Erkenntnis und Irrtum

Skizzen zur Psychologie der Forschung

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Mach was trained as a mathematician and a physicist and is mostly known for his work on shock-waves and the concomitant notion of a Mach measuring the relative velocity with respect to the speed of sound. Later in life he turned to philosophy, more precisely that of epistemology. His approach was idealistic by starting from immediate sense perceptions, i.e. psychological and subjective, and how to recreate from those a more physical and objective worldview, whose ontological status remains somewhat vague. He points out that a Natural Law is of course not a Legal Law, when broken it merely means that it was wrongly formulated. Laws should be in concordance with the facts (i.e. sense perceptions) in the sense that the restrictions they impose on our expectations should not be violated[1]. He also stresses that expectations precede observations. In this he is in accordance with Popper. Where he differs is in his reliance on sense perceptions, those according to Popper are not simple entities but also dependent on our expectations. True, Mach would to some extent concede that point, as he makes a distinction between immediate sensations, and those who need to be perceived in a round-about way via the higher faculties of the brain. Of course the point is whether it is possible to draw a clear distinction. Many sensations, such as seeing a crooked pole skewedly inserted in water, the mind has taught itself to discard as a mere illusion[2]

In his approach he emphasizes the biology, of which psychology is but a part, but the part more immediately known to us, and the need to obtain biologically useful knowledge. Thus his general problem is not limited to man alone, but applies to all organisms, which are subjected to the process of learning in order to survive. In other words to conform (anpassen) to the environment. Mach makes a distinction between what is before my eyes (and within the reach of other sensory organs) referred to as U ('Umgebung') and what lies beyond it, but nevertheless has a definite influence on what lies within. What meets the eye and are of importance for survival are bodies, which sometimes also can be touched, and which typically move around. Mach makes fun of the vulgar notions that make a distinction between appearance and reality, which is nothing but a confusion

[1] Ihrem Ursprunge nach sind die 'Naturgesetze' Einschränkungen , die wir unter Leitung die Erfahrung under Erwartung vorschreiben.

[2] I recall once seeing a plane in the sky through a venetian blind. The apparent path of the plane was zig-zagging, but concomitant with the sensation, I realized the obvious reason for the absurd motion, namely that the plane was successively seen by alternating eyes, being alternately occluded by the blinds, while those had slightly different perspectives. Normally slightly incompatible images are integrated in the brain, creating the indescribable and hence incommunicable sense of stereoscopic depth, indicating that simple visual sensation is indeed something very complicated.

of encountering things under different circumstances and under specific. The monstrous, non-knowledgable 'Das Ding an sich' is just an imprint of this confusion in philosophy.

The relationship between the psychological and the physical is of course a fundamental problem, into which he does not probe in greater depth, apart from claiming them to be inseparable. In fact the necessary sciences, such as biology, are not yet developed enough to provide reliable foundations for such elucidations, he points out. My thoughts, unlike things, are only directly accessible to myself, but they may have physical expressions, and from the fact that my neighbor exhibits similar ones to the ones I produce myself I can by analogy (and analogy only?) conclude that he himself entertains similar thoughts. This urge to make analogies makes us, however, occasionally go astray, reading too much into a scene. When we see insects perform rational acts, flying from flower to flower collecting nectar say, or evading our efforts to catch them, we naturally endow them with an almost human power of thought through our instinctive identification with them. But when we see them trapped in a stupid action, like in futile attempts to fly through a window pane, we are made aware of their mindlessness (although we no doubt ourselves often engage in actions as futile and stupid, when seen 'from above'). The idea of simulating the actions of living organisms through machines, is of course a very old one, with roots in antiquity, and is nothing but the ultimate manifestation of rational understanding. With the advent of the fast electronic computer, unavailable to Mach (he died in 1916) those ideas, in the form of artificial intelligence, have been revived, and some of his ideas have still relevance. Our mental life rest on memory, reproduction and association, the latter being a biologically significant extension of the first two enabling us to go beyond mere experience. But it only works thanks to the essential invariance (Beständigkeit, Stabilität) of our environments. An organism has certain given (angeboren) characteristics which we usually refer to as instincts or reflexes, which sets the process of individual, acquired learning going. The importance of making associations in problem solving is emphasized, and it together with the power to reproduce make up the basis of consciousness. Consciousness, Mach points out, consists not in a single 'quality' (Qualität), but in the intricate relationship between many 'qualities'. The sense of consciousness cannot be explained, it is so fundamental and simple, that it cannot be reduced to something even simpler, at least not at present time, Mach adds a caveat. He then starts to discuss memory, and points out that there are many different kinds of memories, each corresponding to different parts of the brain.

As to make a more specific investigation, he refers to experiments of removing the higher brains from frogs[3]. They still function, but there are no longer any initiatives taken, nor any spontaneous actions, all actions are reflexes. But even organisms without brains manifest actions of sorts. He refers to the so called geotropic and heliotropic phenomena, in which a plant compensates from being deflected from vertical growth, or turns towards the sun respectively, through some simple principles. Similar processes can also be seen in the animal kingdom, especially among the more primitive ones. He also tries to explain 'Will'. In primitive organisms the automatic reflexes are enough to maintain life, but in more involved ones, living in a more varied and changing environment, those are not enough, but have to be supplemented by associations, which allows more flexibility, and it

[3] similar experiments, now on hens, and similar conclusions, are also reported on by William James in his tract on Psychology.

is those modifications of the automatic which is meant by will. Man differs from animals in his ability to imagine sophisticated round-about ways of achieving ulterior goals, which may appear of little biological use, such as doing science for its own sake. He emphasizes that there is no will, nor any attention, as special psychological powers. They all stem from the same power that keeps a body intact. In fact it is difficult, if not impossible to make a clear distinction between will and attention, in both it is a question of choice.

It is hard to make a clear distinction between the 'I' and the world outside. If the 'I' is the collection of all our remembered sense-perceptions, those are just manifestations of our brain, which is a physical thing. From this we are led into the social consciousness, in particular the development of culture, including science, which can be seen as a collective analogue to the efforts of the individual to learn and obtain useful knowledge out of the process. Humans as isolated entities, would surely not go beyond much that higher animals achieve. Just as apes may exploit fire to warm themselves but not figure out how to engender it themselves, the isolated human would find himself in the same frustrated predicament. But of course just because we are many does not prevent false beliefs, such as that of spirits, to arise in collectives, only that in the long run such cul de sacs of knowledge will be atrophied. Initially religion, philosophy and science, in the sense of observation of nature, cannot be separated.

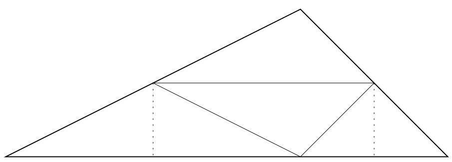
A key concept is the concept, the abstractness of which leads some philosopher such as Berkeley to deny their existence. One cannot imagine a general triangle without any specific properties. Thus concepts are just empty words - 'flatus vocis'. To this Mach takes exemption, pointing out that abstract notions such as 'energy remains constant' which is well understood in view of how correctly it can be applied in specific situations. Although he takes sense-perceptions as his basic point of departure he is aware of the complications that modern machinery introduces by greatly expanding our scope of sensations. Should one trust ones eyes when viewing through a telescope. In fact the observations we make by artificial aids depend on theory to be interpreted, In fact, as Popper points out, even our seemingly immediate sense-perceptions depend on theory to be properly interpreted. As to theories or mental pictures (Vorstellungen) we make of the world, it is only then we need to look for consistencies, Mach points out, the world itself that we know through our senses, possess no contradictions, they only arise in our own mental creations. But it is not through inconsistencies that old theories are discarded and replaced by new correct ones. The Ptolemaic theory was consistent, and could in principle provide better and better approximations, by simply adding more epi-cycles. Mach points out that Ptolemy was in fact a forerunner of Fourier series, and that the same kind of thinking that motivated him, is still prevalent. Kepler's theory, was just simpler. Neither was that inconsistent, Newton's theory was even simpler. Thus simplicity and economy of thought and concept is what characterizes a good theory, but that of course leaves open its ontological status, to Mach it seems sufficient that it is convenient.

As to experiments, Mach points out that not only scientists do them, but also children, and even animals, although the range of those are very narrow compared to the wider interests of man. One particular experiment is the 'Gedankenexperiment' which is very convenient as it is very cheap and hence allows a lot of variations and repeats. In fact every physical experiment is preceded by thought experiments to set it up appropriately and to narrow its focus. Many of the experiments of Aristotle were indeed thought experiments, and many of the more facts of basic physics were not the fruits of physical inquiry but that of thought alone. In particular the fact that bodies independent of weight fall at the same speed to the ground, which is actually hard to physically show due to all the extraneous circumstances, Galileo concluded by thinking what would happen if two bodies of different weight would be connected. Would the slower falling lighter body slow down the faster heavy one? Or should they be thought of one big body and hence fall to the ground faster than any of its components? Likewise the fact that a body on which no forces act will sustain itself in perpetual uniform velocity, is clearly an idealization, not physically realizable. From a logical point of view the fact can be seen as a tautology by indirectly introducing a definition of force. From thought experiments Mach discusses real physical experiments and sets up a few general principles towards a general methodology of how to do science. Meaning how to vary parameters, how to focus on extremal cases, and of fundamental importance how to think in term of analogies, not only for experiments, but in order to fashion theories (and hence motivate new experiments). He also points out the rise of abstraction in modern science, but keeps emphasizing that it is out of isolated facts that science develops. It is those facts which force us to frame hypotheses. It was daring of Newton, and how singularly fruitful, to present his hypothesis of inverse square without having any explanation of it. He points out, as does Popper later, that the main point of a hypothesis is to inspire new observations and experiments.

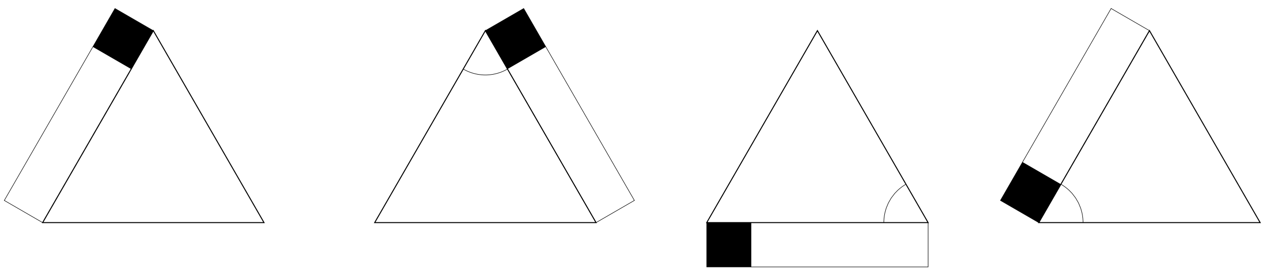
Crucial is the problem. The problem consists basically of trying to resolve a contradiction, something does not really fit. When facing a problem, the mind becomes unsettled and cannot resume its previous equilibrium before it is resolved. Thus we are talking about problems which are not sought out, that is different, but thrust upon us. How to solve a problem? He reports on how Galileo reconstructed the telescope, of whose existence he had just heard of, or of a more a recent vintage to take place in a footnote on Edison's invention of the phonograph. He makes a particular point of the analytic method, supposedly going back to Plato, in which a solution is sought when the end result is known, a kind of reconstruction. Some problems are unsolvable, or make no sense. An important part of the progress of science consists in recognizing such dead-ends and to reject them. Incidentally Mach does not make much of cause and effect, better to speak about mutual dependence, to be expressed by a functional relationship. An example is the Gas law, out of which any two the third can be determined, and thus it makes little sense to speak about it as being caused by the other two, except as a provisional metaphor.

One of the outstanding problems is how to account for the organic world. Has it arisen out of the inorganic? He compares it to fire. Would it be so that man could not generate fire himself, only take advantage of it, when accidentally encountering it, he may be tempted to think of it as something mysterious, not made out of the ordinary world.

Maybe the most interesting section we find in the book is how we can build up an objective geometry from our subjective perceptions of space. First and foremost the metrics of our perceptional space is very different from the objective one, and we use a lot of different senses to gauge it. In the mouth it is the tongue, and hence we feel it to be quite big. Our sense of touch also gives us a sense of space, but with different measures from what we gauge with the eye. If we take the pointers of a compass and trace it over the mouth, it will feel as if the pointers get together at the cheeks, presumably because we have a higher density of touch nerves in the immediate mouth region. It is true that our two frontal eyes give us stereoscopic vision, but that only works at rather close distance, and our most tangible sense of space is due to our movement in it. Many geometrical facts we find out intuitively by physically moving around rigid objects. Rigidity being a fundamental notion, or maybe even only an assumption, to make sense of space. If everything would be in a constant flux, as Mach points out repeatedly, we would get no purchase. Measurement is clearly crucial in geometry as in physics, but how do we know that when we move a rod that it preserves its length? Rods do change their lengths when heated up after all. In fact we cannot know, the question is meaningless, all we can know of lengths are by direct comparisons. An object cannot be rigid in itself, only relative others. In modern parlance, we can talk about equivalence classes, and it is a matter of convention, which one we decide to use as our norm[4]. The fact that three sides determine a triangle but not a quadrilateral we learn from actually manipulating, although it is at times different from distinguishing what we conclude from hand-on manipulation and through thought-experiments.



Mach also supplies a lot of practical experiments to show how we can understand that the angular sum of a triangle is two right ones by folding (left) or by rotating a ruler (below) when drawing a triangle, or even Pythagoras theorem by infinitesimally translating a righthand triangle in the direction orthogonal to the hypotenuse.



Mach very much regrets that Euclidean geometry is not presented in this tangible way to young pupils, but instead codified as purely logical reasoning, which hides intuition and makes of it all a merely pedantic exercise, whose true meaning is lost on the young minds. And of course when Euclid proves things, he actually waves his hand and goes beyond the logical set-up, invoking movements of triangles, in fact the theorems of congruence, are nothing but an expression of such movements in space. In fact Mach does not keep deduction in very high regard, claiming that it does not engender any new knowledge, that everything is already present in the assumptions (he does not make too much of induction either, suggesting that there are different forms of it, and some are as sterile as deduction). Its main value is critical, not a creative tool of discovery. This can be discussed, but the logical codification of geometry has many advantages, which may not be lost on the better

[4] Not quite an arbitrary convention if you think of it, there seems to be an overwhelming class of objects mutually rigid.

students, namely that this alone makes objectification possible, allowing arguments to be discussed and modified, and as to formalism, it itself often makes discoveries possible, which would otherwise be out of our reach. It is doubtful, I believe, to expect that non-Euclidean geometry, and I mean the Hyperbolic, which unlike spherical, was a true discovery avant the fact. Mach spends some time giving a pedagogical presentation of hyperbolic geometry, but very much doubts that it will have any physical applications, and thus regards it with some contempt as a merely mathematical plaything.

The book is in many ways a period piece, like late Victorian furniture. Somewhat heavy, at times ponderous, but always solid. It abounds in anecdotes, often from the authors own personal life, to illustrate a point. In this one is reminded not only of Freud but also of William James, whose physiological approach to psychology, confirms that of the author. The many examples of scientific examples testify to the technical expertise and experience of the author. The many references to scientists and philosophers of the past, who now tend to be forgotten, also gives the account a datedness, which too a large extent is unfair. It is also noteworthy that not only the quotations from English and French (and even Italian) are untranslated, but also the very many extensive ones in Latin. An educated reader was apparently expected to have a command of a half a dozen languages.

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