledge and ideas were disseminated throughout the world, and many of they were happy; not true or false.

In sum, today, especially in occidental society, everybody is living (behaving, thinking, speaking, acting, and feeling), more and less, this phenomenological reality that was described-prescribed in the past. Germans lives in a phenomenological reality where person are autonomous, individuals, and freedom to compete (PERSON IS AN AUTONOMOUS – humanism and iluminism description-prescription). Many Brazilians lives in a phenomenological reality where human being is a special creation of god, and

Darwin have no sense in this context (PERSON IS A CREATION OF GOD – christianism description-prescription). Many physicists live in a phenomenological where electrons are corpuscles, piece of matter, and waves (ELECTRON IS A PARTICLE, ELECTRON IS A PIECE OF MATTER – Democritus and Epicurus description-prescription). To sum it up, language and work are the two ways, the two instruments, by means of which people are able to co-build the phenomenological reality, because when human being acts on reality, reality reacts on human being; there's not any division between mind and matter, like David Bohm (1990) defended.

### Conclusion

What can be concluded from the cognitive and linguistic analysis of the Double Slit Experiments? The observer function in the collapse function wave is co-building the phenomenological reality, since the observer doesn't have access to the tautological reality (the thing in itself), and always needs to conceptualize and understand a domain (more abstract) in terms of another domain (more concrete). In other words, the observer function is conceptualizing, that is, giving order and meaning on the chaos, structuring a domain in terms of another domain, because the observer is embodied. Is this process individual or collective? What are the relationships between subject and object? Here, there are paradoxes due to "part-whole" schema, since western society has emphasized physiology and anatomy (part), and has not considered that a person (body, thought, language, morality) is shaped by culture too (whole). When a researcher says "I am a doctor" or "I am married", it is a metonymic conceptualization, because this person is more than just a doctor or just a husband. He is also "a son of", "a husband of", "a friend of", "a *Homo sapiens sapiens* that belongs to the "X" species, that is, he builds an indivisible totality with environment.

A person (as a totality) is built in a culture, and the culture, in turn, has "persons", which internalize, processing and externalizing cultural activeness, consciously or unconsciously. Then, there is a dialectical interaction between subject and object,

where the subject is co-building the phenomenological reality and, at the same time, he or she co-builds himself or herself. When Charles Darwin used to describe the HUMAN BEING in terms of ANIMAL, he was not just describing, but, at the same time, prescribing a cultural model of HUMAN ANIMAL. It's a metonymic conceptualization, a little part of the whole, because a human being is more than an irrational animal. There isn't any *a priori* human being or observer in the Cartesian sense, neither a post-modern structuralist human, but an observer embodied here-and-now (Varela *et al.*, 2003; Lakoff and Johnson, 1999). But, why does the phenomenological reality, the everyday lives, appear to work in a classical way, not in a quantum manner, since everyone is more or less able to judge, decide, solve problems and make some inferences about the world?

For the ingenuous realism, represented by natural sciences, the function of the observer is just to watch the reality "out there" in a impartial way, because it has its own properties, which are considered separated from the culture, the cognition and the language. For example, the animals and plants are in the world "out there", each one has its properties, and the function of the biologist is just to take it and then classify it. It is not right, because this paper tried to demonstrate that nobody has directly access to the reality, and everybody must conceptualize a thing in terms of another. Metaphors like ELECTRON IS A PARTICLE, ELECTRON IS A WAVE and ELECTRON IS A PIECE OF MATTER are not realities about the "electron" in the world "out there", but embodied metaphors. On the other hand, for the radical idealism, represented by social sciences, the function of the observer is to build the world, because everything is a social and cultural construction. For example, the idea that the occidental society has about the world (animals, plants, human beings, physical world and so on) is a product of ideologies, dominations, myths, power relationships and so on. It is not right either, because this article tried to prove that the body has a central role in the experience, since the sensor-motor system is accomplished with environment, in a dialectal interaction. For example, the metaphors PROBABILITIES ARE PATHS

and ELECTRON IS A BALL explain why the human being is not able to watch the electron pass through the two slits at the same time, because nobody watches a ball in everyday life passing through two holes in a similar situation.

If we decided to use the term “build”, this paper would seem idealist, subjectivist, and we have no intention to be it when we said “co-build phenomenological reality”. The term “co-build” is more exact than “build”, because we defend the idea that the world has its own process, but the human beings are also able to co-construct. It was based on Lavoisier, who said that “in nature nothing can be created or destroyed, but just changed”, and we add to that saying that “the language ability” and “the work ability” are two ways of co-building. Computers, books, clothes, dances, cars, etc. are examples of co-constructions through work, whereas myths, narratives, ideologies, science theories are examples of co-construction by language ability. When a person acts mediated by his or her body, the world reacts, and then we have a dialectal interaction between body and environment. The term “phenomenological reality” is a way to say that people don’t behave, feel, speak, and act in relation to the “real world out there”, but actually they do it in relation to his or her own phenomenological meaning. It is learned, and it changes in each culture, because nobody has direct access to the world “out there”. For example, many people, especially women, who have a curly hair feel bad and ugly, not because this kind of hair is so in the world “out there”, but because these people are living a European and American description-prescription: “you have to be skinny; you need to have straight hair; you must not be fat; you are able to be like famous people; have a plastic surgery in your body, and you will happy”.

It’s a simple example of ideology, which is not necessarily based on facts and evidences, where language had a central role in co-creation of the phenomenological reality, including people. The scientific theories are not absolutely different from ideologies, myths and narratives, because scientific theories are also metaphors, although rigorous metaphors, that must be tested, proved, replicable, based on evidences and fact, and so on (Popper, 1972). The double slits experiment, analyzed here (Table 1), is a good example of scientific metaphor, because it is conceptualized and understood in terms of travel. It’s important to consider that every researcher around the world has the same results about the double slits experiment (including electron) not because they are discovering the reality “out there”, but actuality because the domain of travel is very old and universal in cultures; it is experienced like real and true. Human beings have traveled since their nomadic life, and it is entrenched and conventionalized in his or her conceptual system, that is embodied and accomplishing with environment. Sciences should be more open-minded to other cultures, and trying to pick new domains up and trying to test it scientifically, yet the Description-Prescription Principle is a manner to approximate natural sciences and social sciences.

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