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A Possible Definition of Time

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Abstract: In the scientific literature there are many different ideas on the nature of time and its measurements but some assumptions seem quite debatable: i.e. the nature of time could depend on the type of physics dealing with it; that we could forget time, and so on. Of course we need to measure the duration of time both in everyday life and in science because we want to compare (instant by instant) sets of physical variables which typify an investigation. So that the comparison is possible, we need to use time as an alignment parameter. *That could be a good definition.*

It has been claimed that the duration of a second depends on which side of the bathroom door you are. Actually, the perception we have of time (duration of an interval) is very subjective but, thanks to the natural biological clock and simple observations of the changes in our surroundings, all human beings experience the flow of time and this is not subjective. The connection between a fundamental physical quantity like time and our psychological status influences any scientific research concerning time and other physical quantities connected with it. It is well known that Saint Augustine affirmed how difficult it was to discuss time. In Book 11 of the Confessions, Augustine asks "what exactly is time?" and says, somewhat comically, "If no one asks me, I know what it is."

The difficulty of transitioning from qualitative to quantitative time is well expressed by Poincaré [1]: “In a word, psychological time is given to us and must needs create scientific and physical

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[1] Poincaré, Henri (1913), The Foundations of Science, New York: Science Press, pp. 222-234

time. There the difficulty begins…". Of course this kind of difficulty is not a peculiarity of the time but of any other physical quantities faced in everyday life and investigated by scientists. Poincaré's remark is sufficient to justify the number and variety of thoughts about time. A good example of such a variety can be found in a paper by C. Borghi[2] where the author concludes*: "Only through an accurate investigation about the behavior of real clocks, that measure durations through irreversible phenomena that occur inside them, a re-foundation of physical thought about time can be born, from which the inability will probably emerge to describe reality in the light of a unitary conceptual structure"* . The opposite of this kind of reasoning is, e.i., "Forget Time" by C. Rovelli [3] who suggests *"to interpret mechanics as a theory of relations between variables, rather than the theory of the evolution of variables in time"*. If we accept this last line of reasoning we can probably 'forget' any physical quantity we want. On the other hand, we do not believe that the connection between the nature of time and thermodynamics (time's arrow) is so strong. The concept we have of irreversibility should be slightly revised: by reversible process we intend a process where a system reverts to its initial state from a final one; but nothing is said about all the infinite intermediate states. True reversibility is only when a system goes back through all the same intermediate states.

Ideas about the nature of time should not depend on which part of physics is being investigated: the nature of time for Newton and Einstein were not different although in Special Relativity the usual coordinate time $\boldsymbol{t}$ needs to be distinguished from proper time $\boldsymbol{\tau}$ measured by a clock on a given world time-line.

We should be aware that, although Special Relativity works very well and has been checked in many different physical contexts, it was enormously lucky the existence of an universal constant with dimension of a velocity. This 'lucky strike' led to the creation of the space/time interval between two events. Nevertheless, the intrinsic difference between time and space should not be forgotten: while in a reference system we can imagine putting a particle at any point between $-\infty$ and $+\infty$ around an arbitrary origin, we cannot do the same for time axis coordinates. In other words it is not a secondary detail that we can travel in space but not in time.

Despite the variety of viewpoints and thoughts on the nature and operational processes of its measurement (i.e. on the measurement of the time durations), any scientist has to agree on the necessity of adopting a physical quantity called 'time' . The main question is: why do we need to introduce the variable called 'time'? Could we disregard time in our calculations and/or elaboration of experimental data?

In a non-scientific 'context' we use time to order everyday events because we need to know what happens before and after a given event or how long we have to wait and so on. In all these cases, in general, we don't need a continuous comparison over the evolution of an event nor a very accurate measurement.

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2 Borghi Claudio, Physical Time and Thermal Clocks, Found Phys, **46**(10), 2016

3 Carlo Rovelli, Found Phys, **41**(1475),2016

In a scientific context our needs are very different. Indeed we can analyze, for example, an experiment only if we can continuously compare the physical quantities, which describe the experiment. Any physics experiment is the result of measuring a set of variables $V_1 \ldots V_n$ from the beginning to the end of the experiment. The comparison makes sense only if we can align any variable in time by expressing their evolution in the form of a function of time $\mathbf{V_{1(t)} \ldots V_{n(t)}}$. The error in measuring this independent variable **t** will contribute to the total experimental error. This amounts to saying that the real role of time is the alignment parameter of the values that physics variables assume during their evolution which, in general, determines a mutual dependence and correlation. Even in theoretical calculations the role of time is the same. Therefore the role of an alignment parameter to compare evolving physics quantities could be taken as a definition of time.