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Artículo/Article

THOUGHT EXPERIMENT ANALYSES OF ALBERT EINSTEIN'S ELEVATOR

ANÁLISIS DEL EXPERIMENTO MENTAL DEL ELEVADOR DE ALBERT EINSTEIN

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ABSTRACT/RESUMEN

Abstract:

In this contribution we identify, analyze and interpret Einstein's elevator as a paradigmatic thought experiment (TE) that shows how modern physics may surpass classical mechanics.

On surface analyses we show that Einstein's elevator is, in fact, a series of interrelated TE, TE1 through TE6, involving two frames of reference – or two systems of coordinates, K and K', deducing principle of relativity from Galileo – and two observers, an inside and outside observer. On deep analyses of Einstein's elevator appears a deconstructive TE featuring principle of relativity, destructing, falsifying Newton's theory, that does not hold on to principle of relativity, and constructing, verifying Einstein's, that does.

On interpretation, admitting theoretical TE may have flaws as with regard to imaginability, conceptual and terminological coherence, we argue that TE are usually valid as arguments, and are rather considered antifallacies than fallacies. TE may develop on analysis from *prima facie* or *secunda facie* (in)conceivability to ideal (in)conceivability; our logical analyses validate Einstein's elevator as a paradigmatic TE.

Lastly, we may add two 21st-century conditions to (e.g. Karl Popper's) view of growth of science –global cross-culturalism and environmental pragmaticism– to arrive at a balanced view of progress of science and society[1].

Resumen:

En este trabajo identificamos, analizamos e interpretamos el elevador de Einstein como un experimento mental (TE) paradigmático, que muestra cómo la física moderna puede superar a la mecánica clásica.

De acuerdo con un análisis superficial, mostramos que el experimento del elevador es, de hecho, una serie de TE interrelacionados, TE1 a TE6, que involucran dos marcos de referencia, o dos sistemas de coordenadas, K y K', deduciendo el principio de relatividad de Galileo, y dos observadores, uno interior y otro exterior. Por otro lado, de acuerdo con un análisis de profundidad, el elevador de Einstein aparece como un TE deconstructivo que presenta el principio de la relatividad: destruye y falsifica la teoría de Newton, que no se aferra al principio de la relatividad, y construye y verifica la de Einstein, que sí lo hace.

En cuanto a la interpretación, admitiendo que los TE teóricos pueden tener fallas con respecto a la imaginabilidad, la coherencia conceptual y terminológica, sostenemos que los TE son generalmente válidos como argumentos y se consideran más bien antifalacias que falacias. El TE puede desarrollarse en el análisis desde lo (in)concebible prima facie o secunda facie hasta lo (in)concebible ideal. Nuestro análisis lógico valida al elevador de Einstein como un TE paradigmático.

Por último, podemos agregar dos condiciones del siglo XXI a la visión (por ejemplo, de Karl Popper) sobre el crecimiento de la ciencia –el transculturalismo global y el pragmaticismo ambiental– para llegar a una visión equilibrada del progreso de la ciencia y la sociedad.

Thought Experiment Analyses of Albert Einstein's Elevator

…Here again, idealized experiments will be discussed. Although these may sound very fantastic, they will, nevertheless, help us to understand as much about relativity as is possible by our simple methods. (Einstein & Infeld, 1938, p. 226)

The *Elevator* TE first appeared in Albert Einstein and Leopold Infeld 1938 popular textbook for the general public *The Evolution of Physics*. The book tells the story of how physics developed from the rise of the mechanical view to quantum mechanics as by elimination and quantification of more and more metaphysical substance concepts as heat, light and ether to kinetics and quanta.

Elevator TE is in Section Outside and Inside the Lift of Part III, *Field, Relativity.*[2] In

fact it is a series of interrelated TE involving two frames of reference –o r two c.s. or systems of coordinates K and K[1] as Einstein says after Galileo deducing from Galileo his Principle of Relativity– and two observers, an inside and outside observer.

In the surface analyses we will discuss the various TE independently, in deep analyses we will proposea couple of logical analyses revealing again some epistemological principles and in the last paragraph we will expose flaws of imaginability, conceptual and terminological incoherences as after Gendler (1996) that however don't reduce the argumentative and logical force of the TE.[3] Different from *Magnet and Conductor* TE and *Chasing a Beam of Light* (*CABOL*) TE which are aboutSpecial Relativity the *Elevator* TE relates to General Relativity involving relativistic concept of gravitation.

Surface Analyses –Six Sub –TE

Einstein and Infeld's discussion starts off with a consideration on nature and import of idealized experiments:

> The law of inertia marks the first great advance in physics; in fact, its real beginning. It was gained by the contemplation of an idealized experiment, a body *moving forever with no frictionnor any other external forces acting*. From this example, and later from many others, we recognized the importance of the idealized experiment created by thought.... (Einstein & Infeld, 1938, p. 226, italics added)

and acknowledging the next TE may sound very fantastic,

> …Here again, idealized experiments will be discussed. Although these may sound very fantastic, they will, nevertheless, help us to understand as much about relativity as is possible byour simple methods.
>
> We had previously the idealized experiments with a uniformly moving room. Here, for achange, we shall have a falling lift. (Einstein & Infeld, 1938, p. 226)

The *Elevator* TE then starts off by a traditional TE indicator as *Imagine* like this:

> Imagine a great lift at the top of a skyscraper *much higher than any real one*. Suddenly the cablesupporting the lift breaks, and the lift falls freely toward the ground. Observers in the lift are performing experiments during the fall. *In describing them, we need not bother about air resistance or friction, for we may disregard their existence under our idealized conditions....* (Einstein & Infeld, 1938, p. 226, italics added)

The lift is not a real lift from everyday life, e.g. the skyscraper it is part of is much higher than any realone —possibly moving forever, there is no air resistance or friction—possibly nor any more external forces acting, as under the idealized conditions of a TE.

Dropping Handkerchief and Watch TE (TE1)

The first sub-TE, TE1, is a TE about *Dropping Handkerchief and Watch* that remind both Galileo's TE of *Falling Bodies* and Galileo's *Ship*, "...One of the observers takes a handkerchief and a watch from his pocket and drops them. What happens to these two bodies? ...". (Einstein & Infeld, 1938-pp. 226-227) Next, two observers are introduced, an inside observer in the lift and an outside observer outside of thelift –which may represent two frames of reference or systems of coordinates, cs's, K and K_1 in Einstein's Galilean terminology–

> … For the outside observer, who is looking through the window of the lift, both handkerchiefand watch fall toward the ground in exactly the same way, with the same acceleration...
>
> … For the inside observer the two bodies remain exactly where they were when he let them go. The inside observer may ignore the gravitational field, since its source lies outside his c.s.[coordinate system] He finds that no forces inside the lift act upon the two bodies, and so theyare at rest, just as if they were in an inertial c.s. [coordinate system] Strange things happen in the lift! …. (Einstein & Infeld, 1938, p. 227)

North Pole Equator TE (TE2)

In classical mechanics it is supposed the inertial frame of reference is neither limited in space nor time. However, the inertial frame of reference of the freely falling lift in *Elevator* TE is limited in time,

> ...The inertial character of his [i.e. inside observer's] c.s. [coordinate system] is limited in spaceand time. Sooner or later the uniformly moving body will collide with the wall of the lift, destroying the uniform motion. Sooner or later the whole lift will collide with the earth, destroying the observers and their experiments. The c.s. [coordinate system] is only a "pocket edition" of a real inertial c.s. [coordinate system]. (Einstein & Infeld, 1938, p. 228)

Next, as to demonstrate that the inertial frame of reference is also limited in space, Einstein advances a second TE.

> This local character of the c.s. [coordinate system] is quite essential. If our imaginary lift were to reach from the North Pole to the Equator, with the handkerchief placed over the North Poleand the watch over the Equator, then, for the outside observer, the two bodies would not havethe same acceleration; they would not be at rest relative to each other. Our whole argument would fail! The dimensions of the lift must be limited so that the equality of acceleration of all bodies relative to the outside observer may be assumed. (Einstein & Infeld, 1938, p. 228)

As we will elucidate later on, we think this TE is rather unimaginable –what to imagine and how toimagine it? – and if in any way it won't be about a lift anymore, reasons why there could be some terminological incoherence here.

Two Lifts in Relatively Uniform Motion TE (TE3)

Third, Einstein expands the TE with another lift, a second coordinate system or frame of reference inrelative uniform motion:

> ... If we imagine another c.s. [coordinate system], another lift moving uniformly, relative to theone falling freely, then both these c.s. [coordinate systems] will be locally inertial. All laws are exactly the same in both. … (Einstein & Infeld, 1938, pp. 228-229)

Generation of Scientists TE (TE4)

Fourth, the outside observer, who finds the lift is in accelerated motion because of earth's gravitation, is contrasted to a generation of scientists born and brought up in the lift

> However, a generation of physicists born and brought up in the lift would reason quite differently. They would believe themselves in possession of an inertial system and would refer all laws of nature to their lift, stating with justification that the laws take on a specially simple form in their c.s. [coordinate system] It would be natural for them to assume their lift at rest andtheir c.s. [coordinate system] the inertial one. (Einstein & Infeld, 1938, p. 229)

Again, this TE is not imaginable, it is not realistic to suggest that there can be a whole society in thefreely falling lift--that moreover is soon to be destroyed by collision with the earth.

We can only imagine anything with this TE if we forget it is about a lift and (e.g.) metaphorically stretch the concept of a lift to (e.g.) a planet and so also forget about the supposed fact that was testedin TE2 but would invalidate this TE, the fact that the lift will soon be destroyed.

So, this TE is inconsistent with stipulations to previous TE but most importantly it is not—or cannot—be about something as a lift anymore which defect we consider a second instance of terminological incoherence. However, it is possible to render the TE more imaginable and realistic by elaboration on exact circumstances etc.,[4] but Einstein does not think it necessary as probably he only advances the TE for the sake of argument!

Pulling Up the Lift TE (TE5)

Now Einstein changes the situation by considering the lift in constant accelerated motion departingfrom presuppositions of Galilean-Newtonian classical mechanics:

> Now for a somewhat different idealized experiment. There is, let us assume, an inertial c.s.[coordinate system], in which the law of inertia is valid. We have already described [picture showing rectangular block, say, lift, hanging to a cord being pulled up asindicated by an upward arrow] what happens in a lift resting in such an inertial c.s. [coordinate system] But we now change ourpicture. Someone outside has fastened a rope to the lift and is pulling, with a constant force, in the direction indicated in our drawing. It is immaterial how this is done.
>
> … Since the lawsof mechanics are valid in this c.s. [coordinate system], the whole lift moves with a constant acceleration in the direction of the motion.... (Einstein & Infeld, 1938, pp. 230-231)

The clause it is immaterial how this is done suffices for a TE, when it is a real E, of course, we need toexplain how it is done supposing that it is physically possible.

Now the external observer experiences his situation as an inertial frame of reference and the lift moveswith constant acceleration. According to him the observers in the lift are in absolute motion, for them the laws of mechanics are invalid. He thinks about the people in the lift,

> ... They do not find that bodies, on which no forces are acting, are at rest. If a body is left free,it soon collides with the floor of the lift, since the floor moves upward toward the body. This happens exactly in the same way for a watch and for a handkerchief. It seems very strange to me that the observer inside the lift must always be on the "floor", because as soon as he jumps the floor will reach him again. (Einstein & Infeld, 1938, p. 231)

The internal observer does not experience his frame of reference as inertial,

> *The inside observer:* I do not see any reason for believing that my lift is in absolute motion. I agree that my c.s. [coordinate system], rigidly connected with my lift, is not really inertial, but Ido not believe that it has anything to do with absolute motion. My watch, my handkerchief, andall bodies are falling because the whole lift is in a gravitational field. I notice exactly the same kinds of motion as the man on the earth. He explains them very simply by the action of a gravitational field. The same holds good for me. (Einstein & Infeld, 1938, p. 231)

From a literary, semiotic perspective there are some flaws here as there seems to be an anonymous narrator who neither belongs to the people in the lift nor to the outside observers for on the one hand the inside and outside observers don't know of each other experiences and on the other hand it seems they are reacting to each other, that is, the inside observer seems to respond to the outside observer apparently knowing how he experiences his frame of reference but the outside observer does not knowwhat the inside observer is thinking.

These seem rather literary flaws than logical ones and Sorensen discusses this sort of flaws both as fallacy (e.g. voyeur fallacy) and antifallacy (kabuki antifallacy) and we will consider them antifallacies, as this phenomenon is common in literature and even journalism and goes by the name of omniscient or multiple narrator or viewpoint character.

We could only say that the report of this TE does not live up to nowadays standards of laboratory E but, (1) we have already seen that Einstein makes no secret of the fact that it is a TE as it is about idealizedconditions that don't need to be explained and (2) we will see that in fact no TE does. Of course, it is physically possible to pull up an elevator by a rope in constant accelerated motion, but initial stipulations as abstraction from air resistance, friction etc. may only be realizable in vacuo where observers can't survive. Moreover, North Pole Equator (TE2) and Generation of Scientists (TE4) are quite probably still physically impossible in our days and for this and more reasons not realistically imaginable at this stage of progress of science and society. We will return to these seeming fallacies later.

Bending a Ray of Light TE (BAROL)(TE6)

We are now in a situation in which there are two observers and two frames of reference who have bothconsistent but mutually incompatible experiences, and the last TE is meant as a way out of this ambiguity "... Imagine that a light ray enters the lift horizontally through a side window and reaches theopposite wall after a very short time. Again, let us see how the path of the light would be predicted by the two observers". (Einstein, Infeld, 1938, p. 232)

Paraphrasing, the external observer believing in accelerated motion of the lift, may argue that the ray oflight travels not along a straight, but a slightly curved line and that the inclination of the straight line is due to the distance covered by the lift during the time the ray of light is crossing the interior of the lift.

The internal observer believing in a gravitational field acting on all objects in his lift would argue that there is no accelerated motion of the lift, and a ray of light will travel in a straight line in horizontaldirection.

However, the internal observer may also suppose light is weightless "... A beam of light is weightless and, therefore, will not be affected by the gravitational field...". (Einstein & Infeld, 1938, p. 233) and it's there where Einstein intervenes,

> ...He said: 'A beam of light is weightless and, therefore, will not be affected by the gravitational field.' This cannot be right! A beam of light carries energy and energy has mass. But every inertial mass is attracted by the gravitational field, as inertial and gravitational massesare equivalent. A beam of light will bend in a gravitational field exactly as a body would if thrown horizontally with a velocity equal to that of light. If the inside observer had reasoned correctly and had taken into account the bending of light rays in a gravitational field, then his results would have been exactly the same as those of an outside observer. (Einstein & Infeld, 1938, p. 234)

As it is quite unbelievable a ray of light with velocity of 300,000 km/s will bend over a distance of, say,two meters Einstein refers to two *Solar Eclipse* experiments—as executed

by Arthur Eddington by simultaneous measurements in four cities in Africa during the May 29, 1919, total sun eclipse--which have verified his theory of the bending of light,

> The gravitational field of the earth is, of course, too weak for the bending of light rays in it to be proved directly, by experiment. But the famous experiments performed during the solar eclipses show, conclusively though indirectly, the influence of a gravitational field on the pathof a light ray. (Einstein & Infeld 1938, p. 234)

In the TE it is the law of gravitation that bridges the opposite points of views of internal and external observer and render both views compatible as by correcting the grave fault of reasoning of the internalobserver that light is weightless. Einstein concludes:

> The ghosts of absolute motion and inertial c.s. [coordinate systems] can be expelled from physics and a new relativistic physics built. Our idealized experiments show how the problem of the general relativity theory is closely connected with that of gravitation and why the equivalence of gravitational and inertial mass is so essential for this connection. It is clear thatthe solution of the gravitational problem in the general theory of relativity must differ from the Newtonian one. The laws of gravitation must, just as all laws of nature, be formulated for all possible c.s. [coordinate system], whereas the laws of classical mechanics, as formulated by Newton, are valid only in inertial c.s. [coordinate system]. (Einstein & Infeld, 1938, p. 235, bracketed words added in this and previous quotes)

Summarizing, *Elevator* TE consists of some six sub-TE and reference to famous *Solar Eclipse* experiments from astronomy. Most of sub-TE involve a freely falling lift, one involves two uniformly moving lifts and the lasttwo ones a constantly accelerated lift being pulled up by a rope.

Deep Analyses--Deconstructive TE and Principle of Relativity

We will propose *Deconstructive TE* analyses of the main argument of *Elevator* TE. Before doing so we present next formalization of Principle of Relativity as after Galileo's *Ship* TE.

Galileo's Ship TE.

[1]

Suppose

S_1 Setting 1
S_2 Setting 2
P Effects of activities

$(S_1 \vee S_2) \rightarrow P$

Analogously

Principle of Relativity

[2]

Suppose

F_1 Frame of reference 1
F_2 Frame of reference 2
L relevant Laws

$(F_1 \vee F_2) \rightarrow L$

It says Laws of physics are the same for every Frame of reference, let's say, either one or another,either F_1 or F_2 and we could add more, or F_3 or F_4 … etc.

It is about relatively uniformly moving Galilean systems of coordinates (cs) where Einstein'sterminology holds on to Galileo's K and K^1 and which we call F_1 and F_2.

Einstein extends the principle from inertial uniformly moving frames of reference to all frames of reference redefining gravitation for (supposingly) all of the universe instead of only Planet Earth asaccording to General Theory of Relativity.

Elevator TE - Deconstructive TE

Most of the *Elevator* TE involve two observers, an inside observer, O_{in} – internal Observer, and an outside observer, O_{ex} – external Observer, and two frames of reference (c.s. coordinate system) related to these two observers, F_{in} – Frame of reference of O_{in} or internal frame of reference and F_{ex}, Frame of reference of O_{ex} or external frame of reference.

The observations, experiences of O_{ex} and O_{in} are different from each other, even opposite, but both are consistent, and only after adjusting the frames of reference by Principle of Relativity they become compatible.

Conclusion and general structure of *Elevator* TE is the same and goes like this:

[3]

Suppose

T: Theory
T_N: Theory of Classical Mechanics, Newton's Universal Law of Gravitation
T_R: Theory of Relativistic Physics, Einstein's General Theory of Relativity (which is in fact a new theory of gravitation)
F_{ex} : Frame of reference of outside (external) observer(s)F_{in} : Frame of reference of inside (internal) observer(s).

Next,

$(F_{ex} \vee F_{in}) \rightarrow T$	Principle of Relativity (P_0)
$T_N \rightarrow F_{ex} \wedge F_{in}$	two opposite but internally consistent views on T_N (P_1)
$T_R \rightarrow F_{ex} \vee F_{in}$	T_R new account of gravitation bridges the gap (P_2)
$- T_N \wedge T_R$	T_N is/appears not true, T_R is true (C)[5]

This result corresponds to *Deconstructive TE* structure of *Magnet and Conductor* TE and applies ourtheory of TE Matrix.[6]

It confirms that TE in physics often reveal hidden principles as in *Magnet and*

Conductor TE principle of symmetry (akin to simplicity) and in *Elevator* TE principle of relativity involving a new relativistic concept of gravity which reduces two competing, opposite views to one more fundamental theory which explains all frames of reference (cs's) instead of only inertial ones (as Newton's Law of Gravitation is often wrongly called Universal). And it does away with metaphysical ghosts as absolute motion and inertial system of coordinates.

So, it is simpler and more symmetrical in at least two ways!

In TE Matrix terminology (that has been developed in ... 2015c) – To *Bending a Ray of Light* (*BAROL*) TE (TE6) the First Substitution Thesis (ST1 or Transformation Rule 1, TR1) applies, that is,the TE can be substituted by real experiments as mentioned by TE-er Einstein himself as in this case famous experiments of 1919 *Solar Eclipse*. This resolves problems of unimaginability and it warrants validity and soundness of logical analyses.

Like *Magnet and Conductor* TE *Elevator* TE is a contraction of two TE, one falsifying Galilean-Newtonian classical mechanics, a second one verifying Einstein's General Theory of Relativity.

Elevator TE as Destructing T_N

[4]

$$\frac{\begin{array}{l}(F_{ex} \veebar F_{in}) \rightarrow T \\ T_N \rightarrow F_{ex} \wedge F_{in}\end{array}}{- T_N}$$

Elevator TE as Constructing T_R

[5]

$$\frac{\begin{array}{l}(F_{ex} \veebar F_{in}) \rightarrow T \\ T_R \rightarrow F_{ex} \veebar F_{in}\end{array}}{T_R}$$

Our analyses show how both *Destructive TE* and *Constructive TE* are based upon Principle of Relativity that has already been developed by Galileo but has not yet been consistently

applied to allpossible frames of reference as including non-inertial frames of reference in relative accelerated motion.

Different from *Magnet and Conductor* (T)E *Elevator* TE cannot readily be performed as a laboratoryexperiment and its 1938 statement has some flaws of realist imaginability that need to be adjusted to have it performed in reality. These adjustments may include change of scope from Planet Earth to micro- and macrocosm, world of subatomic particles and astronomy. However, both micro- and macrocosm are not part of our daily living world and--in this sense--the TE may remain fantastic andonly backed by theoretical knowledge and assumptions about micro- and macrophysics.[7]

What and Whose TE?

Our surface analyses have identified a series of six interrelated TE involving an elevator instead of onlyone. It appears that different philosophers indeed refer to different sub-TE when referring to *Elevator* TE.

Brown (1991a) (incl drawing) and Brown & Fehige (2011) (Stanford Encyclopedia, no drawing) discuss TE6, light beam entering window of elevator.

Sorensen (1992) (including two drawings) discusses some alternate to TE1, dropping a ball, two balls,and features on difference of lift falling down versus going up.

Norton (1991) –Norton is a scholar on Einstein– refers to more places in Einstein's oeuvre as one in which Einstein may have presented same argument in non-TE form, stripped of the experimental particulars, a clear example of what Norton calls the Elimination Thesis, and proposes an informal TE argument of some alternate to *Dropping Handkerchief and Watch* (TE1) about falling free bodies (nextto TE arguments of *Magnet and Conductor* TE, *Two Fluid Bodies* TE etc.).

It is only one example how return to authentic TE texts can clarify TE whereof discussions havebecome inaccessible, ambiguous and speculative.

As to counter a variety of analyses and alternates we have reduced *Elevator* TE

structure to an argument about two observers, two frames of reference, common to both *Dropping Handkerchief* andWatch (TE1) and *Bending a Ray of Light* (TE6).

Tamar Gendler's Tri-partite Criticisms of TE

We have made some comments on imaginability and semiotics of *Elevator* TE as after Tamar Gendlerand Roy Sorensen. Here we will say something more about Gendler (1996) tri-partite structure of TE, and related adjudication, as it may apply to more TE than just this one.

At the end of the paper, we will return to Sorensen's adjudication as based on a taxonomy of fallacies and antifallacies at the same time possibly representing different teleologies, uses and functions of TE.

Tamar Gendler does not necessarily adhere to the argument view, defines TE as (guided) contemplation of imaginary scenarios and reveals a tri-partite fundamental structure of TE in Gendler (1996, pp. 37, 39) as (1) [a]n imaginary scenario is described[,] (2) [a]n argument is offered which attempts to establish the correct evaluation of the scenario[,] (3) [t]his evaluation of the imagined scenario is then taken to reveal something about cases beyond the scenario.

Although this positive taxonomy is not especially interesting (its breadth of application comes inpart from the imprecision of its categories) its negative counterpart is surprisingly useful.

Corresponding to (1), (2) and (3) above are three criticisms:

(1') Unimaginability: The scenario described is not (fully) imaginable (n56).

(n56) This may be for one of two reasons: the scenario might be *incoherent*, or it might by *underdescribed*. If the latter, it might be either *resolvably* or *irresolvably* underdescribed. ….

(2') Unsound Argument: The scenario described is imaginable, but the argument establishingthe correct evaluation of the scenario is unsound (...).

….

(3') Inapplicability: The scenario described is imaginable, and the argument establishing the correct evaluation of the scenario is sound, but the conclusion does not reveal about the actual world what it is that the author takes it to reveal.

We believe most TE are valid as an argument, that's to say, there is no more reason to doubt validity of a TE argument than a (non-TE) argument. Whether an argument—TE or non-TE—is sound depends on the truth value (or probability, plausibility value etc.) of premises and conclusion, not that much on the logical inference from premises to conclusion.

By TE Matrix procedures incomplete TE arguments or enthymemes can be rendered complete as by revealing hidden presuppositions, assumptions, premises, axioms, principles etc. from argumentative structure, textual and (meta)theoretical contexts.

Judgment of soundness of premises, correctness of principles etc. goes beyond identification, analysis and interpretation--that is logical adjudication--of TE and, so, we will not assess the soundness of arguments. Sometimes we may say something about it as it is tempting and quite often easy to speculate, but it is beyond the limited logical scope of this paper.

We will assess what Gendler calls imaginability and applicability but in most cases, we could conclude flaws in imaginability and applicability are independent of logical structure of the TE. The, let's say, psychological or phenomenological dimension of a TE is often described by terms of conceivability and possibility which are rather terms from cognitive science where imaginability still has a direct relation to the traditional psychological faculty of imagination that is that often related to discussions on TE.

Flaws of imaginability and applicability of TE can be caused by e.g. terminological or conceptual incoherence and blurring of dichotomies as in *Elevator* TE science and popular contexts.

We have already shown how in North Pole Equator (TE2) and Generation of Scientists (TE4) the concept of lift is metaphorically extended beyond its usual boundaries

to something that can't be considered a lift anymore but rather a spaceship, a heavenly body, a planet possibly Planet Earth itself etc.

We think these flaws of imaginability, and applicability are caused by blurring of science and popular contexts as that *The Evolution of Physics* has been written for a general audience which context requires more simplification and reference to daily experience than really possible when exposing microphysical and astronomical phenomena.

Imaginability Flaws, Conceptual Incoherence (Blurring of Science and Popular Culture)

Like more examples from philosophy of mind and consciousness studies TE as Nagel's *What Is Liketo Be a Bat* and Chalmers's *Zombie World*, at least some part of terminological incoherence is caused by mix of popular and scientific contexts, in fact scientific definitions and popular images.

Nagel's *Bat* and Chalmers's *Zombie* are parasitic on images of bats and zombies from popular culture though their TE discussions are merely philosophical-scientific. *Wikipedia* lists many sorts of zombiesamong which movie zombies, voodoo zombies etc. as well as philosophical or p-zombies.

We guess that these blurrings between popular culture and science cause flaws of imaginability exactlylike in some of the *Elevator* TE series of Einstein and Infeld, that tell difficult things in too easy a way trying to bring quantum and astronomical discussions down to everyday experience and imagine cosmological and quantum phenomena in everyday context, while at least nowadays nearly everyone knows that these levels are quite different as with regard to scientific descriptions, and also the TE themselves appear unimaginable and, so, unrealistic. Perhaps it was different in 30s and 60s but at leastwe can draw these conclusions now. Nevertheless, the TE do what they want to do and retain their logical and elucidating force possibly more so because of their conceptual and metaphorical extensions.

Roy Sorensen's Fallacies and Antifallacies

Sorensen introduces his account of fallacies and antifallacies in Chapter 10 of his (1992) *Thought Experiments*. The disadvantage of the account of fallacies and antifallacies is that it supposes we live ina sort of Cave of Plato where nothing is what it seems. The advantage is that we can correct some imperfections and shortcomings of TE, even though we may doubt whether it will have the same effect on the general public that would rather be deceived by imagery than listen to 'dry Truth and real Knowledge' as John Locke (1975) already sadly complained.

Our criticisms of flaws of imaginability, lack of literary skill etc. as partly derived from e.g. Gendler (1996) can be restated in Sorensen's words as possible fallacies and biases of missupposing, oversupposing (overassuming, overgeneralization), undersupposing (or underspecification), literary biases against complexity (superficiality, oversimplification as in telling TE stories too quickly without sufficient detail to make it more imaginable or convincing e.g. *Elevator* TE and *Chasing Beam of Light* TE), literary biases in favor of familiar facts (e.g. applying micro- and macrophysics to earthly mesolevel), some blindspot fallacies as well as voyeur and kabuki (anti)fallacies (as in sometimes confusing points of view of author, viewpoint character, third-person omniscient narrator and multiple narrators in phrasing of *Chasing a Beam of Light* TE and *Elevator* TE).

More importantly we want to say something about TE as antifallacies, that is, defending 'bizarre' TE against common objections as that they are unrealistic--on which we somehow agree too--and fantastic(which Einstein himself acknowledges both on *Elevator* TE, 'very fantastic', and *Chasing a Beam of Light* TE, 'child-like') which we have taken for granted in previous discussions.

Moreover, we want to pay attention to a bit of genius on Sorensen's part in defending fantastic TE tout court instead of sidestepping the objections by referring to nonmodal non-TE confirmations or showing that an objection might be right generally speaking but, fortunately, not in this particular instance, etc.

As a first category of antifallacies Sorensen (1992) discusses *The Far Out Fallacy*

> One of the most popular objections to a thought experiment is that it is '*too* hypothetical,' 'unrealistic,' or 'bizarre.' The fact that so many people make this objection suggests that theyhave some *common* complaint against far out thought experiments ...

In analyzing possible lines of reasoning underlying this objection Sorensen concludes,

> …. Reverse verbalism occurs when properties of the referents are ascribed to the words.
>
> In this case, the fallacy is transferring 'down to earth' and 'realistic' from the situation under discussion to the discussion itself. A realistic topic does not ensure realistic comments. Hence,some other justification is needed for preferring realistic thought experiments over fantastic ones or for preferring actual cases over imaginary ones.

And the other way around a bizarre or merely imaginary TE can trigger realist comments anddiscussions.

Excellent examples are the 'very fantastic' and 'child-like' TE by Einstein (his epithets) who is believedby many philosophers to have been a scientific realist as with regard to the nature of laws of nature.

Next, Einstein's TE are excellent examples of the success of TE methodology as no one doubts the truth and applicability of the Special and General Theory of Relativity anymore.

Instead of considering the TE methodology accidental to Special and General Relativity's success as the theory only became scientifically accepted by e.g. verification by *Solar Eclipse* experiments and explanation of many more previously not satisfactorily explained phenomena (as bending of light), onemay as well consider the TE methodology

essential to its success.

Despite its many minor mistakes particularly flaws of imaginability, terminological incoherences and metaphorical interpretations, these considerations may give same TE again the benefit of the doubt like--as Sorensen contends--we keep trusting a compass though sometimes it systematically errs, and we may not really understand how it works.[8]

As second category of antifallacies Sorensen discusses related *Strangeness In, Strangeness Out?*, which antifallacy comes down to blaming possible strange results of use of TE on the TE suppositions instead of on the theories as a whole. Sorensen argues that counterfactuals with bizarre antecedents need not entail bizarre consequents.

An example is Einstein's rather sci-fi *Chasing a Beam of Light* TE as used to explain the constancy of the velocity of light which latter fact is a truism nowadays while the TE itself remains sci-fi, not realistically imaginable as we also concluded.

Rather than fallacies TE may not just seem but, in fact, appear to be antifallacies—good inference rules that look and feel like bad fantasies (see again note 7). In our words, though TE may have shortcomings with regard to imaginability and conceptual coherence, they are usually valid and sound arguments.

Lastly, as in defense of bizarre suppositions of TE premises we advance an argument by Nicolas Rescher as that TE may reason from false suppositions. Some even mistake TE-ation for reasoning from suppositions that are in fact known to be false and that are only provisionally assumed 'in the interests of making a point or resolving a conclusion.' However, Rescher also counters it again in a footnote as 'only one particularly strong form' of TE: “Sometimes thought experimentation is taken to call for a supposition that is known or believed to be false. But this is in fact only one particularly strong form of thought experiment”. (Rescher, 1991, pp. 40-41 n1)

Same argument may hold for restriction of TE definitions to reductios, TE are only incidentally (i.e. sometimes) reductios, not essentially (i.e. always). Moreover, there are philosophers who don't consider reductios valid forms of reasoning as from doubting

relevance of tertium non datur in a particular field of research.

David Chalmers's Prima Facie and Ideal Conceivability

In interpreting *Chasing a Beam of Light* TE we have applied David Chalmers's 2002 distinction between prima facie conceivability, secunda facie conceivability and ideal conceivability whichconcepts Chalmers summarizes in next definition of TE:

> A typical philosophical thought-experiment starts with prima facie positive conceivability.
>
> A subject does *not* imagine a situation *in fine detail*: microphysical details are usually left *unspecified*, for example. Instead, a subject imagines a situation with certain important featuresspecified, notes that a situation of this kind appears to verify S, and judges that the remaining details are not crucial: they can in principle be filled in to yield a full coherent conception of a situation that verifies S. For the thought-experiment to yield the intended conclusion, this primafacie judgment must be correct, so that S is ideally positively conceivable. If better reasoning would reveal that the details cannot be coherently filled in, or that the situation does not truly verify S, then the thought-experiment will typically fail in its purpose. If the prima facie judgment is not defeatable in this way, however, then the thought-experiment succeeds, and S isideally positively conceivable. (Chalmers, 2002, from Section 2, Positive vs. Negative Conceivability)

In case of *CABOL* the (in)conceivability of the TE premise may depend on one's (theoretical) point ofview.

The picture of someone, say, riding on a beam of light is perceptually possible and it may remind of witches flying on a broom, flying carpets, angels, martial art heroes, rockets etc. However as in dreams perception may trick detailed investigation of the situation at hand and in this example we may readily conclude that a broom, carpet, logos, aether, qi (e.g. 气) movement is not like a beam of light and next that a beam of light moves

that fast that we will hardly be able to discern it.[9] So, on reflection, at second sight, the TE may fail. If we can't conclude to it ourselves, someone may convince us of it as in rational discussion as in reply to questions as What is the speed of light? How would you envision an object moving at a speed of 300,000 km/sec? Probably, someone who considers *Chasing a Beam of Light* TE SF valid has never thought about physical definitions of the phenomenon of light, its alleged speed etc. as this is knowledge we never need in everyday life.

For the same reason the *BAROL* TE of *Elevator* TE is only prima facie conceivable as on reflection wewill realize that light won't bend over a distance of only one or two meters. Both TE start off with PF perceptual imaginability or (PF or SF) physical inconceivability and the latter will only appear sure after logical reconstruction which may show the traditional picture physically impossible but imaginable as an image from Objective Imagination because that is how it is traditionally envisioned. One may argue if the intersubjective assessment of TE apparently presupposes knowledge of modern physics we will not need in daily life, we are blurring daily, earthly physics and micro-and macrophysics.

The same argument may hold for

Water is H_2O

or

Hesperus is Phosphorus

that are considered necessarily true on relevant background knowledge that everyone is supposed to have nowadays as according to Chalmers. This reminds Einstein's digression that nowadays –that is already in his days– every child in school learns that c is 300,000 km/sec in vacuum (Einstein,1920, p. 19):

> There is hardly a simpler law in physics than that according to which light is propagated in empty space. Every child at school knows, or believes he knows, that this propagation takesplace in straight lines with a velocity c= 300,000 km/sec.

Again, one could counter that in these cases one is blurring science and life, macro/microphysics, and daily physics and for these reasons prefer Wittgenstein's ostensive definitions over (e.g.) Saul Kripke's and Hilary Putnam's scientific realist essentialist definitions.

As we will see next Section on e.g. Russell-Einstein Manifesto, our extended reason not to accept some sorts of scientific realism is not that they possibly presuppose background knowledge not everyone may readily have these days, or that one may expect that though one has this knowledge one has never really considered possible consequences on daily life (in which case the TE fails as ideal conceivability) or that in recent decades it has appeared that fashionable scientific lifestyles that take science as ultimate guide to life have failed, but—though former reasons may be convincing, too—thatthese sciences have proved to have so many environmentally damaging and polluting effects that they may not be true from an environmentally pragmatist point of view for their applications in technology have, in fact, failed and one is still trying to adjust these side effects--and when one eventually can't effectively adjust these effects the fundamental scientific theories underlying them may be considered environmentally pragmatically false and they should be substituted by theories with less damaging technological applications and side effects.

Environmental Pragmaticism and Global Cross-culturalism (Progress of Science and Society)

By the theses of environmental pragmaticism and global cross-culturalism we update Karl Popper'sformula of progress of science unto Progress of Science and Society (PSS).

On basis of thesis of Progress of Science and Society TE are defined as problem-solving devices; it holds that science and society are congruous, not antithetic.

It includes global cross-cultural thesis as prerequisite that TE preferably draw on corpus of globally available and accessible general and specific knowledge (background assumptions) of human experiences, science and technology, observations and

experiments, concepts and images of global objective imagination.

Next, it involves thesis of environmental pragmatism i.e. testing of theory should include the effects of its technological applications—foundational scientific theories which technological applications keep on causing damaging (side-)effects for human health and natural environment are environmentally pragmatically speaking false. E.g. *Russell-EinsteinManifesto* on abuse of quantum mechanics in warfare.

The thesis of environmental pragmaticism says a (fundamental science) theory should be assessed on its (side) effects to ecology, too, and if its technological applications are damaging to man and nature, itis therefore less true than any other theory which technological applications pollute less.

We share environmental and pacifistic concerns about societal and military applications of advanced scientific research as in nuclear energy (with its huge yet unresolved waste problems) and atomic weapons (with its globally strongly disapproved disastrous effects on health of generations of Japaneseinnocent civil war victims as we reject any use of atomic weapons in past, present and future) that wereshared by Einstein himself as became apparent from e.g. 1955 *Russell-Einstein Manifesto* that Einsteinsigned some days before his death. The *Manifesto* reads e.g.

> …. Such a bomb, if exploded near the ground or under water, sends radioactive particles into the upper air. They sink gradually and reach the surface of the earth in the form of a deadly dustor rain. It was this dust which infected the Japanese fishermen and their catch of fish. No one knows how widely such lethal radioactive particles might be diffused … It is feared that if many.
>
> H-bombs are used there will be universal death, sudden only for a minority, but for the majoritya slow torture of disease and disintegration. (Russell, Einstein et al., 1955)

It are the moral and societal objections that weigh most in contemporary stage of science and society and we regret that considerations and concerns like these are missing in so-

called scientific texts whilethey are indeed advanced in the humanities but, fortunately, we have also seen exceptions to the rule as Albert Einstein, Leopold Infeld and nine more signatories of the *Russell-Einstein Manifesto* whocould both develop science—eight of them were awarded Nobel Prizes in Physics, Chemistry and Medicine--and still hold on to warnings of possible dangers of its societal applications—two of them were awarded Nobel Peace Prizes.[10]

Already in 1946 Hermann Muller got a Nobel Prize for showing damaging effects of radiation ongenes, and in 1995, forty years after signing of *Russell-Einstein Manifesto*, Joseph Rotblat received a Nobel Peace Prize for campaigning against the nuclear arms race.

Even though recommendations to develop research into areas as environmental philosophy and nonwestern African, Latin American, and Asian philosophy are missing in mainstream philosophical literature, they are, in fact, not out of touch with reality of nowadays (western and non-western) societies—to the contrary!

Attention for and de facto use of new environmentally friendly renewable energy resources are growingworldwide. There are already practical alternatives for gasoline cars as sugarcane (bioethanol) cars (Brazil) and electric cars. Development of wind and solar energy, hydroelectricity, wave and tidal power, geothermal energy etc. may prevent transition to nuclear power plants.

New EU (European Union) norms raise global standards of environmental policies. *Wikipedia* entry onEuropean Union tells us:

> In 1957, when the European Economic Community was founded, it had no environmental policy .... Over the past 50 years, an increasingly dense network of legislation has been created, extending to all areas of environmental protection, including air pollution, water quality, waste management, nature conservation, and the control of chemicals, industrial hazards, and biotechnology. ... According to the Institute for European Environmental Policy, environmental law comprises over 500

> Directives, Regulations and Decisions, making environmental policy a core area of European politics.... (https://en.wikipedia.org/wiki/European_Union - retrieved April 30, 2024)

We can summarize the maxims of two postmodern conditions to 20th-century philosophy of science - global cross-culturalism and environmental pragmaticism--in an addition to Karl Popper's formula on growth of knowledge, progress of science ('…fundamental evolutionary sequence of events… $P_1 \rightarrow TS \rightarrow EE \rightarrow P_2$' (Popper, 1979, p. 243), modifying it into progress of science and society $P_1 \rightarrow$ TS $\rightarrow$ EE/EP GC $\rightarrow P_2$ where *P* stands for Problem, *TS* for Tentative Solutions, *EE* for Error Elimination; *EP* for Environmental Pragmaticism and *GC* for Global Cross-culturalism. The forward slash at EE wants to allow for 21st-century global cross-cultural and environmental criticisms (as to save Planet Earth, see, e.g., Harari (2016, p. 20):

> .... When the moment comes to choose between economic growth and ecological stability, politicians, CEOs and voters almost always prefer growth. In the twenty–first century,we shall have to do better if we are to avoid catastrophe.

However, in our view, green policies and economic growth do not necessarily exclude, but possibly enhance each other, and we need to change to green technologies etc. as soon as possible, e.g. by development of renewable energy instead of fossil fuels).

Conclusion - Adjudications of TE

On surface analysis Einstein's *Elevator* TE appears a series of interrelated TE. This has caused some yet unnoticed confusion as one may not always encounter exactly the same TE in various analyses, oneanalyzing two lifts, a second only one lift, a third about dropping things in a free-falling lift, a fourth about a light beam entering the lift etc. After clearing this confusion our main analyses feature on *Elevator* TE considered as a *Theoretical TE*, in fact, again a *Deconstructive TE* composing both a destructive (falsifying) and constructive (verifying) TE.

There is a second reason to consider these TE theoretical as that they appear not

to be about our daily living world but about imperceivable micro- and macrophysics, that is the physical worlds of (sub)atomic elementary particles and astronomy that can't be perceived anymore by the naked eye butonly with help of machines and instruments.

Lastly, we have concluded to some imaginability flaws partly caused by too concise an account of theTE, partly by nature of the text which was written for a general public whereby popular and scientificcontexts have got blurred which can explain the defects, partly by the fact that these TE are in fact about micro- and macrophysics and for this reason can't be presented as about our daily living world. For these reasons, the TE can only be properly understood on a metaphorical interpretation.

Possible rationale is that philosophers commonly judge plausibility of TE against background of common knowledge (instead of daily experience) and as this common knowledge nowadays also comprises school and popular knowledge about quanta and the universe, one would be consideredilliterate if one would not know about it and would not consider these TE convincing. We hereby criticize this elitist attitude of westerners and western philosophers and scientists in particular as: (1) one can't expect all of the world population to be educated in western science and (2) there are still fundamental doubts about western science as because of damaging and polluting effects of applicationsand technologies derived from western theoretical sciences. As we have clearly stated in quotes from Russell-Einstein Manifesto we think scientists may share this view and Einstein's attempt to bring down his astronomy theory to daily experience is a vivid illustration that western scientists want to reach out to everyone, everywhere instead of roaming in an elitist position of secluded esoteric knowledge. After all the theories need to be accepted not only by the scientific community but also by political world communities.

Notes

[1] We won't discuss Magnet and Conductor (MAC) TE and Chasing a Beam of Light (CABOL) TE at length here. They are discussed in 2015 Prov. PhD Thesis 'Semantics of Thought Experiments' (Hertogh 2015). On deep analysis MAC is a Deconstructive TE featuring epistemological maxim of simplicity, it falsifies (destructs) Maxwell's theory and verifies (constructs) Einstein's; CABOL is a Paradox TE of principle of relativity and speed of light (c), initial paradox is resolved by explicating application of postulate of constancy of speed of light c. Deconstructive TE are joints of Constructive and Destructive TE, Paradox TE may show a paradox that can be logically resolved to adjust the seeming contradictory result of the TE.

[2] Einstein & Infeld, 1938, pp. 226-235. There are many more TE in Einstein & Infeld (1938). Einstein refers to his TE as 'idealized experiments' that is experiments 'created by thought' (Einstein & Infeld, 1938, p. 226) by which procedure there is abstracted from friction, air resistance etc., and he often mentions example of c, that is speed of light in vacuum.

In Einstein & Infeld (1938) there are--next to the Elevator TE--many more TE, from classical mechanics, electrodynamics ('repeating Faraday's experiment with a circuit shrinking to a point', 'small sphere with an electrical charge') and quantum physics involving electrons or photons.

Einstein & Infeld (1938) classical mechanics TE are about a 'cart on a perfectly smooth road', 'wheels with no friction at all,' 'a perfect sphere rolls uniformly on a smooth table', 'a body moving forever with no friction nor any other external forces acting', and so on.

Einstein seems to consider these TE necessarily unperformable in reality

> Imagine a road perfectly smooth, and wheels with no friction at all. Then there would be nothing to stop the cart, so that it would run for ever. This conclusion is reached only by thinking of an idealized experiment, which can never be actually performed, since it is impossible to eliminate all external influences. The idealized experiment shows the clue which really formed the foundation of the mechanics of motion. (Einstein & Infeld, 1938, p. 8)
>
> We have seen that this law of inertia cannot be derived directly from experiment, but only by speculative thinking consistent with observation. The idealized experiment can never be actually performed, although it leads to a profound understanding of real experiments. (Einstein & Infeld, 1938, pp. 8-9)
>
> The division leads to an idealized experiment, for a physical process in which only the mechanical aspect appears can be only imagined but never realized. (Einstein & Infeld, 1938, p. 47).

[3] In last section of this paper on adjudication of TE Gendler's adjudication is partly confirmed by Sorensen's, partly contradicted as Sorensen discusses fallacious interpretations of TE next to antifallacies and arrives at a more justified and positive evaluation of possibly very fantastic, sci-fi etc. TE generally speaking.

[4] Elaborating on exact details and circumstances of an imaginary scenario is just one of advices we find in TE theories when a TE is considered (resolvably) underdescribed (Gendler) or undersupposed, underspecified, superficial, oversimplified (Sorensen's missupposition, literary bias against complexity).

[5] ↔ could be preferred over → but we hold on to the latter because of, e.g., similarity to other formulas in research into TE, Hertogh 2015.

[6] Using TE Matrix terminology, first matrix M1 is P2 , P3 → C and on second step M2 the matrix brackets can already be omitted as M2 , P0 , P1 , P2 → C is logically valid and sound. We arrive at M2 by explicating hidden principle of relativity P0 , one of the major principles of Einstein's theory of relativity as mediated by E = mc2, light/energy and mass equivalence, for TE6.

[7] Micro- and macrocosm and related micro- and macro- or astrophysics relate to both world of subatomic particles and astronomy. For both areas Galilean-Newtonian mechanics won't hold, but Einstein's relativistic mechanics as (e.g) in quantum mechanics velocities of subatomic particles and quanta are many times higher than usual speeds on Planet Earth, and in astronomy it is about many more heavenly bodies than just Planet Earth that may have different, weaker or stronger gravitational fields. However, as may be clear from Hammer and Feather Experiment as performed on the moon by astronaut David Scott from Apollo 15 in 1971, a hammer and feather may be falling slower on the moon than the earth, but they will still be falling with equal velocity.

[8] 'Like compasses, there is a mystery as to how thought experiment works.' (Sorensen, 1992, p. 289). This sounds like a compromise to the sceptics. As our analyses of rather bizarre TE as Elevator and Chasing A Beam of Light show logical deep analyses can be elucidating. Our Extended Argument View and TE Matrices describe the process of picking out possible worlds that can validate and justify both inference and doubtful

premises of TE. Although we may have to go through procedures of fallible guessing and won't know the outcome in advance, TE appear quite transparent devices, instead of mysteries. The feel of mystery may be caused by psychological phenomena as cognitive dissonance, and with respect to cognitive psychological and phenomenological analyses and interpretations of TE we propose a many-valued probability logic as applied in TE Diagram, assigning relative plausibility values to a set of TE by, e.g., audience of a lecture on TE (see Hertogh, 2022).

[9] Mythical and religious images and explanations may be related to pre-scientific accounts of light and some of them as aether are mentioned by Einstein as still being part of dominant (meta)physical theories of his days.

[10] From the eleven signatories of the Manifest all but Leopold Infeld have won a Nobel Prize, eight in Physics and related areas, two in Peace and one in Literature (Bertrand Russell 1950). Next to Albert Einstein (1921, Physics, law of photoelectric effect) it is about Max Born (1954, Physics, interpretation Schrödinger equation quantum mechanics), Percy W. Bridgeman (1946, Physics, physics of high pressures), Frederic Joliot-Curie (1935, Chemistry, artificial radioactivity), Hermann J. Muller (1946, Physiology or Medicine, discovery of X-ray mutagenesis), Linus Pauling (1954, Chemistry, chemical bond, 1962, Peace, campaigning against e.g. nuclear weapons tests), Cecil F. Powell (1950, Physics, discoveries on mesons by photographic emulsions), Joseph Rotblat (1995, Peace, efforts towards nuclear disarmament), Hideki Yukawa (1949, Physics, prediction of pi mesons).

References

Brown, J.R. (1991a). *The Laboratory of the Mind, Thought Experiments in the Natural Sciences*. (Paperback Edition 1993)

Brown, J.R. (1991b). Thought Experiments: A Platonic Account. In Horowitz & Massey 1991, pp. 119-128.

Brown, J.R., & Fehige, Y. (2023). Thought Experiments. *Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/thought-experiment/

Chalmers, D.J. (1996). The Conscious Mind, In *Search of a Fundamental Theory.* Oxford University Press.

Chalmers, D.J. (2002). Does Conceivability Entail Possibility? In Gendler & Hawthorne 2002, pp. 145-200.

Chalmers, D.J. (2017). Zombies on the Net. http://consc.net/zombies.htm

Einstein, A. (1905). Zur Elektrodynamik Bewegter Körper. Annalen der Physik, 17, 891-921.

Einstein, A. (1920). *Relativity: The Special and General Theory*. Henry Holt.

Einstein, A. (1923a). On the Electrodynamics of Moving Bodies. Trans. Einstein 1905. In Einstein 1923b/1952, pp. 37-65.

Einstein, A., Lorentz, H.A., Minkowski, H., & Weyl, H. (1923b/1952). *The Principle of Relativity, A Collection of Original Memoirs on the Special and General Theory of Relativity, With Notes by A. Sommerfeld*, Translated by W. Perrett and G.B. Jeffery. Methuen [1952 republication by Dover]

Einstein, A., & Infeld, L. (1938). *The Evolution of Physics-From Early Concept to Relativity and Quanta*. Cambridge University Press.

Einstein, A. (1949/1969). *Autobiographisches/Autobiographical Notes*. (Trans. Paul Arthur Schilpp) In Schilpp 1969, pp. 2-94.

Einstein, A. (1956). *Autobiographische Skizze*. In Seelig 1956, pp. 9-17.

Galilei, G. (1632/1967). Dialogue Concerning the Two Chief World Systems, Translated with Revised Notes, by Stillman Drake, Foreword by Albert Einstein. University of California Press. (Trans. Galileo 1632. *Dialogo sopra i Due Massimi Sistemi del Mondo*. Batista Landini.)

Galilei, G. (1638/1914). *Mathematical Discourses and Demonstrations, Relating to Two New Sciences/Dialogues concerning Two New Sciences*, Translated from the Italian and Latin into English by Henry Crew and Alfonso de Salvio. With an Introduction by Antonio Favaro. MacMillan. (Trans. Galileo 1638. *Discorsi e Dimostrazioni Matematiche, Intorno à Due Nuove Scienze*. Elsevirii.) http://oll.libertyfund.org/titles/753

Gendler, T.S. (1996/2000). *Imaginary Exceptions: On the Powers and Limits of Thought Experiment.* Dissertation Harvard University 1996. (Routledge, 2000) https://www.academia.edu/945481/

Gendler, T.S. & Hawthorne, J. (Eds.)(2002). *Conceivability and Possibility*. Clarendon Press, Oxford University Press.

Harari, Y.N. (2016). *Homo Deus: A Brief History of Tomorrow*. Harvill Secker.

Hertogh, C.P. (2015). *Semantics of Thought Experiments*. Prov. PhD text Philosophy VUB Brussels.

Hertogh, C.P. (2022). Semantic Analyses of Hilary Putnam's Twin Earth (Ft. TE Diagram). In Rezaei 2022, pp. 501-531 (Ch. 24).

Hertogh, C.P. (2023a). Semantics of Galileo's Gravity (Thought) Experiments/Semántica de los experimentos (mentales) de gravedad de Galileo. *Analítica*, 3, 39-63.

Hertogh, C.P. (2023b). *The Conceivability of Consciousness - Kirk's and Chalmers'sZombie Thought Experiments*. London Journal of Research in Computer Science and Technology, 23 (1), 21-41.

Horowitz, T., & Massey, G.J. (Eds.)(1991). *Thought Experiments in Science and Philosophy*. Rowman and Littlefield.

Kripke, S.A. (1980). *Naming and Necessity*. Basil Blackwell.

Locke, J. (1975). *An Essay concerning Human Understanding*. Ed. and Foreword P.H. Nidditch. (First Pub. 1689) Clarendon Press.

Nagel, T. (1974). What Is It Like to Be a Bat. *The Philosophical Review*, 83 (4), 435-450.

Norton, J.D. (1991). Thought Experiments in Einstein's Work. In Horowitz & Massey 1991, pp. 129-148.

Popper, K.R. (1979). *Objective Knowledge: An Evolutionary Approach,* Revised Edition. First ed. 1972. Clarendon Press.

Putnam, H.W. (1973). Meaning and Reference. *The Journal of Philosophy,* 70, 699-711.

Putnam, H.W. (1975a). The Meaning of 'Meaning'. In Putnam (1975b), 215-271.

Putnam, H.W. (1975b). Mind, Language and Reality. *Philosophical Papers*, Vol. 2. Cambridge University Press.

Rescher, N. (1991). *Thought Experimentation in Presocratic Philosophy*. In Horowitz & Massey (1991), 31-41.

Rezaei, N. (Ed.)(2022). *Integrated Science 2050: Transdisciplinarity.* Springer Nature.

Russell, B., Einstein, A. et al. (1955). *Russell–Einstein Manifesto*. Read by Bertrand Russell on July 9, 1955, on Press-Conference in Caxton Hall, London. https://pugwash.org/1955/07/09/statement-manifesto/

Schilpp, P.A. (Ed.). (1969). *Albert Einstein-Philosopher Scientist*. (Third Ed., First Pub.1949) Open Court/Cambridge University Press.

Seelig, C. (Ed.). (1956). *Helle Zeit—Dunkle Zeit, In memoriam Albert Einstein*. Europa Verlag.

Sorensen, R. A. (1992). *Thought Experiments*. Oxford University Press.

Wertheimer, M. (1959). Productive Thinking. Harper and Bros.

Wittgenstein, L.J. (1953). *Philosophical Investigations*. Basil Blackwell.

Wittgenstein, L.J. (1961). *Tractatus Logico-Philosophicus*. Trans. McGuinness, B.F. and D.F. Pears and with the Introduction by Bertrand Russell. Routledge and Kegan Paul, The Humanities Press.