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Epistemological Remarks on Libet's Experiments on Free Will: Between Voluntarism and Will

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Abstract Libet's experimental setting has been criticized at length ever since its first appearance, under both methodological and empirical aspects. In this paper, the attention will be driven on a neglected underpinning theme which has not yet been investigated, central for the economy of the argument: the time of choices. The pivotal role played by mental chronometry at the beginning of psychology and neurophysiology will be pointed out, and how the lack of a proper definition of time affected the course of the following research on the subject. The Aristotelian definition of time will be considered in order to cast some light upon Libet's empirical findings.
KEYWORDS: Benjamin Libet; Neuroscience; Time; Free Will; Voluntary Action.

Riassunto *Osservazioni epistemologiche sugli esperimenti di Libet sul libero arbitrio: tra volontarismo e volontà* – Il setting sperimentale di Libet è stato duramente criticato sin dai propri esordi, sia dal punto di vista metodologico che empirico. In questo lavoro si porterà l'attenzione su una questione di fondo che sin qui non è stata indagata, e tuttavia centrale per l'economia dell'argomento: il tempo delle scelte. Saranno messi in evidenza sia il ruolo centrale svolto dalla cronometria mentale all'inizio della psicologia e della neurofisiologia, sia gli effetti sul corso della ricerca determinati dall'assenza di una definizione appropriata di tempo. La definizione aristotelica di tempo sarà considerata per gettar luce sui risultati empirici di Libet.
PAROLE CHIAVE: Benjamin Libet; Neuroscienze; Tempo; Libero arbitrio; Azione volontaria.

IN THE '80S, NEUROPHYSICIAN BENJAMIN Libet observed a correlation between a neurophysiologic parameter, the readiness potential (RP), and a simple voluntary movement, such as moving one finger. Surprisingly, the RP was found to precede the awareness of the incoming movement by about 350 ms. A radical interpretation of these observations is that free will is an illusion, since the subject becomes aware of his/her intention to move when his/her brain has already started to plan the movement. The author himself states his conclusion in these terms:

> The experimental findings led us to the conclusion that voluntary acts can be initiated by unconscious cerebral processes before conscious intention appears.[1]

Since then, Libet's experiments on free will have been discussed many times and under different points of view: neurophysiological, philosophical, psychological, etc. In this paper I will focus on a neglected fundamental theme which has not been investigated yet and that is, in my opinion, central to the economy of the argument: the time of choices.

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Although the strength of Libet's argument lies in time, this subject has not been analyzed in depth. In this paper I will try to fill this gap and to cast some light on the delicate relationship between neuroscience and free will. In order to accomplish this task, the concept of time will be precious, since it entails both these dimensions. It is indeed a quantitative parameter, therefore a legitimate object of science, and a qualitative measure, deeply rooted in the inner region of the self.

A historical account

The role played by the notion of time in the rise of psychology has not been fully acknowledged. As a matter of fact, it was Hermann Helmholtz[2] who first found a way to measure the responding time of an electrical stimulus along a frog nerve, and he discovered that nerve impulses travel surprisingly slow, at about sixty miles per hour. Once the experiment was repeated on human beings, by asking subjects to push a buzzer as soon as they perceived the experimenter's touch on their legs, the average speed Helmholtz was able to calculate was about two hundred miles per hour, still much more than expected.[3] It is worth noting that Helmholtz was one of the most brilliant Johannes Müller's scholars, who thought that the so called "neural principle" should be something similar to light, therefore immeasurable.

These findings, not only grounded a whole new chapter of Science, namely psychophysics, but also made clear that consciousness, despite its appearance, might be fast, but cannot be instantaneous. The issue concerning how long exactly it will take for a stimulus to generate an impression was studied by Wilhelm Wundt,[4] Helmholtz's assistant at the University of Heidelberg, who opened the season of mental chronometry experiments, which are nothing but an earlier version of Libet's experiments. From a whole array of experiments, Wundt developed a theory of mind grounded on what he called perceptions and apperceptions. Perceptions are those kind of pre-aware responses to the environment that allow us to quickly react to any stimulus, like driving a car or playing ping pong, while apperceptions are the full, self-reflective, and conscious thought, well aware of what is going on.

There is no need to go any further on details concerning the amount of discoveries found in this field; they range from optical illusions to tactile ones, where it is easy to see the adjustments carried out by our brain in order to fill sensorial gaps perceived by our perceptual system. It is interesting to note, though, that Libet himself started his physiological career in the same branch, investigating[5] the amount of time a stimulus needs to persist in order to reach the threshold of consciousness.

As we can see, the notion of time did not just play a central role in the rise of psychophysics, but it was already on the background even in the first steps of the emerging theories of the mind. Nevertheless it was never really investigated, and I think that much of the debate concerning these kind of experiments is due to a lack of understanding of this central concept. But let's take now a deeper look on Libet's experiment before carrying on the analysis about time, to see all the elements here at stake.

On the role of conscious will in Libet's experiment

Libet started his inquiry defining what he means by a voluntary action. In his perspective, a voluntary action is identified by the following conditions:

(a) It arises endogenously, not in direct response to an external stimulus or cue;

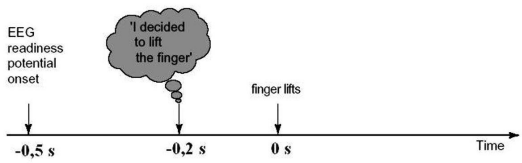
(b) There are no externally imposed restrictions or compulsions that directly or immediately control the subjects' initiation and performance of the act;

(c) Most importantly, subjects feel introspectively that they are performing the

> act on their own initiative and that they are free to start or not to start the act as they wish.

These conditions could be translated in classical philosophical theses: (a) self-determination; (b) absence of constraint; (c) a new edition of *liberum arbitrium indifferentiae*. The neurophysician proceeds by asking the subjects to move their hand, or finger, just when they feel the desire, urge, decision, or will to do it. This movement will sign the time 0 of the incoming cognitive processes. The whole experiment is focused to estimate the amount of time running between the intention to act and the necessary neurophysiologic processes related.

Here is a picture/chart of the experimental setting time table:



At the end of the paragraph describing the experimental setting, Libet's reader finds these words:

> Finally, one should note that the voluntary action studied was defined operationally, including appropriate and reliable reports of introspective experiences. The definition is not committed to or dependent upon any specific philosophical view of the mind-brain relationship. However, some implications that are relevant to mind-brain theories will be drawn from the findings.[6]

This kind of statement is not rare in Libet's pages. He often claims to make just scientific remarks, free from philosophical commitments, but this unrequested defense shows rather his unwillingness to undertake an explicit philosophical debate. The choice to measure the time of intentionality, previously defined as the awareness of the stimulus to act, implies the reduction of intentionality to its corresponding stimulus. Of course, this reduction is not so philosophically uncommitted as the author thinks; on the contrary, it shows a sort of materialistic monism which is a peculiar philosophical perspective with its own apories.

Libet's experimental setting has been criticized at length ever since its first appearance, both for methodological and empirical reasons.[7] Here, I am going to point out a few underlying assumptions which might undermine the argumentative strength of those experiments.

Libet thought that the absence of a detectable meaning of the action was an essential feature of his experiment, so that the subject could feel himself totally free to pursue the action or not.[8] In our view, it is questionable that the absence of meaning constitutes a condition of free acting, quite the opposite. Human actions tend to be intrinsically meaningful. When conduct strikes as meaningless, human beings do not feel freer, but rather try to infuse meaning into it.

Besides, as much as the researcher may try to create a neutral setting, this goal cannot be achieved, since it is not neutral deciding to participate to this kind of trials. As a consequence, every subject shares the goal to contribute somehow to the success of the experiment, no matter how much effort has been put to make the environmental influence unperceivable.

It is however worth noting that Libet himself did not think that his findings led to the complete denial of free will. Instead, he thought that his findings clarified how it works, by choosing whether to carry out tasks unconsciously initiated. The author considered these findings coherent with the great western moral traditions, and pointed out how moral prescriptions in most ethical systems are conceived in negative terms. In this view, the "ten commandments" are paradigmatic as injunction not to act in certain ways.[9]

According to Libet's point of view, "the veto

function" is where the subject is in charge of his own behavior. In his terms, then, we are not free to will, but we can choose to accomplish or not what elsewhere has been decided to do. According to this conclusion, the author says that we should criticize those moral systems which aim to make people feel guilty for intentions, since intentions arise independently from the subject's will.

On this point, it should be noted that this paradigm does not apply to the type of ethics which stems from Christianity, where the principle of acting is conceived in positive rather than in negative terms.[10] This is also consistent with the assumption that acting freely does not require only an absence of constraint, which could be one condition of its possibility, but also a goal to achieve. This point is full of consequences, indeed as in classical philosophical terms, will has always been conceived as dependent on intellect,[11] while in more modern times, the relationship between intellect, which sets goals, and will has changed. Starting with Occam's voluntarism, will began to be conceived as something absolute, preceding intellect.

Libet's experiments endorse this kind of assumption, together with all the apories which result from it. In order to summarize some of the most problematical Libetian assumptions, it is possible to say that:

(1) concepts like "free will", "consciousness", "will", and "voluntary" have been adopted according to different meanings, so that they determine what in logical terms should be considered a paralogism, that is an apparent argument that is however formally incorrect;

(2) will has been considered just as a quantitative substance, whereas this assumption is highly problematic;

(3) one assumption in Libet's studies is that will has to be "pure will", which is however something that does not exist in reality: every will is a will of something and it is expressed by someone. Moreover, this assumption is not empirically verifiable. This is also the reason why the empirical setting is inappropriate. There is a measurement bias: while different times have been measured in different ways, corresponding to electrophysiological times and introspective times, nevertheless these times have been put together on an identical scale, rated in milliseconds, conforming therefore to one another;

(4) even if we adopt Libet's empirical setting, it is possible to give a different interpretation of his results, by stressing the difference between free will and the awareness of free will, which is properly what has been investigated;

(5) if we had to repeat these experiments, we should not pretend to investigate a chimerical pure free will; rather, we should study the actual free will, necessarily connected with the intellect, which means that the will is somewhat bound to the object that the intellect knows. In philosophical literature, will is classified in two ways: a potential one, and an actual one; the former leads to the elicit act, the latter to the imperate act; in other terms, there is a clear difference between a voluntary action and an action which has been wanted "per se". Elicit action, the will to will, is direct, without intermediations, not coercible; imperate action comes from will by means of other operative skills, such as walking or talking, which could be impaired, by forcing those imperate actions (which were performed by the voice or the legs in the previous examples).

When someone decides to reach an object on a table, he has to stand up (assuming he was sitting), and start to walk towards his goal; while the decision to reach the object is an elicit one, the chain of actions needed to accomplish that task can be voluntary, of

course, but not necessarily wanted "per se". Standing up and walking in our example are instrumental actions performed to fulfill the original intention to reach the aimed object. It is our thesis that Libet's experiment describes at its best the course of a voluntary action, not free will, since the elicit decision to cooperate at the experiment was already taken when people started the experimental session, so that the tasks performed (finger/wrist flexion) were just voluntary actions.[12]

I find two kinds of intertwined problems in Libet's works: the mind-body problem and the conception of time. These two problems, which are clearly different problems, are interconnected in Libet's experiments, where time is conceived as the measure of the relation between mind and brain. Given to his "spatial" conception of time, Libet sets the mind-brain problem in a way that is both subtly spatial and materialistic. In epistemological terms, Libet swings between a dualistic and a monistic point of view.

Mental chronometry

As it is correctly stated in Libet's last monograph on this topic: it's all about time. Then, the question becomes: what kind of time?

Since Helmholtz, time has been considered just as a quantitative parameter[13], something suitable to be rated in seconds or parts of seconds, such as actual millisecond (Ms), but this is not time, it is just a possible kind of its measurement. This misunderstanding inevitably compromises the debate about these experiments.

Let's take a closer look to this problem. Time is one of the deepest philosophical problems of western thought. Of course, it is not possible to offer here not even a small picture of its history. Let's just consider Aristotle's classical definition of time: «the *number* of *motion* in respect of before and after».[14] I choose to start from Aristotle's perspective not simply for its classical and well deserved status, but above all for its explicit reference to the notion of number, which makes this definition more useful to develop a quantitative perspective.

So, time is a kind of number. Therefore, we need to understand what a number is in order to grasp the essence of time in Aristotle's philosophy. In Aristotle's arithmology, number covers at least three different kinds of meanings: *numerus numeratus, numerus numerabilis,* and *numerus numerans*. The first is the sense of what is counted, the second is the sense of what is possible to count, and the third is the sense of what we count with. The former and the latter of these meanings constitute respectively the matter and the form of the number, while the middle one, *numerus numerabilis*, synthesizes both of the previous concepts, and this is the sense in which Aristotle thought of a number in reference to time.[15]

These concepts can be exemplified by saying that the first sense of the word refers to the existent beings, the objects of the action of numbering; the second refers to the possibility of being numbered, and the third refers to the active principle of number, which is intellect in Aristotle's view. So, the question becomes: what does "possibility of being numbered" mean?

Something can be numbered for the sake of both the other meanings of the concept: either the faculty of intellect to enumerate something, or the capability of existent beings to be counted. However, Aristotle's real idea on this point was more radical, as he meant that possibility is not something just due to the intellect or existent beings, but is, rather, a real property of movement.

The constitution of possibility is a subtle metaphysical problem in Aristotle's philosophy that cannot be further explored in the present work. For the present purpose, it is enough to point out that this notion of number entails both the objective and the subjective dimension, and time lies at the intersection of these two realities.[16]

So, if time is a real possibility which can be expressed in mathematical terms, one first counterintuitive consequence is that every

phenomenon has a proper time, suitable to be numbered according to its own nature. This is why simply rating every consciousness' phenomenon in Ms fails to discover its inner temporality. Let's consider an example. If we take the action of grasping a glass of water on a table and we divide the action into its steps, ranging from the intention to reach the glass (maybe because we are thirsty), to the motor planning of the task (how we plan to move our arm), to the actual movement of grasping, we obtain at least three different aspects of the same reality. The key point is that these aspects are always essentially related to the same action, which is described, first, under the perspective of phenomenology (intention), then, under that of physiology (motor planning), and eventually under the domain of the intended goal (the actual reaching for the glass).

It is of course possible to time every single aspect of this analysis, by measuring the time running in each phase of the action, but these measurements should not be misunderstood, by assuming that they express the time of the single phase, since this phase does not really exist extrapolated from its context. This very simple truth is never taken into account in Libet's experiments. In fact, he divides the course of the action in different steps, each one with a proper timing, and claims that the former is the cause for the latter.

Besides falling into the well known *post hoc ergo propter hoc* logical fallacy, Libet's argument takes for granted the epistemological legitimacy of the segmentation of action that he operates. Unfortunately, this segmentation does not seem to be justified. To consider the awareness of the incoming action as something that could stand alone, without relations to the following action or to the previous intention to act, is simply epistemologically incorrect, since the action has a proper physiognomy, which entails the intention of acting and the actual action. The same goes for timing. The time of awareness, which must follow logically the object of consciousness, gradually arises from the stimulus, either internal (an intention) or external (a perception).

Toward a different interpretation of Libet's experiments

French philosopher Henry Bergson, in his doctoral thesis named *Essai sur les données immédiates de la conscience,*[17] *significantly* translated in English as *Time and Free Will: An Essay on the Immediate Data of Consciousness*, points out that modern science, but above all, the emerging psychophysics, fails to address "the problem of time", since conceives it in spatial terms. Although it is not possible to repeat the dense argumentative structure of this work, it is worth noting that it starts with a logical analysis of the concept of number, which brought the author to discern two opposite senses of time, a quantitative one, namely spatial, and a qualitative one, related to the central concept of *durée*. Bergson clearly saw how time and space have been mistakenly merged together. In his view, on the contrary, duration, or time, has no juxtaposition of events.

According to Bergson,[18] duration has to be understood as a qualitative multiplicity, as opposed to a quantitative multiplicity. In *Essai sur les données immédiates de la conscience*, it is possible to find several examples of a quantitative multiplicity. When someone looks at a flock of sheep, what is noticed is that they all look alike. Thus a quantitative multiplicity is always homogeneous. Moreover, it is possible to enumerate the sheep, despite their homogeneity. This is why each sheep is spatially separated from or juxtaposed to the others; in other terms, each occupies a discernable spatial location.

Therefore, quantitative multiplicities are homogeneous and spatial. Since a quantitative multiplicity is homogeneous, it is also possible to represent it with a symbol, for instance, a sum: "33". On the contrary, qualitative multiplicities are heterogeneous and temporal; qualitative multiplicity implies heterogeneity without juxtaposition.[19]

While the external world can be defined by the juxtaposition of its elements, and therefore can be considered as ruled by the law of impenetrability of bodies, duration implies the opposite feature: the mutual interpenetration of bodies. Here lies the main and irreducible difference between time and space. All the mistakes about time, in Bergson's perspective, derive from the illegitimate spatialization of time.[20]

If Bergson's analysis has to be taken seriously, time needs to be framed in a different way. In other words, time cannot be rated just in Ms anymore, as this would constitute an improper spatialization of its nature. Time should rather be seen as duration, as something persisting throughout the becoming of things. Bearing these remarks in mind, it is possible to interpret Readiness Potentials, which are Libet's main argument to his thesis, in a new way, according to new studies conducted on choice-reaction tasks experiments.

In other terms, if I am correct in considering the consciousness of time as a lasting reality because of its reference (numerability in Aristotle's vocabulary) to the mind, RPs should be considered as a sort of orientation to action. This simple phenomenological insight is not only coherent with the normal experience of actions, but also allows us to avoid the logical fallacy of *post hoc ergo propter hoc* aforementioned. It is indeed clear that orientation does not mean determination, but only an inclination to take a course of action, which can be stopped whenever it should appear reasonable to not carry it out.

C.S. Herrmann[21] conducted an experiment where participants observed a stimulus on a computer monitor and were instructed to press one of two buttons, depending on the presented stimulus. It has been found that neural activity precedes the motor response, as in the case of Libet's experiments. However, this activity was already present prior to stimulus presentation, and thus before participants could decide which button to press. Therefore, it has been argued that this activity does not specifically determine behavior. Instead, it may reflect a general expectation.

While there is no need to point out how this interpretation would not interfere with the notion of free will, it is interesting to note again the role played by time in this new experimental setting. Chronologically priority is a key to understand a certain phenomenon. In this case, it is the electrical activity recorded into the brain that precedes the possibility of the soon to come choice, so it cannot be inferred that this activity determines the incoming action. RP can rather be considered a sort of preparation to action, which is consistent with a theory of action in which time is not discrete, but continuous.

Predisposition, expectation, preparation are all concepts meant to describe the condition triggered by this Readiness Potential which draws a structure not suitable to be divided in a clear cut sequence of stages. Rather it identifies the preparatory phase of continuous course of movements, ranging from the orientation to act, to the intention to act, to the preparation to act, and eventually to the action itself. The final action is more than the actual visible effect; it entails all the preparatory states which have been previously considered, so it would be naive to divide the action from what it stems from.

It is worth mentioning that the idea that RPs is connected with the subsequent intention to act had already been put forth by John Eccles[22] in his commentary on Libet's work. Libet was more interested in the "veto function" of consciousness, which in his mind showcased a sort of consciousness primacy (though not temporal).

Conclusions

Libet's experiments have different merits: they have revived the topic of mental chronometry; they have showed the need to develop a working hypothesis on mind, in order to understand the meaning of experiments involving brain-mind connections; they have

relaunched the mind-body problem, and have opened to both the classical answers given to that issue, namely dualism and monism, even if Libet himself never clearly endorsed either of these perspectives (while Eccles, his mentor, did).

It is not just of historical interest to note that psychophysics gained a new and sound vitality by rediscovering its original roots, namely, mental chronometry. It is also of great philosophical interest to see how the role of time has played a pivotal role in this revival. I find it truly fascinating to note that whoever has tried to think about the mystery of consciousness (both with a scientific or philosophical approach) was driven to considering the problem of time. Just consider, among the others, eminent thinkers such as Aristotle, St. Augustine, St. Thomas, Kant, Bergson, Helmholtz, etc.

There is a strong link between time and will, as well as between time and intellect, since time defines their "perimeter" (but pay attention to the spatial image) of exercise: you cannot want something already happened in the past, nor you can actually want something yet to happen in the future. It is of course possible to desire something different for past and for future, but desire is different from will under many respects. The same goes for intellect, which can exercise its capability of understanding strictly speaking just on current things; of course one can try to predict the course of events, or even retrace historical facts, and yet, prediction and rebuilding facts differ from intellect. They are both intellectual operations, but both predictions ad retrospections are based on the analysis of present, which allows us to project our conjectures on future and past.

Going back to the picture I've chosen to exemplify Libet's findings, it is possible to see the arrow of time upon which the different times of events are marked: the recorded RP onset; then the inner decision to move (although it would have been more correct to say that it was the time of the awareness of that decision); and eventually the actual movement. It has not been paid enough attention to the fact that, besides all these different and punctual times, each of these events is "placed" on an arrow. This means that there is a sort of general time, within which other different times fall.

Although this kind of representations is quite usual in scientific papers, where it is common to see time symbolized on the x-axis and therefore remaining in a spatial parametrical background, it could be said that this more general time, the time of the arrow, is the real time of the action, within which are possible other timings, as long as we bear in mind that these further times depend on the first and comprehensive one.

In other terms there is a basic time inherent to the course of the action as a whole, which is represented by the arrow, and then many other possible times to be sequenced, each of them referring to the main one in order to be intelligible. If this reference gets lost, as it happens every time these temporal sequences are considered per se, the meaning of them gets lost, too. So, if we accept that the action cannot be too harshly divided, we should also understand why each time recorded on that arrow has to be read as interconnected to the others.

Therefore, it makes no sense to say that RP anticipating the awareness of the incoming action is determining our will. In this conceptual framework, the meaning of RP is completely different: it is the brain's first detectable signal of the incoming chain of events, eventually culminating into the action, as it is shown also by Hermann's empirical evidences.

An adequate conception of time, both inner and external, allows us to shed some light on the relationship between voluntary acts and willed ones. The classic distinction between elicit and imperate acts can be read in the same way time and times relate to one another within the action, being the former a sort of *princeps analogatus* of the latter. This means that will has to be conceived primarily in the sense of the elicit act, the aware choice,

and only secondarily in the sense of the imperate act, which is intelligible only in relation to the first act.

Starting with Aristotle's conception of time, it was natural to adopt his theory of analogy to show the relationship between time and Will, which are both analogical concepts. They have different meanings, but all depend on a main meaning, which in the case of time is "the *number* of *motion* in respect of before and after", and in that of will is the elicit choice to will something for itself, not for any other reasons. A thoughtful interpretation of Libet's experiments should not confuse an imperate action and an elicit choice. That is the real illusion, because no matter how much effort the experimenter has devoted to mask the task, the choice of the time to lift a finger is not an elicit action.

Notes

[1]B. LIBET, *Unconscious Cerebral Initiative and the Role of Conscious Will in Voluntary Action*, in: «Behavioral and Brain Sciences», vol. VIII, 1985, pp. 529-566.

[2] Cf. H. HELMHOLTZ, *Messungen über Fortpflanzungsgeschwindigkeit der Reizung in den Nerven*, in: «Archiv für Anatomie, Physiologie, und wissenschaftliche Medicin», 1852, pp. 199-216.

[3] On this topic see R. FANCHER, *Pioneers of Psychology,* Norton, New York 1990.

[4] Cf. R. RIEBER (ed.), *Wilhelm Wundt and the Making of a Scientific Psychology*, Plenum, New York 1980.

[5] Cf. B. LIBET, *Mind Time. The Temporal Factor in Consciousness*, Harvard University Press, Cambridge (MA) 2004.

[6]*Ivi,* p. 530.

[7]Cf. R.J. NELSON, *Libet's Dualism, Commentary/Libet*, in: «Behavioral and Brain Sciences», vol. VIII, 1985, p. 550; J. UNDERWOOD, *Mind Before Matter*, in: «Behavioral and Brain Sciences», vol. VIII, n.4, 1985, p. 554; C. WOOD, *Pardon, Your Dualism Is Showing*, in: «Behavioral and Brain Sciences», vol. VIII, n. 4, 1985, p. 557. More details in A. MELE, *Effective Intentions: The Power of Conscious Will*, Oxford University Press, Oxford 2009.

[8]He put this idea in these words: «The absence of any larger meaning in this act appears to exclude external psychological or other factors as controlling agents», see *ivi*, p. 532.

[9]Cf. B. LIBET, *Unconscious Cerebral*, cit., p. 539.

[10]Cfr. "*Dilige et quod vis fac*". St. Augustine, *Epist. Joannis*, VII, 8 (Migne PL, t. 35 col. 2033).

[11]This was, broadly speaking, the Aristotelian-Thomistic perspective.

[12] Cf. A. ACHTZIGER, P. GOLLWITZER, P.M. SHEERAN, P. SHEERAN, *Implementation Intentions and Shielding Goal Striving from Unwanted Thoughts and Feelings*, in: «Personality and Social Psychology Bulletin», vol. XXXIV, n. 3, 2008, pp. 381-393.

[13] Cf. G. GHILARDI, *Il tempo delle neuroscienze*, SEU, Roma 2012.

[14] ARISTOTLE, *Physics*, Δ, 11 (219 B2). On the topic see also J. ANNAS, *Aristotle, Number and Time*, in: «Philosophical Quarterly», vol. XXV, n. 99, 1975, pp. 97-113.

[15] Cf. L. RUGGIU, *Anima e tempo in Aristotele*, in: L. RUGGIU (a cura di), *Il tempo in questione*, Guerini & Associati, Milano 1997, pp. 37-62.

[16] Although Aristotle acknowledges the role played by both intellect and beings in the constitution of time, nevertheless he sees time as something inherent, the real possibility of the "object" (whatever this is) to be counted, rather than something fully dependent on the soul's capability to number, or to be numbered on the object side.

[17] H. BERGSON, *Essai sur les données immédiates de la conscience,* Alcan, Paris 1889.

[18] Cf. L. LEONARD, M. LEONARD VALENTINE, *Henri Bergson*, in: E.N. ZALTA (ed.), *The Stanford Encyclopedia of Philosophy* (Winter 2013 Edition), URL = <http://plato.stanford.edu/archives/win2013/entries/bergson/>.

[19] This could sound a bit contradictory, but it is not, since heterogeneity and juxtaposition are similar but not the same thing: the former meaning the irreducibility of one thing with another, due to each different origin (*ἕτερος, heteros* > *other; γένος, genos* > *kind)*, the latter meaning the spatial relationship of being counterposed to one another.

[20] For a full account of the notion of time in Bergson's work cf. V. MATHIEU*, Bergson, il profondo e la sua espressione*, Guida, Napoli 1971; A. PESSINA, *Il tempo della coscienza, Bergson e il problema della libertà*, Vita e Pensiero, Milano 1988; G. GHILARDI, *Per un profilo teoretico della temporalità in Bergson*, in: «Per la filosofia: filosofia e insegnamento», vol. XXIX, n. 84, 2012, pp. 21-32.

[21] See CS. HERRMANN, M. PAUEN, B.-K. MIN, N.A.

BUSCH, J.W. RIEGER, *Analysis of Choice-reaction Task Yields a New Interpretation of Libet's Experiments*, in: «International Journal of Psychophysiology», vol. LXVII, n. 2, 2007, pp. 151-157.

[22] Cf. J. ECCLES, *Mental Summation. The Timing of Voluntary Intentions by Cortical Activity*, in: «Behavioral and Brain Sciences», vol. VIII, n. 4, 1985, pp. 542-543.