THEORETICAL TERMS AND THE ONTIC STRUCTURAL REALISM

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF SOCIAL SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

NEVZAT KAYA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF ARTS
IN DEPARTMENT OF PHILOSOPHY

DECEMBER 2009

Approval of the Graduate School of Social Sciences

_____

Prof. Dr. Sencer Ayata

Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Arts

_____

Prof. Dr. Ahmet İnam

Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Arts.

_____

Doç. Dr. Samet Bağçe

Supervisor

Examining Committee Members

Dr. Burak Yedierler	(METU, PHYS)	_____
Prof. Dr. David Grünberg	(METU, PHIL)	_____
Doç. Dr. Samet Bağçe	(METU, PHIL)	_____

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name : Nevzat Kaya

Signature :

ABSTRACT

THEORETICAL TERMS AND ONTIC STRUCTURAL REALISM

Kaya, Nevzat

M.A. in Philosophy

Supervisor: Doç. Dr. Samet Bağçe

December 2009, 84 pages

The main purpose of the present study is to show that scientific realism is still worth advocating despite its vulnerability in the face of anti-realist objections. For, it does not seem possible to 'do science' without realist commitments. The second purpose of this study is to investigate the plausibility of the novel versions of realism in the sense that whether they can satisfactorily respond to the anti-realist objections. Regarding the main purpose, I try to show that theoretical terms are neither reducible to observables nor they can be dispensed with. Hence in scientific theories there always remains a metaphysical part. Regarding the second purpose I discuss ontic structural realism which holds the individualistic attributions responsible for the metaphysical parts in theories and suggests that non-individualistic interpretation of theoretical terms is possible. The legitimacy of Ontic structural realism's suggestion, as its advocates claim, lies within quantum facts.

Keywords: Theoretical terms, realism, instrumentalism, structural realism.

ÖZ

TEORİK TERİMLER VE ONTIC STRUCTURAL REALISM

Kaya, Nevzat

Yüksek Lisans, Felsefe Bölümü

Tez Yöneticisi: Doç. Dr. Samet Bağçe

Aralık 2009, 84 sayfa

Bu çalışmanın ana amacı bilimsel gerçekçiliğin anti-realist itirazlara rağmen hala savunmaya değer bir görüş olduğunu göstermektir, çünkü "realist iddialar" olmadan bilim yapmak olanaklı değildir. Bu çalışmanın ikinci amacı gerçekçiliğin yeni biçimlerinin anti-realistlerin haklı itirazlarına ne derece tatminkar cevaplar verdiğinin araştırılmasıdır. Ana amaçla alakalı olarak, teorik terimleri içinde metafizik barındırmayan betimlere indirgemenin ya da gözlemlenebilir nesnelerle açıklamanın mümkün olmadığını göstermek çalışmanın kapsamı içindedir. Diğer taraftan, çalışmada ikinci amaca ilişkin ontik structural realistlerin şu iddiası tartışılmaktadır: Bilimsel teorilerdeki metafizik kısımlar aslında teorik terimlere tikel göndermeler yapılmasından kaynaklanmaktadır. Kuantum fiziğindeki bazı buluşlar bu iddiayı destekler niteliktedir. Son olarak tezde bu durumun geçerliliği tartışılmaktadır.

Anahtar Kelimeler: Teorik terimler, realism, instrumentalism, structural realism.

To Mustafa Cercis Ceşen,

ACKNOWLEDGEMENTS

Firstly, I would like to express my sincere appreciation to my supervisor, Doç. Dr. Samet Bağçe for his guidance, comments and contributions throughout the evolution of the text. I would also like to express my thankfulness to my committee members, Dr. Burak Yedierler and Prof. Dr. David Grünberg for their important suggestions and valuable comments that made this work possible.

I would like to thank to Burcu Kaya İktu and Orhan İktu who facilitated for me the process of writing. I also would like to thank Tonguç Seferoğlu and Volkan Demirciler for their great support and patience.

I owe special thanks to Canan Pehlivan who has never stopped supporting me throughout the process of the preparation of the text. Her company is priceless.

TABLE OF CONTENTS

CHAPTER I

Introduction

The aim of this thesis is twofold. One is to show that scientific realism is a more pertinent stance in the face of instrumentalism. Despite its pertinency, scientific realism is still vulnerable to sound objections which concerns, especially, the ontological discontinuity in the history of science. On this basis, the second aim of the thesis is to discuss whether the recent changes scientific realism underwent have satisfactory responses to these objections.

In the first chapter, regarding the first aim, I focused on the debates about the status of theoretical terms (t-terms). Instrumentalists and advocates of similar stances suggest that t-terms, in fact, are not metaphysical[*] assumptions nor imply anything metaphysical. But, on the other hand, as I will try to show, for most of our best scientific theories, it does not seem possible to establish them without assigning some empirically inaccessible individual as responsible for the occurring phenomena, meaning that the establishment of most theories necessitates metaphysical assumptions which are also inherent in comprehension of the theories. It has to be noted that not only assumptions of individuals and intrinsic attributions to them should be considered as metaphysical, but also attributions of relational properties to an observable individual should be considered as such. In this respect, a metaphysical utterance in scientific theories, not surprisingly, can be done

[*] I understand from the term 'metaphysics' that which cannot be empirically tested.

either as predicate (as a relational property) or as subject (as an individual[**]). Actually, what allows metaphysical implications to be hosted in theoretical statements is the conventional understanding of scientific practice which begs for the coherently made explanations.

Roughly speaking, t-terms are employed either as predicates or as subjects. That is simply because we tend to infer from the observable the unobservable. It does not matter whether the observable part is interpreted as a relation or as an individual, we tend to infer one from the other to fill up the explanatory gaps, in other words to fully explain the phenomena in hand.

The disagreement between realism and instrumentalism rests on how to construe this mental activity mentioned above, more specifically, the disagreement is about how to interpret the inferred t-terms.

Most thinkers among instrumentalists suggest that the inference we make is simply a construction and t-terms are simply syntactic constructs containing nothing metaphysical.

For instance, in the case of the theory of heat, it is might be acceptable –at the expense of being circular, thus being less explanatory- that we construct the concept of temperature for arithmetical convenience where a t-term is a predicate (an object having the temperature of such and such a degree). Whereas, in the case of atomic theory in whose statements t-terms are

[**]That which is regarded as being endowed with intrinsic properties.

considered to be singular terms denoting individuals like atoms or electrons, it is does not seem possible to accept that these t-terms can receive a likely treatment. Their being inferred as existing individuals brings forth the belief -with no extra cost- that they must as well have intrinsic properties. That is what gives room for metaphysics in scientific theories.

In the second chapter, I discuss Carnap's structuralism wherein he suggests that on the basis of all systems[***] lie the formal properties, meaning that t-terms should be read off as functions or combinations of these formal properties. Carnap's main attempt is, as it were, by means of an appropriate semantic approach, to explicitly show no metaphysical implication is due to a genetical inherence in scientific statements. 'The mode of speech' we are inclined to choose by logico-linguistics, presupposes the property-class distinction It is this very distinction which makes possible to explain the phenomena properly but on the other hand it is again this distinction to make one come up with metaphysical (individualistic) claims. If that is the case[****] then we can reveal the defects of the current language by the help of a metalanguage which allows ignoring property-class distinction and makes way of a neutral usage of concepts (t-terms).

[***] Carnap thinks that all systems are constructed due to the relevant phenomenal domain. This is one of the main assumptions of his 'Logical Construction of the World and Pseudo-problems in Philosophy'

[****] If the property-class distinction is in fact a pseudo distinction for, either a member of a class or a property, t-terms are simply denotations of formal property functions.

As I will try to discuss, one can, in immediacy and from a pragmatic point of view, ask what is the use of that metalanguage other than showing possibilities of choosing another mode of speech? For, in that metalanguage there might not be contained anything metaphysical but it terminates the explanatory power of theories as well. Besides, here, we are not concerned with logical possibilities but rather, so to speak, nomological contingencies whose denotations require the property-class distinction. Because of these reasons (and others which are discussed below), Carnapian structuralism falls short of being satisfactory in showing the possibility of 'doing science' in metaphysics-free fashion.

Speaking of explanatory power, it has to be noted that, for Duhem, science should not be committed in the sense that it explains the phenomena. But once the property-class distinction or relational-intrinsic property distinction is assumed in theoretical statements, or say, once any denotation or designation is done due to above dualities created in conventional language, scientific theories automatically become explanations of the phenomena even though they do not have such a goal. So a Duhemian objection is not good enough reason to give up the discussion of the status of t-terms, either.

The generally considered picture above, on my account, tells enough why the burden of proof is on the instrumentalist side rather than on the realist one. But on the other hand, traditional scientific realism can not intelligibly respond to objections involving the theory change. This objection simply

says that central t-terms of even a successful[*****] theory, so far as learned from the history of science, can be proved to be not existing at all. With respect to the second aim of the thesis, following chapters concentrates on the responses given by recent versions of scientific realism.

There are (were) scientific theories which have striking predictive success but somehow are (were) entirely false in their ontological claims. It is a recent version of realism, namely Worrall's structural realism to explain the explanatory power being at odds with predictive success. Worrall simply says that for the predictive success of scientific theories, we owe to structures (the system of relations) and their being captured in an apt manner. It makes sense when we consider Fresnel's ontologically false but predictably successful theory of optics. Worrall shows the shift from Fresnel's optics to Maxwell's is not a structural one. According to Worrall, Maxwell did not change the mathematical structure of Fresnel's theory but did some reinterpretations (on the designations). Worrall's point might be plausible and even true but he simply 'leaves the ontological questions untouched'. That is most probably why Worrall's position is named as Epistemic Structural Realism.

If it is the fact that one cannot satisfactorily give an account of phenomenon without metaphysical explications or implications and if it is not possible to remove the metaphysical from our best theories even by the semantically

[*****] Successfull both in making coherent explanation and in future predictions.

interference, the only rescue can come from the empirical, a phenomenal event that can be considered to be before our eyes.

The Ontic Structural Realists are the advocates of modern realism who are motivated by empirical facts. Their case involves the Quantum Mechanics wherein entities like electrons –which are regarded as individuals- loose their identity, thus loose the legitimacy to be regarded as of objecthood or individuality in the sense that they are conventionally understood. As I will try to discuss in details, despite the logico-linguistic shortcomings of preventing from metaphysics, we still can come up with claims as such: There are relations without relata as opposed to the understanding in habitual reasoning. This speculative but righteous claim is elicited from the fact that electron behavior is strikingly at odds with conventional understanding because it is not possible to detect whether they are particles or waves[*****], meaning that the phenomenon conceptualized (inferred as an individual) as electron do not posit individualistic behavior as we conventionally understand.

Given the above fact, what is learned from that empirical fact (electron behavior), conveys a question which can be summarized as follows: is it our habitual reasoning (or semantic conventions) or metaphysical parts (ontological claims) of theoretical statements which leads us to skepticism.

[*****] It will become more clear when Heisenberg's point is discussed in the last chapter .

And if it is so, can that lately introduced empirical fact absolutely restore their relation?

CHAPTER II

The Status of Theoretical Terms

The aim of this chapter is to explore the debates about the status of theoretical terms (t-terms) in physical theories so that it can be seen what instrumentalism and similar stances tell us in contrast with realism. Despite the fact that different instrumentalist stances have sharp distinctions, as I will try to show, all promise to remove the metaphysical transcendence that is said to be inherent to our scientific theories. More truly, instrumentalism and similar stances including verificationism and reductive empiricism strongly believe that commitment to t-terms (in the sense that they really are referring to a portion of reality that is not directly observable) can be abandoned. On my account, metaphysical transcendence cannot be legitimately overcame, at least, in the fashion as instrumentalists suggest for we either have to give up expecting full and coherent explanations of phenomena or else we have to ignore the fact that t-terms are posited as subjects or predicates, meaning that their utterance is not uniform. On this basis, I believe that they all fail in their projects and after all there is still room for scientific realism.

It has to be noted that not all stances mentioned above directly say that the t-terms do not exist. For instance, Duhem's instrumentalism can roughly be comprehended as an attempt to achieve metaphysics-free definitions of scientific theories. If it is possible to explain scientific events or phenomena in general without any metaphysical implication, then, at least within

empirical sciences metaphysical debate can be ignored. Duhem simply says that we do not need to assume that there exists an unobservable reality beyond our epistemic access and that it is not the aim of science to describe what it is.[1] On the other hand, a more radical version of instrumentalism, represented by Mach, agrees with Duhemian position but unlike Duhem, Mach thinks it is not a matter of need to accept or deny the existence of t-terms behind the observable phenomena. In other words, we need not; more truly, should not assume that t-terms refer to anything because there is nothing else to reality but experience.[2]

To put it straightforward, considering these two versions of instrumentalism, Duhem wants to distance scientific theories from metaphysics for he thinks to look for unobservable reality beyond phenomena is not the aim of science while, Mach suggests a kind of demarcation from metaphysics. With respect to this distinction between Mach and Duhem, for Psillos[3] the first one is non-eliminative instrumentalism and latter is eliminative instrumentalism. Though Machian instrumentalism might stem from the assumption that there does not exist anything other than what is experienced it still has to tackle the problem of t-terms[4]. Because, as it will be discussed, the whole

[1] Duhem, P. 1996. Essays in the History and Philosophy of Science Edited by R. A. a. P. Barker. Indianapolis: Hackett Pub. Co., pp. 7-9

[2] Mach, E. 1960. The Science of Mechanics; A Critical and Historical Account of Its Development. . Translated by T. J. McCormack. LaSalle, Illinois: Open Court Pub. Co., pp. 580-591

[3] Psillos, S. 1999. Scientific Realism: How Science Tracks Truth London, New York, Routledge, p. 17

[4] If we are allowed to use the term ‘ metaphysics’ as anything that can not be empirically tested, then Mach’s view is that there exists nothing in scientific theories which cannot be

instrumentalism debate based on or excited by the fall of empiricist project which attempts to show that t-terms can be dispensed within scientific theories by means of translating them or reducing them into observational language.[5] In order to trace the roots of instrumentalist stance, let us begin with how empiricists handled the theoretical discourse and in what sense the so-called dispensation is possible.

The question of what the status of t-terms is a difficult confrontation for the empiricists of early twentieth century because of their commitment to the principle of verification (PV) according to which an assertion is meaningful if and only if it can be verified, meaning that only the assertions that are subject to direct experience, hence observational, are meaningful. Since every theory posit t-terms that are said to represent unobservable entities, does that make all theoretical assertions(t-assertions), thus empirical sciences meaningless? According to *reductive empiricism* not necessarily they are so. T-assertions can indeed be meaningful as long as they are about observational entities. Actually, a reductive empiricist tends to take t-assertions as semblances of o-entities. That is to say t-assertions are misrepresentations of o-entities and they can be translated into observational language, thus become verifiable. Moreover, they can be subjected to truth interpretation in accordance to the observational conditions. This is possible,

---

empirically tested. But he still has to show in what sense t-terms are also subjected to empirical tests.

[5] Psillos, S. 1999. Scientific Realism : How Science Tracks Truth London, New York, Routledge, p.3

for instance, when one commits to only his or her preferred ontology. So, according to the reductive empiricist, is it to say that the possibility of translating t-assertions to observational language lies within mere subjective grounds? Not if one considers the possibility of a semantic form that would hold for every scientific case and rescue the meaning from subjects.[6]

Considering the PV and its requirement of direct experience (or being observable) for rendering a theory *meaningful*, the test of whether that t-assertion does represent its intended idea cannot depend on subjects. For, otherwise that would contradict the widely accepted aim of science which is to explore the laws of nature and make inter-subjectively meaningful explanations. That is why, there needed a semantic form to substitute metaphysics, so to speak a prescription to translate t-terms into observable and to test whether t-assertions are meaningful.

To talk about the total dispensation with t-terms (substitution of metaphysics with observables) can only be accepted if only t-terms can be explicitly defined by means of o-terms: in other words, if the latter can exactly cover for the first. It was first Rudolf Carnap who attempted to examine if this is ever possible. According to Carnap, to define a particular t-term Q, we should use the following form: For all x, Qx if and only if Sx then Ox, where Q is the t-term or predicate, S is the relevant test condition and O is the

[6] Psillos, S. 1999. Scientific Realism : How Science Tracks Truth London, New York, Routledge, pp. 4-6

observational response. With respect to Carnap's thought, let us assume that an object x has a certain temperature (t-term Q) of c degrees if x is put in contact with a thermometer then the thermometer shows c degrees (if S then Q).[7] It can be immediately seen that Carnap's form has to presuppose a test condition for any t-term that would reveal the observational response. It follows that if a t-term is posited in a scientific theory has to have a certain test condition (or a *scientific indicator)* in order to for it to be translated into observational terms or to be explicitly defined by observational terms and finally to be dispensed with. Considering the PV and Carnap's point together, the issue turns out to be that if a certain theory lacks the certain scientific indicator that would make possible to verify the certain t-terms posited within, then it is meaningless. Carnap's point is at best circular, if not trivial because of the following reasons.

First of all, one can hardly talk about a scientific theory that lacks its indicator or test condition otherwise it would not be subject to science at all or better it would stay on the level of hypothesis. In scientific practice, every theory has either a scientific indicator or a special experimental set-up, no matter how precise or sophisticated they might be. Secondly, since Carnap's attempt can be interpreted as to examine whether scientific theories can commit to PV, as Psillos righteously puts it "this already presupposes the

[7] Carnap in Psillos, S. 1999. Scientific Realism : How Science Tracks Truth London, New York, Routledge, pp. 4-8.

commitment to PV".[8] For if there is not any scientific theory without an indicator and if scientific indicators are necessarily required to verify a theory and render it meaningful, then no scientific theory is meaningless. In this sense Carnap's argument is circular notwithstanding the nature of definition but with regard to the presupposition of the commitment to PV.

Even though, we set aside this circularity, Carnap's argument and reductive empiricism has still problems. Not as logical necessity but as matter of scientific practice, it has been said that a scientific theory must have its own indicators otherwise it would not have been considered as "scientific" at all. It has also been said by reductive empiricists that a scientific theory can be subjected to truth interpretation only when it conforms to PV, means that only when it is able to be translated into observable language and hence gather meaning. Despite these, we can still, in principle, accept the existence of a t-term which is posited in a *true* theory but which, however, does not have any indication mechanism that would verify it. Since the t-terms in that true theory cannot be verified, and then reductive empiricist has to accept another unwelcome consequence that a true theory can be meaningless.

Moreover, I think that the reductive empiricist ignores a very crucial point. That is assuming that a scientific indicator, say a thermometer, showing the temperature of an object is simply hypothetical because of a very simple

[8] Psillos, S. 1999. Scientific Realism: How Science Tracks Truth London, New York Routledge, p. 4

reason, that is, it is not the temperature of an object we directly experience but the numerical values that are said to represent the object's temperature by the theory itself. What follows from this is reductive empiricist is defining or translating t-terms by means of another hypothesis whose meaning is also in a question begging practice.

Lastly, it is worth noting that Carnap's argument comes in a form wherein all t-terms have to be treated as if they are only properties of observable objects or state of affairs. But we know that not necessarily all t-terms are supposed to be so; they are in most cases assumed as individuals. The issue of how to take t-terms seems to be highly context-dependent. In this sense, depending on how t-terms are employed by scientific theories, they might be either implied as properties of observable objects or as individuals. The problem with Carnap's form is it cannot realize a t-term when it is employed as an individual, so to speak when it is posited as something to be predicated.

Later on Carnap confessed that the project of dispensation of t-terms by o-terms by semantics is futile. It should be well noted that Carnap did not give in to the objections concerning the non-reducibility of t-terms but agreed that t-terms cannot be defined explicitly by means of o-terms and semantics. This is clear from his own words: "Reducibility can be asserted, but not unrestricted possibility of elimination and re-translation". By these words

Carnap distances himself from reductive empiricists' main argument.[9] Concept of reduction concerning t-terms should not be understood as explicit definition by means of observables or translation into observables but rather a "conditional definition". Accordingly a t-term can be defined by virtue of empirical state of affairs or situations to which it can be applied. So Carnap's new argument takes the form of if Sx then (Qx if and only if Ox). This new form implies that even the test conditions or the relevant scientific indicator are absent we can still accept the existence and meaning of t-terms and notice that even though the antecedent of the conditional is false (Sx), the conclusion might nevertheless be true.[10] By this Carnap liberalizes truth condition of an assertion from the possibility of its translation into observables. This amounts to accept that the truth interpretation of an assertion does not depend on any further indication than the observational state of affairs, meaning that the so-called possibility of translation of t-terms into observables is irrelevant to truth interpretation. So to say that a theory is true or false is possible even though it is meaningless from the reductive empiricists' view.

What else Carnap's modified form tells is that by virtue of those "reductive sentences" we can, more or less, know the domain of the applicability of t-terms in so far as relevant empirical situations (or state of affairs) occur.

[9] As it will discussed in the second chapter, Carnap still believes that he can still show that the confusion of the status of t-terms can be overcame on level of semantic discussion but in some entirely different sense.

[10] Carnap, R. 1937. Testability and Meaning. *Philosophy of Science* 3:419-471.

Since a t-term can be applied to a multitude of empirical situations, then there also has to be multitude of reductive sentences which will only conditionally define it. To put it clearly, a t-term can be reduced to a set of empirical situations but neither of them can explicitly define it. For Hempel, such a consequence itself implies the impossibility of fully interpretation of t-terms and their being eliminable (or being dispensed with o-terms) for there is an 'openness of content' that no group of reductive sentences can fulfill.[11] In addition to Hempel's point, this openness of content can also stem from the problem of how to regard t-terms in face of the multitude of reductive sentences for, as it is mentioned, a t-term is not necessarily regarded as a predicate every time. For instance, there are debates about how to calculate the mass of an electron, meaning that individualistically interpreted t-term can be predicated by another t-term. The point is reductive empiricists' suggestion can not account for such utterances.)

From the totality of the foregoing discussion, it follows that the reductive empiricist's main argument that the t-terms can be translated or reduced into observables and hence explicitly be defined is undermined. T-terms are not eliminable and cannot be dispensed with in the sense the reductive empiricist thinks. The reduction of t-terms is such that it can only concern the empirical situations wherein t-terms are said to have application. Logically speaking t-

[11] Hempel, C. 1963. *Implications of Carnap's work for the philosophy of science*. Edited by P. Schilpp, *The philosophy of Rudolf Carnap*. LaSalle, Illinois: Open Court Pub. Co., p. 683.

terms do not come out of nowhere but they are simply inferences done according to the empirical situations.

In fact, I think, we do not even have to use the concept of reduction because t-terms are not something to be reduced, especially when we consider the nomological statements. Carnap accepts this fact and says that it is not possible to arrive at a powerful and efficacious system of laws without using t-terms (as they are). He adds elsewhere: "No theoretical terms, no comprehensive laws".[12] It follows that without the t-terms, it is not possible for science to produce nomological statements, at least in a coherent manner (without them, we would not be able to attain to the level of such conceptions: mass of an electron or to the level of statements consisting of such conceptions).

So t-terms are meaningful even without reference to observables and although they are entailed by observational situations in reductive sentences, they cannot be rendered as 'fully interpretable' in an observational language. To put it in another way, we have to accept the existence of unobservable entities that are represented by t-terms or at least we have to accept that they cannot be explicitly defined by virtue of observables. Otherwise, it is not possible to give a proper account of casual relations posited in nomological statements nor makes it sense to expect from science to make right predictions about future phenomena. Thus, t-assertions can not be dispensed

[12] Carnap, R. 1939. Foundations of Logic and Mathematics, International Encyclopaedia of Unified Science 1(3). Chicago: The University of Chicago Press., p. 64.

with by observational language, neither are they eliminable in this sense and thus the verificationalist argument concerning the meaningfulness together with reductive empiricism fall.

Psillos thinks that the shift from explicit definitions to reductive sentences is also the shift from verification to confirmation.[13] In a broad sense, the purpose of verificationalist attempt is to get rid of the metaphysical implications aroused by t-terms in scientific theories. Specifically, a verificationalist denies that t-terms do not necessarily have to have factual reference to non-observables since they can be expressed in a relevant observational language. In this sense, what makes verificationism more privileged than confirmation is its promise to explicate phenomena without reference to anything beyond it. But, as it has been shown, verificationism is highly doubtful from several aspects, for instance in the case of nomological statements. The main reason why nomological statements cannot be *verified* is because they are simply about the widest phenomenal range (infinitely many) possible. That means only the thing that is verifiable about them (if verifiable at all) is their instances which come in singular statements. In other words, the domain of verification is limited to certain epistemic situations whose totality and repeated occurrence entail the acceptance of that certain nomological statement and this is no doubt a circular attempt.

[13] Psillos, S. 1999. Scientific Realism: How Science Tracks Truth London, New York, Routledge, p.12.

That is why one has the right to accuse Carnap of presupposing PV already, hence being circular. For, in scientific practice, accepting that every scientific theory has its indicator or experimental set-up is, in this very context, tantamount to inevitably presupposing PV. But the main reason of this circularity stems from the fact that any indication mechanism or experimental set-up is made or prepared due to a certain accepted nomological statement. In other words, under the consideration of the accepted nomological statement, they are such supplemented that the indented observational response obtains.

If the reductive empiricists agree upon this fact that the circularity is inevitable within their own point, then empiricist program, in general, ends up where they have started. The shift Psillos mentions is actually between direct verification to indirect verification or confirmation reference. Because of the failure of verificationism, empiricism is compelled to tackle the dispute of metaphysics and the problem of induction again. Actually, even though verificationalist attempt were successful in verifying nomological assertions, the problem of induction would not have lost its significance, for the nomological statements have synthetic nature and as Feigl puts it they are, if not logically, genetically inductive.[14] Relevantly, such statements are not capable of direct confirmation (verification) but only confirmed by ‘‘its success in explaining past perceptions and predicting future ones.’’. But verification requires *here* and *now.* Since the nomological statements are

[14] Feigl, H. 1981. Inquiries and Provocations: Selected Writings, 1929-1974 Edited by R. S. Cohen. Dordrecht, Holland D. Reidel Pub. Co, pp. 20-29.

spatiotemporally general ones, they can not be verified in this sense because we can not capture the present time by means of such statements but only explain it by means of past experiences.[15] Therefore, t-terms in t-assertions are needed to give account of causal explanation but this does not acknowledge one about whether they are actually referring to something or they are semblances of observable language in the sense that they have 'surplus meaning'. That leads empiricist back to old debates about metaphysics and the uncertainty of success in future predictions to the debates about defects of inductive reasoning. In this sense, Feigl's main attempt is to provide a solution that will avoid both "reductive fallacies" of verificationism and 'metaphysical confusions' that arouse from 'indirect verification' (confirmation).

For Feigl, concepts or hypothetical constructs are "required for the coherent spatio-temporal-casual account to which science aspires". But is there a possible way to relate them to 'directly observables' and at the same time regarding them (t-terms) as factually referring to something? At the same time, is it possible to deem t-terms as not having surplus meaning that can not be reduced without implying anything metaphysical? Feigl thinks that is indeed possible by means of the "metalanguage of pure pragmatics and semantics''. The avoidance of perplexities of metaphysics requires treating t-terms (unobservables) and observables '' on an equal footing if they are on

[15] Ibid., p.207

par within the nomological network''.[16] So, for Feigl, it should not be the case whether t-terms are fully reducible or translatable because obviously, that can not be achieved considering the coherency demanded by nomological network. In so far as they can be linked with directly observables by means of a semantic reconstruction, we can refrain from giving metaphysical accounts. The only possible avoidance of surplus implication, in this respect, is to refer to the meaning detonated (appropriately inferred) by the empirical.

What, then, is the legitimate ground for taking t-terms and observables on an equal footing or semantically on a par? Feigl's reasoning is as follows: It does not make sense, for instance, to speak of the present moment unless it does not have any reference to the act of speech and a framework of other dimensions of time. The same applies to here or the framework of space in general as well as it applies to 'I' and other selves. In the same manner, we can speak of 'directly tested' within a theoretical model, only if it is supplemented by 'indirectly tested'. That is to say; in a certain context, without accepting that the indirectly tested has factual reference just like the directly tested, it does not make sense even to speak of the latter for it would destroy the explanatory power of theories that reveals the coherency of nomological relations. So, the suggestion that t-terms and observables should be taken semantically on par is about the phraseology of theories and their confirmation. Feigl thinks that does not imply anything metaphysical. But, I

[16] Ibid., p.217.

think, on the other hand, it does not expand our knowledge about how to handle t-terms. Feigl agrees on the fact that treating hypothetical constructs as having factual reference may sound contradictory while at the same time saying that there is no metaphysical implication. He adds: "not unless we expect of the semantical analysis some justification of 'independent existence".[17] Perhaps, that (being on a par) is the most plausible way of preserving nomological coherency in the level of language. But, considering overall, Feigl's position can hardly be interpreted as realism in the traditional sense because it only aims to reconcile methods of verification and confirmation for the sake of scientific practice and prevents from ontological claims. When broadly considered, his attempt can be understood as rescuing scientific methods from the difficulties stemming from the debates about the status of t-terms. That is to say, in a sense, our scientific methods do not promise to capture mind-independent reality.

But for Psillos, Feigl's position more or less captures the realist spirit because semantic realism, unlike verificationism, does not assert any connection of truth conditions with verification conditions.[18] That is to say, mere empirical evidence that comes in observable form is not the sufficient condition for rendering an assertion true. In this sense, to say that a theory is confirmed by evidence and hence true, is legitimate only if there one finds

[17] Ibid., pp.209-211.

[18] Psillos, S. 1999. Scientific Realism: How Science Tracks Truth London, New York, Routledge, p. 12.

logical coherency between observation sentences and theoretical statements. And as Hempel suggests it is precisely this logical coherence that gives grounds for the affirmation of the actual 'existence' or 'reality'. Though both Hempel and Feigl object reducibility of t-terms into observables and agree that t-terms cannot be dispensable for the sake of coherency, yet they refrain from saying that t-terms stand for something beyond experience.

If the fact that the truth condition of a theoretical statement can not be reduced only to its empirical evidence but rather it is a deal of logical coherency, is admitted, how is it possible, then, to assert that t-terms, which are necessary for that coherent combination, are not actually existing? Or how does it still make sense to deny that the talk about t-terms requires commitment to unobservables? Instrumentalism promises to answer these questions.

Nagel thinks it can still make sense to speak of theories' dispensation with commitment to unobservables simply because theoretical statements are not assertions. So if they do not assert anything, so to speak if they are not t-assertions in fact, then they should not be subject to truth interpretation at all. Rather, they are 'syntactic constructs' organizing experience such that without whose employment empirical laws and observed phenomena would not entail each other, i.e. they would seem irrelevant.[19] Psillos calls this view syntactic instrumentalism which he believes to come in two variant

[19] Nagel, E. 1950. Science and Semantic Realism. *Philosophy of Science* 17:174-181.

forms: eliminative and non-eliminative.[20] The first view suggests, from a radical point, that there is simply nothing beyond experience. So, it may well be said that t-terms do not require any commitment to unobservables but needed as heuristic tools. On the other hand, second one (non-eliminative view) suggests, more cautiously, that we do not need to assume that there is an unobservable reality transcending phenomena to do science. More truly, it is neither the aim nor the responsibility of science to describe that 'reality' if it really exists at all. Psillos thinks that the second view can be associated with Duhem. Let us begin with Duhem's non- eliminative position.

Duhem thinks that through inductive reasoning, we pass from facts to laws. Observable facts lead the mind to come up with laws. In this sense what is called a good theory is the one that best represents these relevant facts as a whole and elevates them to the level of a law which is above those facts. For instance, mathematical physics for Duhem is closest to perfection in this sense. Because, Duhem, most probably, takes it as the most ideal symbolic construction which he believes to be susceptible enough to range over the widest domain of phenomena. But it has to be noted that, for Duhem, mathematical physics neither explains the phenomena nor explains anything deeper than it. What it explains is the relation between phenomena. This is, as a theory, its role which is 'useful but modest'. He adds: It is open to

[20] Psillos, S. 1999. Scientific Realism : How Science Tracks Truth London, New York Routledge, p.17.

exaggerations. Exaggerations as such have no legitimate grounds: When the laws are clarified, the causes behind them are also revealed.[21]

For Duhem, relationship between observables and unobservables is not something that waits to be discovered or revealed. It is an attribution of scientist mind. For example, the theoretical concept of *temperature* is introduced to compare (or to relate) different degrees of *warmth.* When we speak of warmth of two different bodies, we can at best say that they are as warm as each other, or else one is warmer than other. What lacks at this point is precise measurement to do science. Concept of temperature as a *magnitude* helps the concept of warmth to be construed in such a way that it can precisely be compared when the warmth of two bodies are in question. Here, what a scientist does is to correspond a concept taken from ordinary language to a hypothetical concept or magnitude so that it can be susceptible to, for instance, *addition* or precise comparison. The role of a theoretical concept, thus is clear for Duhem: when we say that body A's temperature is four times greater then body B's, we establish a correspondence in an appropriate mathematical framework.[22] In Nagelian terms we organize experience by using syntactic constructs. Speaking of correspondence, it is not the case that we reveal that correspondence that was already there waiting to be discovered. Duhem adds: 'there is no sort of natural relationship' between warmth and temperature. The first one, we can be

[21] Duhem, P. 1996. Essays in the History and Philosophy of Science Edited by R. A. a. P. Barker. Indianapolis: Hackett Pub. Co., pp. 2-7.

[22] Ibid., p. 3.

pleasant or unpleasant. The latter can be divided, multiplied or added to each other. But this should not prevent us from regarding the latter as the symbol of the first for convenience. What is more important is as Duhem stresses this operation need not to assume that there is another actor that causes warmth. More truly, the scientific practice in use throughout the process of establishing correspondence between warmth and temperature, no other theoretical concept compels the scientist to give account of what lies beneath the warmth we feel. In this case, we do not have to give an account of what *heat* is. On the other hand, for Duhem this never means that there is no such thing as heat, but only means that it is not the issue of science to explain its nature.[23]

With respect to above discussion, a hypothesis, for Duhem is no more than a 'certain number of relations, expressed by mathematical propositions'. Determination of those certain number of relations is, of course, possible insofar as science is able to define or attribute various magnitudes (theoretical concepts). Hence, Duhem consistently suggests that theoretical physics is not a metaphysical explanation of the world. It only corresponds appropriate magnitudes to physical objects. In addition, mathematical physics is closest to perfection since it is highly successful in employing those magnitudes in a mathematical framework to reach a certain number of relations that are expressible in mathematical propositions.[24]

[23] Ibid., pp. 4-17.

[24] Ibid., pp. 4-17.

Duhem uses the term ‘closest to perfection’ on purpose. If the criterion for a perfect theory is the one that the logical consequences which are deduced from it are totally in agreement with empirical laws that the hypothesis assumes, then this idealization would even surpass the ability of the human mind. Such a perfect theory would contain nothing hypothetical in it. Everything in it would be experimentally verifiable. In Duhem’s own words: “ the experimental laws that appeared as consequences of the theory would truly be a logical consequence of the experimental laws taken for hypothesis’’. Perhaps, only then it would be able to call a theory true assuredly. In other words, only then we would have treated a theoretical statement as an assertion and would interpret it as true. However, for Duhem a theory does not even have to be likely true, not because it is not logically possible. For, in reality, a hypothesis is not simply translations of an experimental law. The mind of the scientist more or less gets involved in the process of creating a hypothesis. To illustrate, Duhem takes Newton’s theory of Ampere that rests upon Kepler’s experimental laws. For Duhem, Newton corrects the main proposition of Kepler to join it with a new one that is not verifiable through any experiment or observation and then generalizes the result. On what legitimate grounds Newton’s attempt rests is that he does it without inflating the relevant ontology beyond the mathematical framework which symbolically assumes it already. In Duhem’s words, Newton created his hypothesis ‘in a sufficiently accurate manner’ and his application of theoretical concepts is a ‘considerable elaboration’ that does not extend

beyond the intended domain. Newton's theory is a good theory but it does not even have to be likely true. Newton defined the relevant phenomenal relation but he did not explain the cause or the phenomena itself.[25]

For Duhem, Newton's case represents a general procedure, meaning that it is a matter of scientific practice. So if truth does not matter and if we have to confront scientist's arbitrary interpretations in every hypothesis, how will we decide to choose a theory? Duhem's answer would be simple: choose the best one. Given that, there is no perfect theory and that theoretical statement are not assertions, which theory to chose, for Duhem, seems like a matter of scientific taste. But, on the other hand, a Duhemian would object it and announce his criterion: choose the one that has higher agreement with empirical laws, whose theoretical concepts stays inside the indented domain and if you still can not make a choice, prefer the one which consists of fewer propositions.[26]

We have to remember that Duhem's position is non-eliminative instrumentalism. With respect to Duhem's reasoning, that amounts to two different significances. It is to say that we desperately need theoretical concepts or terms as symbols for physical objects to 'do science'. In addition, it is also to say that there might indeed be unobservable entities but science does not have to give the account of the 'existentiality' or the nature

[25] Ibid. pp. 9-17.

[26] Ibid. pp. 9-17.

of them. As we have seen in the temperature and warmth case, we need the concept of temperature to establish relations in phenomenal domain, to do science. That particular case explains well why we need not to assume anything beyond phenomena because it does not imply anything metaphysical. Moreover, if all theories are established in accord with such supplemented magnitudes' indications, it is admissible that science can refrain from dealing with metaphysical hypotheses but the possibility of admitting this rests upon the degree of legitimacy to construe all magnitudes likely, as done in the case of temperature. It is true that temperature is a magnitude that we introduce. It is as well true that we do not have to tackle the problem of whatness of heat while employing this magnitude. The concept simply is taken as a symbol of warmth rather than as the indicator of quantity of heat.

The question that has to be asked here is that whether the same procedure is applicable in every case or not. For example, it is doubtful whether the same procedure can apply to the theory of light. Is it equally possible to arbitrarily employ a symbol for *light* without accepting the existence of electro-magnetic fields and justifying what they actually are in reality? It seems that it is not that simple to establish so-called correspondences through magnitudes without assuming the unobservables' existential acceptance and supposedly penetrated nature. If the Duhemian agrees on this, she also has to agree on the fact that scientific practice either voluntarily or unwillingly has to be, in a sense, also the metaphysical explanations of the world. Thus, she

must, as well, accept that theoretical statements are assertions and are indeed subjected to truth interpretation.

Unlike Duhem, Mach's position seems more clear about the dispensation of t-terms for he thinks there is nothing deeper than or beyond experience, meaning that metaphysics, in general, is dispensable. In this sense, the aim of science is to classify appearances in a concise and systematic way. For Mach, science is simply 'economy of thought' that generalizes the *facts* in an appropriate way. The status of t-terms then is nothing other than 'provisional helps' that give way to this generalization: they are tools that render experience intelligible to us. To put it in another way, t-terms help us to reconstruct in our minds the multitude of relevant facts, and make it possible for abstraction of casual connection.[27]

For Mach, causality is mind's attribution. "There is neither cause nor effect in nature; nature has but an individual existence; nature simply is".[28] That is to say, there are only facts. But fortunately, we are somehow capable of rendering them intelligible to us by means of mental faculties and deduce laws out of the multitude of facts.

[27] Mach, E. 1960. The Science of Mechanics; A Critical and Historical Account of Its Development. Translated by T. J. McCormack. LaSalle, Illinois: Open Court Pub. Co., pp. 577-587.

[28] Ibid., p. 580.

So it seems that the eliminative position of Mach requires a sharp distinction between the human mind's constitution and how the nature really is. Why, then, do we assume, in the first place, that there are unobservables. In the same manner, the answer is simply because they 'restore casual continuity' and 'disallow casual gaps'. It has to be noted scientific theories regard unobservables in different manners. But the Machian perspective allows us only to take unobservables, like Carnap, in one single sense, that is, as predicates which are attributable to phenomena. Mach illustrates his point giving the example of a rod whose vibration is invisible. For him, though vibration is invisible, we can still experience several effects of the vibration. For the sake of rendering our experience intelligible, we say the rod must be vibrating.[29] On the other hand, when, for example, the theoretical statement of 'the matter is made up of atoms' is considered, Mach's point does not hold. The fact that matter's being made up of atoms can be taken as a predication only when the concept of *atom* introduced as not denoting an individual entity, at least as an implication of individual existence. But we know atoms are treated as objects or as individuals. In this case, considering the Machian depiction of t-terms, it is hard to give account of in what sense the concept of atom restore casual continuity or disallows a casual gap. Besides, it is clear that such a statement does not aim to organize any experience directly unless one pushes it to extremes and suggests that she can feel the effects of atoms of a matter.

[29] Ibid., p. 587.

Actually, it would not be a big deal for a Machian since the mind's attribution and nature's constitution are two separate things, then we should simply give away any theory which is uttered as such. Then, are we to ignore all theories which imply individuality of unobservables among which most successfully predictive and explanatory ones exist? To put it crudely, does science have to economize thought or intellect at the expense of its powers that very aim of its foundations rests? Moreover, if the mind can hypothesize atomic theory, then either Mach's interpretation of nature or the constitution of mind to attribute causality to nature is false. Or else Mach's distinction is false. My point is, according to Mach's depiction, the mind can only attribute causality in one single sense, that is, by means of employing theoretical concepts as predicates. That amounts to saying all the overwhelming explanations of casual relationships whose utterances necessarily have to take theoretical terms as subject form should be ignored.

After all, it seems that theoretical terms are neither eliminable nor translatable into observable language. None of the positions considered above are capable of being enough convincing about the fact that dispensation of theoretical discourse is possible while doing science. Among them, it is only Feigl's position to be considered as closest to the 'realist sprit'. On the other hand, his arguments are at best evasive on behalf of realism, if not contradictory. For he can not fully acknowledge his ambiguity of treating t-terms semantically on a par with observables while at the same time choosing a skeptic path on whether they, really and mind-

independently, exist. Feigl's semantic realism, then, can not even avoid such a naïve question: If, in favor of logical coherency, it is necessary to treat t-terms as if they exist, then what prevents us from saying that they exist? From Duhem's point of view, existential explanation is not the aim of science but as it has been mentioned, scientific theories can not always refrain from assuming an existential hypothesis. In such theories, we have to accept that theoretical concepts play a greater role than just being syntactic constructs. More importantly, if this fact is true then, the grounds for instrumentalism seems undermined for theoretical statements become assertions. On the other hand, Machian position can be admitted only if theoretical concepts are taken, only to be predicates of phenomena. We know there are lots of 'good' theories to attribute individuality or objecthood to its theoretical concepts.

That was one of the objections that we have also raised to Carnap. Despite the fact that Carnap's and Mach's arguments differ both on the subjects of their aim and on their foundations, that overlap stems from the avoidance of metaphysical implication. For, this avoidance is only possible insofar as hypothesis that take theoretical concepts as predications attributable to phenomena. In other words, insofar as they are introduced as indicators of relational properties that the phenomenon is endowed with. Then, say, they will be verifiable for Carnap and will concisely organize experience on Mach's account.

It is not surprising that the two stances overlap; for any implication of individuality of theoretical terms entails metaphysical transcendence. Actually, the entailment might not be necessary for all theories which contain individuality. We can accept the Duhemian approach to some extend, that is the assumption of the so-called individuality does not at the same time have to assume the mind-independent reality. But the problem is there are such theories that the treatment of individuality can not just be construed as employing syntactic constructs. The magnitudes they use to relate phenomena to each other have to assume as well intrinsic attributes to their introduced theoretical concept. None of the positions discussed so far seems capable of overcoming this difficulty. At best they can only suggest to ignore those theories, if not explicitly can say they are false.

As we have mentioned, instrumentalism in general suggests that theoretical statements are not assertions. In this sense, how would a Machian, for instance, respond to the statements of atomism given that certain properties of atoms and even how many there are in a certain molecule can be known by experimentation? Is it still admissible to keep being skeptical towards the existence of atoms? Here, the essential point is not whether a skeptical position, in the face of atomic theory makes sense. One can still feel free to choose a skeptical position without regard to predictive success of any theory. We can go further and say that one even has right to take a skeptical stance, especially when we take into consideration the theories which had real predictive success but then interpreted as false just because their main

theoretical terms were proved to be not referring to anything in reality. This fact makes more understandable the reason why instrumentalism, in general, insist that the theoretical statements should not be taken as assertions conveying truth or falsity. It makes more understandable why theoretical terms should be treated as syntactic constructs or provisional helps that organize experiences and render intelligible the phenomenal domain to our minds. But on the other hand, as mentioned above, not all theories can be established such that its theoretical concept can only play a syntactic role. Besides, it is not a matter of erroneous theoretical utterance or establishment as reductive empiricism puts or in Psillos words, not 'disguised talks' about observables.[30] If they were so, they (theoretical statements) would be fully explicated in terms of observables then Carnap's attempt would be a success.

Instrumentalism can not refrain from tackling existential hypothesis for there exists theories consisting of t-terms that are assumed as individuals and assumed to be intrinsically explored. Accepting this fact means also to accept with no extra cost that theoretical statements are assertions about experience as well as about unobservables.

On the one hand, instrumentalism is not convincing enough about the dispensation of t-terms. The burden of proof seems to be on the instrumentalist side both for the non- existentiality of t-terms and their being

[30] Psillos, S. 1999. Scientific Realism : How Science Tracks Truth London, New York Routledge, p.3.

non-committal. But on the other hand, despite their striking predictive success, there are theories whose central t-terms proved not to be existing. In this sense, the Duhemian denial of science's explanatory role might sound plausible only if the Duhemian can also show that if it was not for theoretical statements assertive and explanatory establishment, predictive success would still be possible. This is the main dilemma in choosing between instrumentalism and realism. But what makes realism the more privileged in face of instrumentalism is the fact that without the acceptance of t-terms really referring something, it is not possible 'to do science'.

CHAPTER III

Carnap's Structuralism

For Rudolph Carnap, one does not have to take a side between the realists and instrumentalism.

In this respect his motive is to show that between instrumentalism and realism, one can stay neutral.[31] That can be possible by means of reconsidering theoretical statements in the scope of adaptation or construction of a certain linguistic framework through whose structure we will be able to see two facts: First, they are denotations of real existences concerning formal relations and secondly, they do not actually stand for unobservable or metaphysical entities. These two facts can respectively be understood as responses two instrumentalism and realism.

In his '*The Methodological Character of Theoretical Concepts'* (1956), Carnap tries to advance a certain linguistic framework, L which is divided into two sub-languages. One is Lt, the theoretical part and other is Lo, the observational part of the theory involving concrete observable things. Lt is the part of L that accommodates t-terms. In this respect, a scientific theory uttered in L consists of the followings: a set T of theoretical axioms and a set C of correspondence rules. C is such that it connects observational

[31] Psillos, S. 1999. Scientific Realism: How Science Tracks Truth London, New York, Routledge, p. 3.

vocabulary to theoretical vocabulary. Thus, for Carnap, a theory is a totality of consequences deduced from the apt conjunction of sets T and C. The role of correspondence rules has the most significant role in the adaptation of a certain linguistic framework for without those, interpreting t-terms is not possible. To put it in the Carnapian terminology, they can be considered as *internal* questions so long as they are introduced appropriately due to the empirical content. Questions concerning existentiality of t-terms do not make any sense unless they are asked regardless the linguistic context whose limits are determined by the empirical content in hand. For instance, the question of what is electro-magnetic field is an external question and metaphysical in nature if it is asked independently from the Lt. For Carnap, the acceptance of electromagnetic fields is the acceptance of language Lt. That means to accept the set of postulates T which includes the laws of electromagnetic fields and to accept some specified correspondence rules which relate those postulates to the observable domain and the term of electromagnetic field as well.[32] That is roughly the Carnapian prescription to avoid metaphysical transcendence without dispensing t-terms, thus to remain neutral.

Unlike instrumentalists, Carnap takes theoretical statements as assertions. By means of correspondence rules that connect theoretical postulates to observables, a scientific theory becomes subject to truth interpretation and allows future predictions. However, he does not suggest that t-terms are

[32] Carnap, R. 1956. The Methodological Character of Theoretical Concepts. Edited by H. F. A. M. Scriven. Vol. 1, The Foundations of Science and the Concepts of Psychology and Psychoanalysis, Minnesota Studies in Philosophy of Science. Minneapolis: University of Minnesota Press, pp. 43-47.

really referring to some unobservable entity. In other words, the acceptance of a t-term in a certain linguistic framework is not necessarily to accept that it refers to an individual existence. A crucial point is for Carnap, concepts are something that can be constructed and that construction need not be due to acceptance of a real entity. In this sense, "it makes no logical difference whether a given sign denotes the concept or the object. There is at most a psychological difference, namely, a difference in mental imagery".[33] Therefore, we either can speak of constructed objects or constructed concepts. One can rather take this as the denial of the mind-independent existence of theoretical entities but it is also to say that we have to employ (construct) t-terms in order for establishing a scientific theory[34]. In addition, Carnap thinks that since there is only one domain of objects, there is only one *science*.[35] Given that concepts are constructed or since they are our own constructs, they contain nothing that is genetically metaphysical in utterance. And since there can be only one science, there can as well be found a formulation which will stand for the form of all scientific theories. In this respect, he attempted to create the 'existential form of theories'. Right after, Hempel warned Carnap that a likely approach was put forward by Ramsey, which has the name Ramsey-sentences (RS).

[33] Carnap, R. 1967. The Logical Structure of the World: Pseudo Problems in Philosophy. Translated by R. A. George. Berkeley: University of California Press, p. 10.

[34] I am aware that is a trivial thing to say but by the notion of construction, Carnap is trying to expose how we are logico-linguistically inclined to use t-terms. This point, I will try to discuss later in sphere of Ontic Structural Realism.

[35] Ibid., p.9

A Ramsey-sentence has the form of $\exists u\ TC\ (u, o)$. That means there are some t-terms or unobservables (*u)* that stand in relation TC (a relation determined by theoretical axioms and correspondence rules) to observables (*o).*[36] There are several reasons why RS must have seemed worth appealing for Carnap. Most noticeable one among those reasons is that RS ranges over the whole domain of observables but does not intend to host all unobservables. That is, it also satisfies what Carnap's requirement of internality for the existential quantifier in front implies that this relation does not hold for all *u* variables but only for the ones that are bound to the relevant empirical content. Therefore, RS does not allow external questions, which Carnap finds purely metaphysical. But the status of t-terms is still vague in RS in the sense that whether t-terms are predicate or subject and whether they have metaphysical implication.

According to Psillos, Carnap's reading of RS is rather a radical one that serves his neutralist position.[37] For Carnap, the range of variables replaced for t-terms in RS can be understood as classes of mathematical objects. That is not simply to suggest that t-terms are, say, reducible to natural numbers but to say that the way they relate among the members of their own classes are isomorphic to natural numbers relating to each other. In this sense, in a constructional system concepts are constructed simply by summation or as logical complexes just as arithmetical concepts can be established by

[36] Ibid. (This is the Carnapian interpretation of Ramsey sentences).

[37] Psillos, S. 1999. Scientific Realism: How Science Tracks London, New York Routledge, p. 53.

deriving from natural numbers. In the case of arithmetical construction, the concept of natural numbers can be taken as the basic or fundamental concept. The difficulty on behalf of t-terms is whether it is possible with the same fashion to determine such a basic concept of the very first level of construction. Besides, would not that be metaphysical to come out with a so-called basic concept? For Carnap, the answer would be no. Because he thinks, the actual basic concepts are not the basic elements but the basic relations.[38]

At this point, Carnap's claim should be kept apart from the matter of choosing a language in which t-terms are able to be uttered without any metaphysical implication. For, a basic relation must be something that is over and beyond the preferred or chosen L, meaning that a basic relation must hold in whatsoever Lt one is speaking.

In chapter 2 it has been said that most of the theoretical statements employ t-terms, which are believed to be individuals and accepted as intrinsically explored. But if Carnap's claim about the basic concept being the basic relation is true, then metaphysical complexions stemming from individuality and intrinsic attributions are resolved. Because that amounts to saying that whole system is constructed up on basic relational properties. Mention of a relational property presupposes the existence of an individual but because it

[38] Carnap, R. 1967. The Logical Structure of the World: Pseudo Problems in Philosophy. Translated by R. A. George. Berkeley: University of California Press, pp. 19-30.

does not imply anything about the nature of that individual, we do not make any metaphysical claim other than the acceptance of its existence.

Carnap gives two different but relevant definitions which make his point clearer. He thinks that there exists a sort of relation description, which should be called a *structure* description. A structure description is the one that, in it, only structure of the relation can be indicated to its formal properties. A formal relational property for Carnap is that can be formulated without reference to the meaning of the relation and the type of objects relating. From these two definitions, it follows that it is possible to generate certain semantics that does not even contain any individuality implication and plus no relational property that would connate individuality. Thus, a structural description of theoretical statements forms the highest level of formalization and dematerialization (non-individualistic interpretation of t-terms).[39]

By the notion of formal relation, Carnap wants to emphasize a relation that is possible by means of certain formal properties which are, for instance, about symmetry or transition or else reflexivity (within the relevant field). It is indeed true that by the help of such properties we can generate a kind of semantics that can account for non-individualistic interpretation of theoretical statements. And it is even possible to re-construe the entire history of scientific theories by the help of these formal properties not only

[39] Ibid., p. 23.

because we are able to mention them regardless the factuality but also because they are the 'basis for the entire system of logic…'[40] Given that formal properties, hence formal relations are the basis of a theoretical statements is true, how should one advance a metaphysics-free interpretation of theoretical statements?

It is acceptable that a system is constructed up on the formal properties but it does not tell us anything about the phenomena unless certain agents or certain state of affairs involve, more truly, unless there exist nothing to posit those formal relations. Such utterance, as easily seen, gives room for metaphysics for it takes granted that the relata somehow must be of objecthood. For Carnap, that is not a problem as long as the inquiry of that objecthood does not transcend the domain of a certain L in which whatness of objecthood is always an internal question. But, beyond that what Carnap wants to emphasize is that the t-terms as well must be, so to speak, certain combinations of the formal properties. So, casually, the phenomena we observe need no further unobserved agent which accounts for its occurrence since after all, when analyzed to its basics, there we will find the formal properties. Thus, what science basically does is to name those certain complex combinations of formal properties to construct itself a language. In other words, science acquires itself mode of speeches on whose basis, without any exception, formal properties are realizable. But then why one need to treat them as separate L's is because formal properties posit

[40] Ibid., p. 21.

themselves in different combinations, in different orders etc… Thus, when one prefers a mode of speech, she does it for the sake of being able to talk about that certain haecceity, so to speak, to talk about that definite phenomenal haecceity, meaning that the phenomenal occurrence in hand can only be investigated or, in Carnap's words, can be spoken of internally only in that certain L. Not because the constituents of that L differ in kind but because the compounding of the common formal properties are different so that a different phenomena's occurrence be able to be uttered and explained on the level of language. In Carnap's words: … so that the questions concerning nature of t-terms[41] become 'intentional' questions. Meaning that as far as such questions intend the certain phenomenal domain whose utterance is possible (or rendered as available by construction) that certain language (or mode of speech), the acknowledgement they intend will not be anything other than formal relations which are perfectly coherent with the whole system of the uttered formal relations that aim to explain whole phenomenal domain at issue.

It follows that t-terms are but denotations of a partiality of a phenomenal domain and if so, more truly, the fact that t-terms are functions of formal properties to posit formal relations in language, then, they do not differ genetically from each other, meaning that their being regarded as class or property in conventional language is a matter of utterance or a mode of speech. That is also to say that class-property duplication is, ontologically, a

[41] As if they are individuals which are endowed with intrinsic properties which are not accessible in that relevant phenomenal domain.

pseudo-problem. If only we can be convinced about that this duplication can be resolved within another language (whose construction does not transcend the limits of the same logico-linguistic constitution) which will prove us that the scientific theories and the metaphysical complexions stemming from them are, in fact, because of the scientific language which employs the distinction for the sake of the best explanation. So, the concepts taking part on (denoting class or property) both side of the distinction can be employed as they can be predicated to one another to inquire into the complexity of the relevant domain of phenomena asking for explanation. But on the other hand, factually, they are two (or more) denotations of separate but formally related phenomena predicated one another for the sake of explanation, not as an implication of any ontological claim. It is us to regard it as such.

In one of his later works[42] Carnap attempts to show the class-property distinction is not a necessary requirement for the translation of phenomena through what he calls neutral metalanguage M'. In conventional language M, there exists phrases like the class A or like property A. Carnap suggests that M' allows a neutral use of A such that its application to t-terms can indeed be read as a designation of a formal relation, meaning that it does not necessarily imply individuality. Below, there are original expressions of Carnap which clarifies his view.

[42] Carnap, R. 1956. Meaning and Necessity: A Study in Semantics and Modal Logic. Chicago: University of Chicago Press, pp. 145-153.

Carnap uses the following examples where extensional and intentional usage concern conventional language. In the following case the predicator is the term ‘Human’

1. The extension of Human in M’ is the class Human (in M).
2. The intension of Human in M’ is the property Human (in M). [43]

What Carnap wants to show by the help of above expressions, is that predicates being subsumed under properties or classes depends on the usage. But the possibility in employing M’ instead of the conventional language M is merely a logical one. In M’, there is no property ‘Human’ or class ‘Human’ but we can only speak of the intentional or extensional usage of neutral concept of ‘Human’ and the investigation of extensional usage is only possible by means of an other L. The predicator of ‘being a human’ can be mentioned without regard to an individual or to any specified relational property. Thus, there is no difficulty in regarding it as formal relation in Carnapian terms. But the question to be tackled is: is it as much possible to do science in this metalanguage? Or to put another way, the logical possibility that gives way to inquiry by means of a metalanguage can as well turn into an utterance that will nomologically explain the aimed phenomena. In other words, can a theoretical statement in M be properly translated in M’ so that the neutral use does no harm to the original statement? That does not seem possible in terms of scientific practice for the establishment of theories

[43] Ibid. p.154. These terms (extension, intension, property, class) cannot occur in M’.

(which are made in M) can not ignore class-property distinction. Theoretical statements in M either imply individuality as regarding a t-term as a member of a certain class or use it as a predicate over another individual to imply that it has such and such a relational property. For instance, when we talk about the mass of an electron, what we mean is that there is such and such a phenomena that can be conceptualized as electron and according to the formal relations posited through those phenomena, it has to have a mass (or it has to relate to an other phenomenon which can be conceptualized as mass).

Choosing a metalanguage to talk about and over the conventional language is no doubt, logically possible. But, if speaking of t-terms can not ignore the relevant phenomena –even though we accept the fact that they are denotations of formal relations- for sake of explanation, then capability of talking about and over theoretical statements in a metalanguage cannot be considered as revealing the true nature of t-terms for, after all, the metalanguage is itself a mode of speech and it is as arbitrary as the conventional language we use to do science. Speaking of arbitrariness, one can still imagine a separate metalanguage which regards t-terms as purely metaphysical constructs by construing those formal relations as intrinsic properties of an individual. Beyond, one can even suggest that conventional language we use is less arbitrary for it is adjusted according to the observed phenomena. It is less arbitrary (though not necessary) because what we simply aim is to reach an empirical adequacy to coherently explain the

phenomena before our eyes, meaning that factuality determines how to interpret t-terms. T-terms might be nothing other than combinations of formal relations; in fact, it might as well be true that they might contain nothing metaphysical in their construction but on the other hand, if the theoretical statements in conventional language are the only appropriate way in hand to explain the phenomena, perhaps, the phenomena is given just as described and explained in theoretical terms. One is, as it were, excited to utter it as such by nomological constitution (by the world itself). Here, the point that has to be made, from a nomological view is follows: it is not the fact of the matter whether it is manageable to expose that a language can be spoken of by another language in a different manner unless it explains the intended issue. In M the intended explanation concerns phenomena, meaning that we have to confront the nomological contingencies rather than logical possibilities.

We have said that Carnap thinks the structure of theoretical statements and the relationship between natural numbers are isomorphic. That is to say, on the basis of both structures lie the same formal relations (or formal properties). This point gets clearer by the concept of extension. Carnap introduces us the term called L-determinate. An L-determinate in language L is a designator which alone – without any factual knowledge- determines its extension by only semantical rules of L. For example, 9 is L-determinate in the sense that it determines its extension alone which is classes of objects (concepts) isomorphic to 9. This must be exactly what Carnap means when

he suggests t-terms should or could be substituted by mathematical objects. As mentioned before, the non-commitment to factuality eases major difficulties because, from a point of view, it implies through the absence of factuality, formal relations. To put it another way, the possibility of speaking of t-terms apart from the empirical content of theories makes sense only if they are basic formal relations or. It follows that the *u* variables in RS have to be L-determinates or they must at least be analyzable, so to speak, to the smallest constituents which are believed to be formal properties.[44] Carnap explicitly says that the entities are identical with mathematical entities 'only in the customary extensional way of speaking'.[45] When we consider the equation *u*=9 in Carnap's metalanguage, number 9 is indeed L-determinate but *u* is not. As he tries to show in expressions below, the identity relations of intensions and extensions differ. So *u* being equal to 9, in fact, does not stand for necessarily deduced structural isomorphism but rather it is a contingent fact in whatsoever observational situation makes it true.[46]

[44] Let us suppose that t-terms are analyzable to its possibly tiniest parts which are formal properties. Then, *u*'s in RS or t-terms (as classes) in general will be L-determined by those formal properties. But on the other hand the term L-determinate makes no sense for its determining its own class would be beyond that chosen L, given that all t-terms in all Ls are simply formal properties and given that formal properties can not differentiate according to different Ls.

[45] Carnap Archive 102-07-05) in Psillos, S. 1999. Scientific Realism : How Science Tracks London, New York Routledge, p. 55.

[46] Carnap, R. 1956. Meaning and Necessity: A Study in Semantics and Modal logic. Chicago: University of Chicago Pres, pp. 86-90.

Suppose we are speaking in a metametalanguage MM which is more similar to conventional language M rather than M'. In MM, we can use expressions which admit property-class duplication as written below.[47]

3. The class Human is the same as the class Featherless Biped.
4. The property Human is not the same as the property Featherless Biped.
5. The property Human is the same as the Rational Animal.

Hitherto, Carnap's point was highly promising for one can get the feeling that Carnap is trying to show that t-terms are reducible to formal relations, at least in a fashion that does not transcend our logico-linguistic constitution (creating a metalanguage and reasoning within its restrictive limits) but denying that t-terms are L-determinates (or their possibility to be analyzed to the smallest constituents which are supposedly L-determinates as mentioned in footnote above) undermines the whole project of neutralism. For, this amounts to saying the description of t-terms depends on the empirical content and extensional class of t-terms simply becomes a class of relational property of individual entities (something being *u* or someone being 'Human')

Since the conditions of identity differ even in expressions in M' (extensional and intentional), more truly, the truth of *u*'s being 9 can only be something

[47] Ibid. p.154.

that is verifiable rather than being logically confirmed, it still stays as being a matter of fact, which requires to be empirically corrigible. The point Carnap wants to emphasize in expressions 3, 4 and 5 is M' can not actually capture identity relations but it has still identity implications and can be translated into MM so that the embedded identity relations can be concretely seen. But the warranted structuralism that would terminate all that is metaphysical should be grounded wherein no identity or individuality implication can find room. If, even by means of a metalanguage, it is not manageable, then it is not manageable at all, at least within the limits of Carnapian line whose approach is basically semantical.

Carnap's neutralism could be successful only if he had proved two different assertions. One is to prove t-terms are formal relations forming the basis of complex structures. Second one is that they are more than syntactic constructs or provisional helps. Then he would have responded both radical proponents of instrumentalism and realism and because of the reasons mentioned above, Carnap's project fails. Although his project of neutralism might be regarded as unsuccessful, Carnap's structural approach to scientific theories is still worth appealing, at least, for one thing, he showed us that the whatness of t-entities, if they exist, could not be examined apart from their connection to empirical content. This fact is also the very reason why he could not manage to use his structuralism to assist his neutralism. Once the RS way of structuralism becomes admissible, or better, once it is accepted that the connection of t-terms to observable phenomena cannot account for a

formal relation, we are again left with the conventional understanding of causality, which presupposes individual agents as responsible for observable phenomena and hence becomes apt to make metaphysical claims.

CHAPTER IV

Structural Realism

4.1. Worrall's Structural Realism

The attempts of reinterpreting t-terms in non-metaphysical means hitherto is far from being satisfactory because there are still strong evidences that t-terms must have been referring to some individual existence endowed with relational and intrinsic properties. On the other hand, this fact does not make scientific realism a more privileged stance in the face of instrumentalism because of two main problems science has been suffering; these are namely *pessimistic meta-induction* and *underdetermination*. In the history of science there are theories which enjoyed highly predictive success but then proved to be false because their central t-terms turn out to be not referring to anything in reality. It was Laudan to emphasize this fact. He concludes true reference is not a necessary condition for the predictive success and adds: since our current theories do not differ in kind with the past theories that were successful in prediction but somehow false, then there is a chance that they might be false, either. Alternatively, as Laudan puts it: '(theories) are more likely to be false than true'.[48] This is called pessimistic meta-induction. Laudan's point could be understood as an objection to 'No Miracles Argument' (NMA) according to which central t-terms must have referred to something; otherwise, it would be miraculous for a scientific hypothesis to

[48] Laudan, L. 1984. Explaining the Success of Science. Edited by J. C. e. al., Science and Reality. Notre Dame: Notre Dame University Press, pp. 91-92.

have predictive success. NMA is also said to be the main grounds for traditional scientific realism (SR) and it is immediately noticeable that the kind of realism NMA warrants rests on causal relations between individual agents.

There exist two separate but righteous reasons why NMA and SR should not be persuaded. First one is, as it is mentioned, in the history of science, there has been theories whose central t-terms proved to be non-existing but on the other hand they (theories) were able to explain the future phenomena successfully, therefore true reference must have got nothing to do with predictive success. Second reason is that the NMA is simply based on an invalid inference. Because, one cannot legitimately (validly) come up with existential or ontological statements inferred from epistemological ones, though, they might nevertheless be true. Therefore, according to a widely held consideration, SR is hardly a philosophical position, it is rather a tendency driven by commonsense which is willing to accept that t-terms refer to some individual unobservable entities.

If we are not likely to explain the predictive success of past false theories with miracles but likely to resist the anti-realist objections at the same time, what sort of path is worth taking? That is also the same thing as asking: If true reference is not a necessary condition for predictive success, then what is? According to Worrall, the answer is it must be structure of theories, not the t-terms. In his words, it is the form, not the content of theories. Worrall

thinks past false theories must somehow have 'latched onto the blueprint of universe' and they must be at least *approximately* true in the sense that, at least, they must somehow have captured the relational structure of the relevant phenomenal domain. The notion of approximate truth, at this point, comes to rescue realism as being enough to explain the empirical success as non-miraculous.[49]

Worrall is well aware that if the structure of theories is the case for truth approximation then we have to talk about transitivity between a theory and the ones that supersede the past false theory. It might be the case that the newer theory can be at odds with the very earlier one at the theoretical level but there might still be spoken of a transitive relation between them. Here the crucial point Worrall wants to emphasize is no matter how radical changes can our theories undergo, there can still be spoken of a conserved relational structure and this relational structure is responsible for past theories' empirical success or so to speak their approximating truth.[50]

Worrall points out the shifts in the theory of light. The shift from Fresnel to Maxwell is relatively a radical one. For instance, it turns out in time that there was no *luminiferous aether*, which Fresnel introduced in his theory as an all-pervading medium; neither was there any vibratory motions carried through that medium. Those t-terms of Fresnel's optic theory are replaced by

[49] Worrall, J. 1989. Structural Realism: The Best of Both Worlds? Dialectica 43:99-124.

[50] Ibid., pp. 105-109.

a mechanical medium and electromagnetic field of Maxwell's. But Fresnel's theory somehow managed to make right predictions about the reflection and refraction of light. Maxwell, on the other hand, added some other features about the nature of light, namely interference, polarization etc… Considering the case in hand, Worrall suggests that although science suffers from ontological discontinuity at the theoretical level, there we can speak of cumulative improvement at the empirical level. The mathematical equations of Fresnel's theory are developed on the basis of false theoretical assumptions but nevertheless made certain and correct predictions. For Worrall, that is simply because those equations could manage to identify accurately the relations between optical phenomena, though Fresnel was entirely wrong about the nature of optical phenomena. Therefore, the picture turns out to be that capturing the relational structure of a certain phenomenal domain is the sufficient condition for the accumulation of empirical level and no matter how erroneously the ontological assumptions are made. Since, if we are to speak of truth that can only be approximately known, we should notice this approximation is not a matter or correct reference to unobservables but a matter of capturing and representing correctly the structural relations.[51]

From this point of view, Worrall's structural realism supports Laudan's pessimistic meta-induction but also suggests, so to speak, we do not need to be so pessimistic. For our theories can indeed be false, t-terms introduced in

[51] Ibid., pp. 121-127.

them can be proved as non-existing but once the relational structure is captured correctly, then it is possible, for instance, by means of modifications at the theoretical level, to increase the degree of approximation. A possible and immediate objection in the logical sense is simply as follows: A theoretical statement is either false or true; it is not a matter of degree. Nevertheless, the objection can only be made legitimately only if the objector can account for a false theory's predictive success. Worrall mentions that a false theory can have billions of true consequences.[52] But what we have in hand is striking predictive success of false theories whose t-terms even though not referring to anything, introduced to explain the intended domain of phenomena. The essential point is in a theory both true and false parts can be contained. As long as the true part is the representation of relational structure of the indented domain, the more the theory approximates truth. Given this picture, criticizing structural realism should extend beyond brute logical sense.

This picture *prima facie* might not seem very different from instrumentalism or from Carnap's structuralism. For it is far from making satisfactory ontological claims which realism demand. On the other hand, it has to be noticed that Worrall's main motive is to respond pessimistic meta-induction by showing that there we can find the structural representation retained in newer theories. He also wants to show that capturing correctly the relational structure of theories is also the reason why we should not regard empirical

[52] Ibid., p. 113.

success of theories as miraculous. In some sense, structural realism points out in what sense can one stay as a realist in the face of theory change and despite the invalidly inferred NMA on which traditional realism is based.

Worrall's structural realism overcomes the task of responding two unpleasant problems mentioned above but unfortunately, cannot account for ontological problems, simply leaves them untouched and limits realism to structures. This is not surprising at all when it is considered that Worrall owes his structural realism to Poincare who thinks of the "… real objects which Nature will hide for ever from our eyes.". Poincare continues in the same passage: "The true relations between real objects are the only reality we can attain…" According to Poincare, "Fresnel's object was not to know whether there really is aether, if it is or not formed of atoms" but rather "his object was to predict optical phenomena" and his theory was a success in this sense.[53]

These lines of Poincare are the main inspiration to Worrall's structural realism but can as well be read off contrarily in the ontological sense. For Poincare leaves no hope for ontological investigation and even for realism in general. Since, Nature will hide forever the real objects, what is the point in being a realist or keeping up with status of t-terms debate? After all, for Poincare and for the structural realist t-terms are 'merely names of the images we substitute for real objects'. Keeping in mind that the

[53] Poincaré, H. 1905. Science and Hypothesis. London: Walter Scott Publishing, p. 186.

structuralism's main attempt is to show theory change, in fact, is not so troubling for science and plus to show realists have other alternatives than committing to NMA, one can still accuse structuralism for limiting realism to only belief in existences which do not allow epistemic access to what they intrinsically are.

From Worrall's point, what Fresnel could manage is to describe the observable effects of light and its structure. In other words, Fresnel managed to represent mathematically the empirical laws light conforms. For this, no knowledge of light's intrinsic properties is needed. Fresnel simply detected the rules of how light relates to observable phenomena. That is to say, although Fresnel made intrinsic attributions to how light behaves and although he tried to describe the nature of light, this was not the crucial point in Fresnel's theory. If correct reference is not necessary, why does Fresnel attempt towards the nature of light, in the first place? The answer is because our logico-linguistic constitution is such that we tend to make intrinsic attributions to what we assume to be of objecthood or individuality. When Fresnel introduced in his theory the vibrating motions, he not only assumed some individual but also assumed for it an intrinsic property of vibration. Therefore, we operate with the distinction of relational properties and intrinsic properties subsumed under the assumption that the unobservables are or consist of individuals. Although it might not be an intension of neither Poincare nor Worrall, they sharpen this distinction. My point is not that the distinction is artificial or wrong but one has to notice that it is this very

distinction of properties of assumed individuals to give rise to "metaphysical perplexities".

4.2. Ontic Structural Realism (OSR)

It should be noted that the ontological discontinuity science has been suffering threatens the promise of scientific theories' being explanatory. This fact could have been ignored only if realists altogether gave up their realist demands of being able to penetrate into the very nature of unobservable entities and take a Duhemian path. As Psillos emphasize if our best theories can not maintain any clue about ontology, then nothing can.[54] The phenomena of theory change throughout the history of science taught us that from the predictive success of scientific theories, one can not infer that these theories correctly refer to unobservables which are thought of as responsible from the concretely observed phenomena, thus explanatory power of even the best theories are in question since they do not "differ in kind" with the past ones. Moreover, we have seen that Worrall's stance -though being explanatory to some extent- leaves the ontological questions untouched.

Recently, there occurred a plausible but a counter-intuitive approach namely, Ontic structural realism (OSR).[55] The advocates of OSR announces that there are (can be) *relations without relata.* This rather a speculative

[54] Psillos, S. 1999. Scientific realism: How Science Tracks Truth, London, New York Routledge, p. 70.

[55] French, S. Ladyman, J. 2003. Remodelling Structural Realism: Quantum Physics and the Metaphysics of Structure, Synthese, Volume 136-141 (1):31-56.

argument as Ladyman and French confess is an inspiration of Quantum Mechanics (QM). According to QM, in the sub-atomic level, electrons which held responsible from various quantum phenomena loose their identity in the sense that they violate *principle of indiscernibles (PII).* It is not possible to determine whether they are particles or waves.[56] What violating PII amounts to is that perhaps, the relata might not be as we take it to be. To put it more clearly, it might be the case that what is regarded as relata in scientific theories are not of any objecthood in the conventional sense. The traditional understanding of unobservables as objects (or subjects) always assumes that the so-called unobservable entities must be of the same kind with observables: They have intrinsic properties as well as relational ones. Relational properties are the ones which can be derived from the observed phenomena but as traditionally understood they have to presuppose and attribute some relevant intrinsic property to the unobserved entity in order to explain what sort of 'things' are to be held responsible from the event before our eyes. For the relational properties and the system of relations (structure) are the only grounds to satisfy the traditional understanding, so to speak, understanding of objects being intrinsically endowed other than being able to relate. So, for instance, Fresnel introduced the intrinsic property of 'vibrating motion' in accord with the system of relational properties in hand. In other words, he must have thought that given such and such relations in the domain of optical phenomena, light must be something that vibrates. Here, the essential point to be explored is that from the relations we observe, we

[56] This will be discussed in details in the following chapter.

tend to derive the intrinsic properties of relata. OSR's, point on the contrary, and is that the discrimination of intrinsic-relational properties, in fact, is a deceitful habitation we owe to our logico-linguistic constitution. We are linguistically and logically constituted as such that perseverance of regarding unobservables as objects or as belonging to the domain of objecthood subdue us from realizing the fact that the discrimination is fallacious. After all, one of the reasons why traditional scientific realism is widely abandoned stems from a realization of a similar fact. That is the obvious invalidity of coming up with ontological claims (intrinsic properties) derived from empirically observed phenomena (system of relations or the structure itself). It follows that we differentiate in a so-called object the intrinsic and relational properties only for logico-linguistic convenience. But in the face of realism that is not convenient at all unless one only gets satisfied with the restricted versions of realism rather than aiming at the whole mind-independent reality.

The OSR emphasis on the liability of linguistic constitution does not by any means aim to arouse pessimism. Given the unanimity in differentiating sub-atomic particles excites the main argument of OSR which is that the description of relata when considered as individuals becomes at odds with quantum events. Classical logic falls short of capturing those events. On this basis, OSR suggests that since the discrimination of intrinsic and relational properties does not hold in the sub-atomic level, one can conclude that they do not differ in kind. That is to say it might be the case that our intrinsic attributions are either further relational properties or else only arbitrary ones

for the sake of scientific explanation. After all, as it is mentioned, when Fresnel concludes light must be something that vibrates, he derived it from the empirical content consisting of a certain system of relations or from the structure. And we have shown that is invalid but on the other hand, this operation is an inevitable consequence because the traditional reasoning conditions us so.[57] Actually with a closer consideration there is no need to attribute any intrinsic property to individuals because there exists no individuals as we understand (at least in the sub-atomic level).

What happens if we accept the fact that there are no individuals? This acceptance is tantamount to saying we can read off the 'metaphysical' from the 'empirical'. To put it more clearly, the absence of individuals makes nonsense the intrinsic attributions and all we are left with is the totality of relational properties, which is the structure itself. So OSR suggests that what we call metaphysical content of a theory is identical with its empirical content. That is why classical first order predicate logic can not capture it because it operates with subjects (t-terms) and predications (the relational attributions).[58] That means it already presupposes individuality.

The above claims are no doubt controversial with the common-sense notions but as Russell mentions:

[57] It is not necessary to come up with the 'vibrating motion'. Fresnel could come up with another notion. What is inevitable is due to logico-linguistic constitution, we tend to make claims about nature of 'things' which we believe to be positing themselves in a relational system.

[58] It might be vice versa.

> *"The common-sense notion of things and their qualities is, I suppose, the source of the conception of subject and predicate, and the reason why language is so largely based on this conception. But the thing, like other common-sense notions, is a piece of half-hearted metaphysics, which neither gives crude data nor gives a tenable hypothesis as to a reality behind the data"*.[59]

Here Russell emphasizes a very crucial point in advance of OSR. This could be rather understood as it might not be the case that there are things and qualities but it is the conception of subject- predicate duality to lead our reasoning and makes room for metaphysical perplexities because once an above logical distinction is made, one necessarily assumes the subject (individual) as intrinsically endowed.

There exists another important question as to whether OSR thesis holds or can legitimately capture the everyday objects where in common-sense most powerfully reigns. At this point, OSR appeals to Cassier. The argument of Cassier is simple and striking: He thinks there is no difference between a mathematical point and a material point.[60] That is an explicit confession of mathematical denotation representing the structure imply no further metaphysical claim. All that can be regarded as to be metaphysical (if there is any at all) can be read off from the semantical utterance of that material

[59] Russell, B. 2001. Logic and Knowledge. London: Routledge, p. 130.

[60] Cassirer, E. 1944. Group Concept and Perception Theory. Philosophy and Phenomenological Research 5:1-35.

point. In other words, the material point is denoted whatever for the sake of a definite description of a geometrical fact. It is being treated as an individual just for another purpose: That is to make clear the system of relations. One can not and need not to infer what it really is or to legitimately (validly) claimed is intrinsically something as well.

CHAPTER V

What has OSR learned from quantum mechanics?

The developments in physics beginning from the nineteenth century have led realism to a crisis that has not been overcome yet. As mentioned, ontic structural realism (OSR), the novel version of scientific realism has some plausible suggestions which should be taken as worth considering. As I will try to show, recent physical theories especially those which concern the nature of light have contradictory empirical results. On this basis, OSR suggests to investigate the possibility of re-construing those empirical results.

OSR prescriptions to overcome the reality crisis based up on (i) generally questioning our logico-linguistic faculty because for OSR, it is obviously subduing us in understanding quantum facts and (ii) specifically in admitting that electrons loose their identity every time it interacts with another entity or force.[61] First one implies that we somehow can not help but try to understand every event in terms of successive causations between objects endowed with both intrinsic and relational properties, that is to say, we appeal to commonsense. But how nature posits itself sometimes does not fit to commonsense. That is how we come up with contradictions and inconsistencies and again we apply products of the same faculty to overcome

[61] French, S. Ladyman, J. 2003. Remodelling Structural Realism: Quantum Physics and the Metaphysics of Structure Synthese Volume 136-141 (1):31-56.

those so-called contradictions and inconsistencies. Second one simply says that not in all events individuality (being endowed with intrinsic properties) is legitimately attributable to relata. This what 'loosing identity' amounts to in traditional understanding? Thus, from this point of view it is not a very speculative thing to say that there are relations without relata that are not individuals. As we will see, conceiving this is bound up in conceiving wave-particle duality. In order to explain this fact, let us frame a part of history of physics mostly involving theories of light. I am going to stick to the chronological order but mostly focus on cases which I think best clarifies OSR's claim.

In 1864 Maxwell announced that what we call light is nothing other than electromagnetic waves. Actually his main concern was the electric fields and the magnetic fields associated with them. He was able to derive a formula of the speed of electromagnetic waves. He found the same value c with the speed of light. He must have thought that this correspondence could not be accidental. Thus he concluded that light consists of electromagnetic waves. Maxwell's theory was experimentally supported by Hertz who showed that EM waves behave just like Maxwell described.[62]

It has to be remarked that long before Maxwell, in the early nineteenths, Young was the first one to show the wave nature of light. Maxwell's contribution was to tell further what kind of waves they are. Up to now, the

[62] Serway, Raymond A., 2000. Physics for Scientists and Engineers with Modern Physics, Fort Worth, Sounders Colleqe Publishers, pp. 1076-1084.

story goes just as most scientists would wish because so far every case concerning optical phenomena seems to be consistent with and there seems nothing challenging the commonsense. A theory exposes the wave nature of light; another theory tells what those waves consist of and supported experimentally. EM waves behave like water waves; they diffract, they interfere each other etc… In short they exhibit every property exclusive to waves. Particles whose acquaintance we owe to Newtonian physics do not behave in such ways. Physics would have concluded assuredly that light is nothing other than EM waves if the strange phenomena called the photoelectric effect (PE) had not been discovered. This phenomenon is such that the wave theory can by no means account for it.

The PE is a corollary of Hertz's experiment to demonstrate EM waves but also the reason that makes physicists to think that the story is not over. Roughly speaking, PE is the discovery of how light and matter interacts. When light is directed towards, say, a metal plate, electrons on the plate are emitted. After all it is not very surprising since light waves have to carry energy and this energy can indeed be concentrated on electrons somehow. But further experiments showed PE can hardly be interpreted so simply. There are strange features concerning the intensity and frequency of light that do not fit neither to conventional understanding of causation in classical physics nor to the commonsense. On the other hand, they are real observations and can not be explicated by EM. Those are listed below:

-The energy distribution in the emitted electrons is independent of the intensity (strength) of light.

- A strong light beam causes more electrons to be emitted than a weaker one of the same frequency but the average electron energy is the same.

-Within the limits of some certain experimental accuracy, there is no time lag between the arrival of light waves on the metal plate and the emission of electrons.

-Below a certain frequency no electron is emitted no matter how much the light is intense.[63]

For the time being, let us concentrate on these features and try to clarify how in what sense they challenge our commonsense. The philosophical implications of the first three are more or less the same so I will consider them altogether.

The physical definition of intensity of the wave is the rate which it transports energy per unit cross-sectional area. That means the energy transfer between light (EM waves) and matter (electron) must supervene on the intensity of light from the definition, i.e. intensity must have casual priority over the event concerning electron emission but it has not. Moreover, according to EM theory, the mathematical formula of intensity of light consists of the electrical permittivity of free space (medium) and the instantaneous magnitude of the wave. It can indeed be true but what is at odds with

[63] Ibid., pp. 1295-1298.

commonsense is that the conditions of free space have only a little, indirect effect. So to speak, it seems like light and matter do not care about spatial conditions that much (on the other hand spatial conditions can not be totally ignored since it is one of variables in Maxwell's calculations of the speed of light).

A good analogy with those strange events is that very tiny waves with high frequency would throw out more swimmers than huge oceanic waves with low frequency and no matter how huge the oceanic waves, if they are not of an ''enough'' frequency, no swimmers will be effected.[64]

For me, the fourth feature is however less conceivable but more interesting. Saying that there is no time lag between the arrival of light waves and emission of electrons is also to say that the cause and effect occur at the same time. What is at issue here is the simultaneous causation. My point is: though it is logically possible, it sounds nomologically inconceivable for we are able to understand Nature by means of successive events and it is this very succession where almost all empirical science of ours is based up on. Given the precision that physics has reached in calculation, this point can not be objected by any claim concerning our incapability to perceive light traveling with an enormous speed between distances that are very small. Reading off the case accordingly to OSR thesis, PE is a very good instance

[64] Herbert, N. 1985. Quantum reality: Beyond the New Physics. New York: Anchor Books, p. 37.

to illustrate in what sense we fall short of understanding nature by means of our logico-linguistic faculties.

It is at best a very naive thing to say that EM wave theory of light must have at least captured a portion of reality because it has been greatly supported by experiments and it must have captured a bit more than a portion. On the other hand PE is not a theory but directly observed phenomena, so to speak an empirical truth. It is certainly ironic that the discovery of PE might not have been possible if the experiments made to demonstrate the EM wave theory were not made at all or the correspondence (the same exact value) of the speed of EM waves and light was considered as accidental. Unlike the mentioned correspondence, the EM and PE case can not be considered as just accidental for a theory which has proved to be true also exposed some other empirical facts that are obviously incompatible with the EM theory itself.

In 1905, Einstein came with a new theory that is motivated by Planck's discovery that the light is emitted in separate bursts, called quanta. Planck's discovery made the case even harder. How come something that has a wave nature come in separate bursts? Einstein concluded that if light is emitted as separate quanta, it should be absorbed as separate quanta namely photons. This was a radical break with classical physics. Einstein most probably thought that PE and Planck's discovery are enough evidence in order to give up on the EM wave theory of light although it has great empirical success.

The significance of Planck's discovery is that it makes possible to resolve the mystery of PE. Given the light is emitted in quanta and electron emission being independent of the intensity of light (dependent on frequency), the energy E that emits electrons (or photoelectrons) should be formulated in terms of frequency v and Planck's constant h that stands for those so called separate bursts.

That is,

$$E=h\nu$$

What Einstein did was to reinterpret the formula above; he regarded hv as energy content of each quantum of the incident light that is equal to maximum photoelectron energy plus minimum energy needed for a single electron to be emitted from the particular metal surface.[65]

It has to be noticed that Einstein's terminology speaks on behalf of matter rather than light. It can be accepted for he tried to explain PE which mostly concerns matter but the terminology also assumes a conceptual framework that is merely based on individualistic terms. Because instead of talking about wave (light) particle (matter) interaction, he altered the issue to particle- particle interaction, meaning that to photon electron interaction. Then are we to give up on EM wave theory which is empirically true but on

[65] Serway, Raymond A., 2000. Physics for Scientists and Engineers with Modern Physics, Fort Worth, Sounders Colleqe Publishers, pp. 1289-1322.

the other hand Einstein's formula was derived from pure empirical facts? In other words, he did not have any other alternative to fill up the metaphysical content other than explaining the event with photons for it would be to ignore the empirical fact that light is absorbed in separate bursts. In light of all these, what seemed as an irony first became a mere logical contradiction in the face of wave particle duality that can be summarized as such: Light either consists of EM waves or particles.

Speaking of contradiction, we have to note that this contradiction can not be, directly or immediately, associated to any theoretical level for it does not involve any physicist's erroneous reasoning. It is, so to speak, an empirical contradiction. That is why Einstein can not be accused of explaining PE at the expense of sacrificing a 'true' theory nor he is responsible for the underdetermination of EM (photon existence is also demonstrated experimentally). But on the other hand, that is how Nature posits herself, contradictory and underdetermined when Newtonian understanding applies to the case. Generally speaking, Einstein's attempt was simply altering the issue due to empirical adequacy. Although introducing the photon was a radical demarcation from Newtonian physics, Einstein can not be said to distance himself from the way Newtonian physics reasons for his theory satisfies whatever it takes for empirical adequacy including the individualistic attribution for the sake of coherent explanation.

Given this picture, it is very hard to take a realist stance in the classical sense. Since light's dual nature was empirically evident, there were made new attempts to explain this nature. All then appeared to be vain attempts, not in terms of scientific contributions but in terms of keeping the belief alive in mind-independent reality. I am saying that because I assume realism is not comprehensible with any kind of duality of this kind.

To continue with the history of physics, let us consider one of these attempts made by de Broglie who assumed particles might behave like waves. That would most probably sound absurd if he had suggested such a thing thirty years before his time because it is obviously contradictory from the definitions of wave and particle. Obviously he did not have any other way to explicate this duality. In this sense he started with formulas that would combine particle properties with wave properties in terms of mathematical relations. For example he explained wave lengths in terms of mass and momentum of a photon in terms of wavelengths. He also was successful in his theory and enjoyed empirical success but as it is mentioned the contribution he made was in favor of science, on behalf of realist demands things got more complicated especially when Heisenberg's Uncertainty Principle is taken into account. Because according to Uncertainty Principle, we can indeed detect a particle associated with a 'wave group' but we have to give up either the knowledge of that particle's position or its momentum.[66] It might seem like a matter of mathematical issue, so to speak, a technical

[66] Heisenberg, W. 1930. The Physical Principles of the Quantum Theory. Vol. New York: Dover Publications Inc, pp.13-39.

problem involving the formulas and calculations by means of those formulas. But when closely analyzed, it is de Broglie's own conceptual framework that keeps the whole knowledge out of reach. Mathematics is only the logico-linguistic tool to represent this framework and to show the relations between concepts of this framework.[67]

From OSR's point of view, physics was begging the question when he employed diverse concepts like 'particle diffraction'. Diversity lies not within binding two terms of different natures or not because it is not analog to how Newtonian particles behave but in the delusion that particle as an individual object can posit diffraction property. In this sense, it does not matter whether the 'particle diffraction' is used metaphorically. Because as it is deducible from his conceptual framework, de Broglie had in mind an individualistic depiction of the nature of particles that are somehow associated with waves and somehow behaves in certain ways as if they are waves. This is indeed begging the question for he took granted the individuality of sub-atomic particles.

On the other hand we have to note that de Broglie's depiction enjoyed an empirical success, it is experimentally supported (Davison and Germer demonstrated in 1927, in the United States that electron beams posit diffraction-like properties). Does that mean OSR is false? It nevertheless

[67] Serway, Raymond A., 2000. Physics for Scientists and Engineers with Modern Physics, Fort Worth, Sounders Colleqe Publishers, pp. 1311-1314.

might be. For my own account it is a matter of expounding the empirical facts or how to construe those facts. Even though OSR is false, it is not false in the face of Einstein's photons or de Broglie's 'confirmed' theory. Contrarily, those must be among the cases to excite OSR thesis.

Considering the uncertainty principle again, more truly to philosophically interpret it, it can be said that the reason why we can not have the knowledge of both the position and momentum of that particle is because that particle or whatsoever it is, can only inform us about one of them at a certain moment . In other words, one can not calculate its momentum because it does not have a wavelength (de Broglie's formula requires the value of wavelength or frequency in order to calculate the momentum), because it is not a wave. Likewise when it is managed to calculate the momentum by the help of wavelength, this time one can not detect the position of that particle because it has none or because there exist no particle at all at that certain moment. It follows that being a wave or being a particle does not imply fixed, permanent existences that are intrinsically associated with a set of properties. They are rather relational properties that are posited throughout the relation or either they are the relations themselves. Thus, the phenomena we observe loose its identity (if it ever had any at all) so it is not an individual. In all physical cases we have discussed above, scientists regarded all the phenomena in terms of conventional causation whose occurrence requires individual agents endowed with intrinsic properties. That is why, for instance, de Broglie's formulas are first thought to have captured the nature

of those individual agents and as we have said it is not a matter of calculation. The formulas (mathematical representation) might be right but has no use when the aimed value does not exist at that moment. OSR seems righteous to blame it on the logico-linguistic constitution of ours as well as to claim that electrons (photons and other ‘particles’) loose their identity.

What follows then from those OSR claims on behalf of realism? When we consider the cases and physical theories, it is easily seen that there were no theory change but variety of revisions in theories. That is because no introduced theoretical term was proved not to exist. On the other hand they were not behaving (interacting) accordingly to their intrinsically attributions, either. Now if we admit the OSR claims, we simply do not need revisions of the same kind since it is also admitting that it does not make sense to attribute intrinsic properties to the phenomena we observe in the sub-atomic level. That is to say that the empirical results also disclose the metaphysical content that consists of only interactions between non-individuals such that they have only relational properties. Thus, in this sense they are only relations. It is very important to notice that such interpretation leaves no room for such an objection: But what is it really that have only observable relational properties? In other words OSR does not have to give account of whatness of quantum phenomena in the traditional fashion. For, in the present context, it does not make any sense. The opposition between the metaphysical and the empirical ceases to exist (at least in the sub-atomic level).

A better way to explicate this point is that when we commit to the fact that only relations and relational properties are to the reality, we do not have to worry about empirical adequacy of a theory in terms of true reference of theoretical terms as casual agents. From the term 'relational property', we have to understand the relation itself and OSR has strong empirical evidences that the issue should only be the relations. So every time the term 'relational property' is mentioned, it must refer to a generic term, not a definite and a literal one because OSR can not use it in the traditional sense. Otherwise, it would give legitimate grounds to a traditional realist to ask about the whatness of quantum phenomena from a very traditional logical point. First, the claim (a claim that is made from a theoretical level regardless of any empirical support) that having relational properties does not let one infer validly that it can not have intrinsic properties. Secondly, the claim that having *only* relational properties comes in the same form as subject- predicate form belonging to first order logic which has to presuppose individuality (as well as intrinsic property attributions). What makes the 'whatness' question senseless is what OSR has learned from Quantum Mechanics that covers all the cases we have discussed above. My point is notwithstanding with the fact that OSR is motivated by strong empirical evidences which legitimize OSR thesis to interpret the quantum phenomena as such, the OSR proponents still has to be cautious about the interpretation of the terminology they employ in order not be undermined by the classical logico-linguistic understanding they are criticizing.

Speaking of having either relational properties or having *only* relational properties as theoretical claims is something, but when those claims derived from the hearth of the empirical, or when taken into consideration with the empirical support (I believe we have more than we need), that is an other thing which is immune to all objections motivated from any theoretical level. At the same time, in the given context, we have to keep in mind that construing or expounding these empirical facts leads to another theoretical level but what makes OSR thesis more adventitious than other realist positions is that it successfully exposes the incapability of logic to capture the sub-atomic behavior through an empirical fact. That is to say, most of the traditional objections from the theoretical or logical level would be ad hoc objections in the circumstances drawn by OSR, if only the context of usage is alive to generic terms. So it seems like sound objections to OSR can only come from the empirical level that are not somehow based up on traditional understanding of causation (the possibility of such an objection is another issue and seems to me as a merely scientific one) . Consider such an objection that does not agree with the fact that only the relations are to the reality. Let Feynman respond for OSR.

The quotation below is taken from one of his lectures. Feynman was lecturing about how to calculate the mass of an electron. His speech can as well be read off as a confession in favor of OSR. He is talking of the difficulties when he was trying to calculate the mass of a ‘real’ electron by

the help of the value of the mass of an ideal electron which is probably calculated in absolute physical isolation. The term 'ideality' stands for an electron that does not *interact with a photon (or any other particle),* that is an electron that only goes from place to place without any interaction. There can not be a better conclusion in favor of OSR:

> *'...But no such ideal electrons exist. The mass we observe in the laboratory is that of a real electron, which emits and absorbs its own photons from time to time… And the charge we observe is between a real electron and a real photon-which can form an electron-positron pair from time to time…Since the mass and charge of an electron are affected by these and all other alternatives, the experimentally measured mass, m, and the experimentally measured charge, e, of the electron are different from the numbers we use in our calculations".*[68]

[68] Feynman, R. P. 2006. QED: The Strange Theory of Light and Matter. Princeton, N.J. : Princeton University Press, p.126.

CHAPTER VI

Conclusion

Feynman's claim about the non-existence of ideal electron can be read off as supporting a kind of Machian instrumentalism which suggests that there are no laws but only cases. Then it would be appropriate to conclude that entities (t-terms) regarded as existing in those factual cases cannot as well be regarded as implying any kind of idealization or universality. But as it is mentioned, in the first chapter, this kind of consideration of factuality is totally at odds with the fact that how we come up with nomological statements.

As mentioned in the first and second chapters, we need the utterance of t-terms to render our theories powerful in the explanatory sense but again, as it is mentioned, overcoming metaphysical implications stemming from t-terms does not seem possible on the level of semantics.

On the other hand, as Laudan shows, we cannot assuredly claim that our presently accepted scientific theories contain correct references to unobservables, meaning that it is not a matter of denotation but rather a matter of methodology of denoting. To put it another way, focusing on the metaphysical part of theories to solve the metaphysical problems with the same fashion is simply begging the question.

Given all these, what makes OSR a righteous thesis is the OSR defenders' suggestion that their claim is driven from an empirical fact. So they do not have to confront the failure of semantical revisions or metaphysical renewals. This does not mean that OSR thesis is immune to all possible objections. It might nevertheless be true that electrons loose their identity and there might indeed be relations without relata. But it has to be mentioned that to claim the latter, we cannot assure ourselves enough for how much the first claim rescue itself from theory-ladenness. That is to say, the possibility of regarding the first claim as purely empirical depends on the legitimacy of assuming electron existence and assuming that the principle of indiscernibles is true. Since the legitimacy of both assumptions is in question, one cannot say that OSR achieves to overcome logico-linguistic defects they criticize.

BIBLIOGRAPHY

Carnap, R. 1937. Testability and Meaning. *Philosophy of Science* 3:419-471.

Carnap, R. 1939. *Foundations of logic and mathematics*, *International Encyclopaedia of Unified Science 1(3)*. Chicago: The University of Chicago Press.

Carnap, R. 1956. Meaning and necessity: A study in semantics and modal logic. Chicago: University of Chicago Pres.

Carnap, R. 1956. The methodological character of theoretical concepts. Edited by H. F. a. M. Scriven. Vol. 1, The foundations of science and the concepts of psychology and psychoanalysis, Minnesota Studies in Philosophy of Science. Minneapolis: University of Minnesota Press.

Carnap, R. 1967. The logical structure of the world: Pseudo-problems in philosophy. Translated by R. A. George. Berkeley: University of California Press.

Cassirer, E. 1944. Group concept and perception theory. Philosophy and Phenomenological Research 5:1-35.

Duhem, P. 1996. Essays in the history and philosophy of science Edited by R. A. a. P. Barker. Indianapolis: Hackett Pub. Co.

Feigl, H. 1981. Inquiries and provocations: selected writings, 1929-1974 Edited by R. S. Cohen. Dordrecht, Holland D. Reidel Pub. Co.

Feynman, R. P. 2006. QED: the strange theory of light and matter Princeton, N.J. : Princeton
University Press.

French, S. Ladyman, J. 2003. Remodeling Structural Realism: Quantum Physics and the Metaphysics of Structure Synthese Volume 136-141 (1):31-56.

Heisenberg, W. 1930. The physical principles of the quantum theory. Vol. New York: Dover Publications Inc.

Hempel, C. 1963. *Implications of Carnap's work for the philosophy of science*. Edited by P. Schilpp, *The philosophy of Rudolf Carnap*. LaSalle, Illinois: Open Court Pub. Co.

Herbert, N. 1985. Quantum reality: Beyond the new physics. New York: Anchor Books.

Laudan, L. 1984. Explaining the success of science. Edited by J. C. e. al., Science and Reality. Notre Dame: Notre Dame University Press.

Mach, E. 1960. The science of mechanics; a critical and historical account of its development. . Translated by T. J. McCormack. LaSalle, Illinois: Open Court Pub. Co.

Nagel, E. 1950. Science and semantic realism. *Philosophy of Science* 17:174-181.

Poincaré, H. 1905. Science and Hypothesis. London: Walter Scott Publishing.

Psillos, S. 1999. Scientific realism: how science tracks London, New York Routledge.

Russell, B. 2001. Logic and knowledge. London: Routledge.

Serway, Raymond A., 2000. Physics for scientists and engineers with modern physics, Fort Worth, Sounders Colleqe Publishers.

Worrall, J. 1989. Structural Realism: The Best of Both Worlds? Dialectica 43:99-124.