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By F. M. DENTON

THE ODD notion so long held by journalists that only twelve people in the world understand Einstein's theory of Relativity has recently been challenged,[1] and the suggestion has been made that instead of a mere dozen in the whole world the number of people who actually do understand Einstein's Theory is many hundreds, while the number mentally capable of understanding it is over a million in America alone.

There must be something queer about a question so difficult to answer. I propose, therefore, to discuss the meaning of the expression, "Understanding Relativity."

Does anyone understand anything? A small child understands the word "apple." A schoolboy understands that two and two make four. A physicist understands Poisson's equation: "Nabla squared V equals nought."

On the other hand no small child understands "remorse"; no schoolboy understands Poisson's equation, and no physicist understands the electron.

After he has lived a few years the child will have learned the meaning of remorse, the schoolboy will have learned the meaning of Nabla, and —may we not hope?— the physicist will have learned all about the electron.

Are there any things so inscrutable that not even time and experience will ever disclose their meaning? I think that Death is one. And rather to my own surprise I have come to think that Einstein's Theory is another.

The examples given may carry the clue to "understanding." The child understands "apple" because it is *familiar* with apples. The boy understands "two and two make

1. See the article "One chance in a hundred to understand Einstein," by J. B. Nichols in the *Scientific American*," Feb., 1934.

four" because he is *familiar* with cases in which the statement holds, and has not been made aware of any in which it does not hold. The physicist understands Poisson's equation because it sums up his notion of a region in which there is no field (no electric charge or no matter). He understands it because he is *familiar* with charge and with matter.

The physicist of today fails to understand the electron because his familiarity with it is incomplete—leaving him unable to predict its future behavior.

The clue thus suggested to the meaning of "understanding" is this, that to understand a thing means to be familiar with it.

Einstein's Theory is new; it is familiar only to those few people who have given it much thought; hence if understanding consist in familiarity it follows that Einstein's Theory is understood today by but few.

This leaves the theory on a par with all the theories of physical science. Will it, like them, be "understood" in due course by all good students? I think not.

There is a great difference between ordinary theories and Einstein's Theory of Relativity, for this is the first theory formulated in the spirit of modern science. It is the first theory that has set out to be "true" in the modern scientific sense.

The slogan of the older pragmatists was, "the truth is that which works." It left unanswered the question who should be the judge of the working. Modern science says, "The truth is that which works to the satisfaction of every conceivable observer," an observer being an intelligent recorder equipped with properly calibrated instruments—namely, a clock and a scale, and differing from other observers only by his position and motion with regard to them.

In accepting the notion that there are indeed such observers and that there is a unique external world of events to be observed, Einstein has shown that either we must give up trying to talk sense at all or we must accept

the weird notions that an arrow gets shorter when it travels and that a watch goes more slowly when tied to a moving arrow. The proof of these things is understandable by any student. Their root lies first in the fact of experience that the only measurable things to be observed in physical events are space intervals and time intervals and their space-time "arrangement"—since, after all, when we measure such "derived" quantities as force, velocity, mass and energy, all that really we observe are space intervals between pointers and zero marks at certain time intervals from a time zero—and, second, that our only means of observing events separated in space or in time is "radiation" (of which visible light is the most familiar form), the speed of which is constant, namely, the well-known speed of light.

The constancy of light's speed (the common symbol for which is "c") is regarded, usually, as an experimental fact. Ultimately, however, it is mere truism, since the relativist's "clock" is a yard-stick and his unit of time is the time taken for light to traverse that stick. Alternatively the constancy of "c" may be regarded as a dogma. As such it is comparable in importance with the dogma on which the whole scientific method is based, namely, that the sort of thing that has happened before is likely to happen again. The virtue of both these dogmas is that, on the average, their predictions have come true.

Any intelligent mind can follow the reasoning, leading to the Lorentz Transformation, by which Einstein has shown that, if we accept this dogma, we must be prepared to find that our "unchangeable" old friends, lengths, times, masses, forces, and energy are things whose magnitudes depend on the motion of the observer. He must accept the notion that these things are "scientifically" unreal.

Having accepted the constancy of "c," and having followed the simple reasoning leading to the Lorentz Transformation, we find, in the further development of Einstein's Theory, nothing but pure mathematics.

Thus the conclusion seems warranted that many thousands of minds are capable of "understanding" Einstein.

The matter, however, is not so easily settled. To understand a thing should mean more than to accept a fundamental assumption and then to follow the mathematical reasoning based upon it. Understanding demands a "physical conception" of the fundamental assumption. A physical conception is a mental picture. And, briefly, I am of the opinion that the only sort of picture my own mind can form—relevant to "physical events"—is one which uses as "means of conception," Newtonian three-dimensional space and uniformly flowing time. It is a picture in which the notion that space and time can have anything in common or be, in any sense, interchangeable is "obviously absurd." It is a picture in which each "instant of time" is the same instant throughout all space. It is a picture in which the time interval and the space interval separating a given pair of events are definite and unambiguous. It is a picture in which the notion that the velocity of a given beam of light can be the same to all observers however these may be moving relatively to the light source is "obviously absurd." It is a picture in which, far from being accepted or "understood," Einstein's Theory is absurd.

Let any intelligent mind look into his own mental picture of physical events and try to fit into it, for instance, the notion that when I mount at 2 m. p. h. the steps of an escalator moving at 3 m. p. h. my resultant speed is not 5 m. p. h. but is less. The notion will not fit in because, in that picture, it is absurd.

Nevertheless, the picture or mental conception which a man must have who "really understands" Relativity must make it both true and necessary that, in the case of velocities, three plus two are less than five.

The conclusion to which I am driven is that no man, not even Einstein, does or ever can "really understand" Relativity.

In order to "really understand" that theory I should have to be — not merely pretend to be — a creature to whom space intervals and time intervals had something in common. I should have to be a creature in whose mind the time order of two given events might be ambiguous. I should have to be a creature to whom the reality of the world of events appeared not as an ever changing three-dimensional picture, but as a fixed four-dimensional "arrangement." And since I hold, in common with all men, the notion that life is change and that absence of change is absence of significance, I find that the theory of Relativity is a thing to which the idea of "understanding" is irrelevant and ought not to be applied. My antipathy to the "changelessness" of Relativity's world is, perhaps, not immune to the charge of childishness, since change demands time and in thus demanding time for the 4-dimensional world to "change" in, I am asking both to eat my cake and have it. The avoidance of difficulties of this sort seems, however, impossible because our spoken language is Newtonian. The symbolic language of mathematics is the only one capable of expressing the notions of Relativity.

The Theory is intensely interesting—it provides a new and delightful form of mental exercise. It is useful because, by careful analysis of the experiences which, logically, the mythical "observers" of Relativity must encounter, I may deduce the course of events which "most probably" tomorrow will disclose to "me."

The impossibility of understanding Relativity is not like that of understanding Death. That a man should understand death is a contradiction, since life (a man) excludes death. The "real understanding" of Relativity demands an extension (a "universalizing") of man's faculties, and though that may be so unlikely that it ought to be called impossible the notion is not logically unsound.

In the study of Relativity the first step should be to understand why the theory passes "real understanding";

after that it may be studied without impatience although without understanding, and its usefulness as well as its beauty will be disclosed.

The question of "understanding Relativity" may be summarized thus:

(1) If to understand Relativity means no more than to accept its fundamental dogma of the constancy of light's velocity and then to follow intelligently the consequences which may be deduced mathematically from the dogma, then there are in the world many hundreds of minds which do understand the theory and many millions capable of understanding it.

(2) If to understand Relativity means to be familiar with the theory's claims and with its more important practical implications, then there are perhaps a few dozen minds which understand it.

(3) If to understand Relativity means to have a clear "physical conception" of its meaning, then no human mind understands or ever will understand it.

Should these suggestions seem to disparage Relativity by "debunking" its "understandability" we must remember that, by similar reasoning, the "real understandability" of all the physical sciences can be debunked.

The mind has failed to invent any physical conception or picture in which the behavior of light appears reasonable. Hence if we accept the latest notions by which all the phenomena of the physical world are phenomena of radiation—material particles and electrical charges being special cases of fields of radiation—we are driven to the depressing conclusion that even those phenomena (such, for instance, as a game of billiards) of which the mind seems to have the clearest possible conception and understanding, are clear and understandable only because the conceptions we have formed are shallow and incomplete. Newtonian mechanics

is clear and understandable; yet it finds no place for radiation and radiation is its essential subject matter.

The modern science of psychology seems to have reached the position which physical science held thirty years ago. In the form of "behaviorism" it has become clear and understandable only because it excludes the essential subject matter of psychology, namely, man's psyche. Some psychologists try to side-step the difficulty by denying that there is any psyche. No physicist has yet ventured to deny that there is any radiation. Psychology's Einstein has not yet come. When he comes—if we may follow the analogy of physical science—he will make it intensely interesting and give it beauty and a new usefulness, while relieving it of every vestige of "real understandability."