PART I

ANALYTICAL AND CAUSAL TREATMENTS OF PERCEPTION*

* Epilogue from K. J. W. Craik's Ph.D. thesis on 'Visual Adaptation', Cambridge, 5 February 1940

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THERE is a marked difference of approach to perceptual problems in psychology and philosophy on the one hand and in physiology and physics on the other. The first two studies emphasize the analysis of the content of a perception into its spatial and temporal parts on introspective and logical grounds. The latter two seek causes and mechanisms, perhaps quite unlike the final conscious process, in order to see how far the features of the perceptual process are attributable to more or less familiar mechanisms or to combinations of them. The first point of view has been put most forcibly by Ward (1875) in his article in the *Encyclopædia Britannica*[1]:[1]

> On the view of experience here maintained, we are bound to challenge the description of sensations as due to physical stimuli...widely current though it is...as one that is psychologically inappropriate.... It is true, no doubt, that what the psychologist calls sensibility has as its invariable concomitant what physiologists call sensibility, or what the more careful of them call irritability; and true again, that this irritability is invariably preceded by a physical process called stimulation. But it may be argued, why not recognize a connexion that actually obtains, since otherwise sensation must remain unexplained? Well, in the first place, such 'psychophysical' connexion is not psychological explanation: it cannot be turned directly to account in psychology, either analytic or genetic. Next the psychological fact called sensation always is, and at bottom always must be, independently ascertained; for the physiological 'neurosis' or irritation has not necessarily a concomitant 'psychosis' or sensation and, strictly dealt with, affords no hint of such. Finally, this inexplicability of sensation is a psychological fact of the utmost moment: it answers to what we call reality in the primary sense of the term. The psychophysicist, in setting out to explain sensation, has...unawares to himself...left this fundamental reality behind him.... The question of method is vital. If the psychophysical standpoint were the more fundamental, psychology would be based on physiology, and the old definition of sensation might stand. If, on the other hand, it is the exclusive business of psychology to analyse and trace the development of individual experience as it is for the experiencing individual, then...however much neurological evidence may be employed as a means of ascertaining psychological facts...the facts themselves must be scrupulously divested of all physical implications, the psychophysical method takes a secondary place, and the objective reality of sensory 'presentations' stands unimpeached.

One may note in this argument that

(1) Ward never proves that psychophysical evidence cannot be turned directly to account in psychology: he merely asserts it; that

(2) he does not specify the *aims* of his psychology—whether to predict

[1] The figures in square brackets refer to the references starting on p. 182.

experience and behaviour, to understand the relation of man to environment or the relations of the parts of experience, or what; and that

(3) he does not specify how far he is willing to treat conscious experience *in vacuo*. On the one hand, he asserts that psychophysical evidence cannot be turned to account in psychology; on the other, he admits that neurological evidence may be used as a means of ascertaining psychological facts.

Finally, he presumably requires man to be in the physical world—breathing the air, eating, having light to see by and objects to see—while he studies himself and others.

Introspective analysis means merely division into spatial, temporal, or logical parts, and is not usually a very fruitful or powerful method of giving insight or predictive and controlling power. Analysis is the first step in scientific method; it presents the data in a tidy form and emphasizes what must be explained. It may be objected that causal explanation performs a task no different in kind—that it goes further but is still so far from completeness as to be an unnecessary and confusing complication. But it surely does have a predictive power and an ability to deal with anomalies which the first analysis and relational statement have not. If experience consisted of a small number of regular conjunctions, successful prediction in terms of the conjoined experiences or events would be easy and we need probe no further than these experiences for our ultimate units. But in fact the variety of experience seems infinite when treated in this way. If we try to class conjunctions into a few groups the situation is simplified and prediction is possible; but occasionally it fails: there are anomalies. This might mean that the attempt at simple classification is misguided and doomed to failure. But if we persevere and try another system of explanatory concepts and relations going a stage further back, the predictive scope increases and the anomalies dwindle. This is the justification for the practical use of the explanatory method, and taken in conjunction with the theory of causality it appears to have theoretical justification in addition.

The keynote of Ward's exposition is the isolation of individual experience from its parents—the physical world and the neurological make-up of the individual—and his consequent insistence on a purely psychological explanation. Surely this would only be justified if one of the following suppositions were agreed upon:

(1) if it were admitted as true that any competent scientist can in his own field decide, on first encountering a new phenomenon, whether or not its explanation will fall within his science. If so, a competent psychologist could rest assured, once he had decided that experience or some part of it required psychological investigation, that its explanation would fall within the defined limits of his science; or

(2) if, conversely, it were universally agreed that 'explanation' should

mean simply the type of relational and causal statement which is possible within the bounds of the particular science to which a competent observer has decided that some phenomenon belongs; or

(3) if, finally, the phenomena of experience itself were so utterly unlike those of any other science and so independent of the objects treated by other sciences that a new and quite separate science was required, and that one could state definitely that the explanation of the phenomena would be found within the boundaries prescribed by the definition of the science.

The first is contrary to precedent in the other sciences. For instance, early chemists claimed fire as part of their territory and propounded the caloric and phlogiston theories; but the satisfactory explanation came from physics when it was realized that heat is a form of motion. Similarly today physics and physical chemistry are required to account for many anomalies which occur in chemical reactions. Bartlett (1932) [2] emphasizes the same point in criticizing 'the astonishing way in which many psychologists, even the most deservedly eminent, often appear to decide what are the characteristic marks of the process they set out to study, before ever they begin actually to study it'.

The second viewpoint, again, demands a narrow definition of 'explanation' in terms of preconceived ideas which fails to cover most of the great explanatory concepts of science—for example, Clerk Maxwell's (1873) [3] identification of refractive indices and dielectric constants, and of the different forms of electro-magnetic radiation.

The final point is the most serious. On the one hand, sensory processes give every indication of being closely dependent on physical and physiological ones. This surely provides strong reason for not treating the individual's subjective experience *in vacuo*. At one time it might have been argued that the physical stimulus merely precedes or initiates a sensory process which thereafter bears every sign of having an independent existence; but modern electrophysiological and sensory research suggests no such sudden and final transition. In the course of neural transmission the physiological message undergoes transformations which foreshadow features of the sensory response, such as adaptation. The sensation, subjectively investigated, is found to be shot through and through with evidence of the physical and physiological processes which occasion it, such as local and diffuse effects of previous stimulation. On the other hand, the immense qualitative difference between the complicated physical and physiological processes and the final simple sensation may appear to entitle the latter to be treated on its own merits. No one has ever demonstrated consciousness of sensory qualities in any non-living mechanism; but neither has anyone demonstrated it in any person or animal other than himself; its presence is inferred from analogy with one's own experience. Again, the simplicity and organization of sensation, despite its complicated physiological causation, are not unparalleled among known

physical mechanisms, though they greatly transcend anything found therein. It is the rule rather than the exception that a complex machine is required to perform a simple task or to produce a unified result—to convert the energy of fuel into mechanical motion, to make tablecloths, or to fly through the air. Finally, some of the flexibility of the perceptual process—for instance, the recognition of relational rather than of absolute properties and of changes rather than of constant stimulation, and a primitive type of abstraction—follows from the known properties of the physiological structure and can be imitated by physical mechanisms. While not underestimating the degree to which sensory qualities consciously apprehended differ from and transcend anything known in the physical world, it seems legitimate in view of all this to treat the two in conjunction and to ask how far the unknown can be explained in terms of the known. This leads to the tracing of the part played by physical and physiological mechanisms in sensation as has been done by Helmholtz, Sherrington, Lashley, Adrian, Hecht, Hartline and many others; this has been attempted also in the preceding chapters. Such assignation of the different features of the final perception to their different causal factors surely forms the most illuminating approach to perception. Another mode of expressing it is the attribution of processes to their physiological and psychological levels. Thus we have aimed at a causal explanation of perceptual processes rather than an analytical description of the content of a perception.

The final and most sterile objection that can be raised is the assertion that sensory qualities should be treated in isolation because they are after all 'reality in the primary sense of the term' and that the existence of all else, including the physical world, is open to doubt. Descartes[4] leaned towards this view, while Hume[5] and Berkeley[6] carried it to its extreme. This is not the place to discuss reasons for rejecting it. But no one can deny that causal and relational explanations for the order of our experiences can be propounded in terms of an external world and that these predictions are fulfilled. Surely this would be extremely improbable if no such world existed. Further, the exact and consistent description of our experiences is actually easier in terms of a physical world which is supposed to produce them than in purely subjective analytical terms. Despite the assertions of the introspectionist and existentialist schools, it is far easier to be certain that a number of people are all seeing the same electric lamp than that they are all having identical sensations of yellow. In the circumstances, then, the reality of the physical world is not to be rashly denied.

PART II

THE MECHANISM OF HUMAN ACTION*

* Craik began drafting a book on mechanisms of learning around October 1943; the sketches and summaries contain some of the earliest references to the relationship between learning, cyclical events in the nervous system, and servo-mechanisms. During the subsequent year it appears to have become clear to him that what he had begun exceeded the bounds of the field of learning processes and mechanisms. The draft as left by him bears the above title. It consists of two finished chapters and fragments for four more; the order of those clearly had not been finally determined, as can be seen from his provisional table of contents, in which many undated changes had been made. (Ed.)

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INTRODUCTORY

THE purpose of this book is a twofold attack on the problems of learning and modification of behaviour, from what may be called the analytic and the synthetic angles. By the first, I mean the anatomical, psychological, and physiological examination of the actual structures and processes involved in man and animals during rigid and modifiable behaviour and learning, and by synthetic I mean the theoretical investigation of the basic principles which an organism would have to exemplify in order to show learning, and the construction of mechanical devices to indicate the possibilities and the shortcomings of the various structures and mechanisms which may be postulated in this theoretical approach.

Both methods have their advantages and disadvantages. The first would be an ideal way of discovering the actual processes at work in living mechanisms, if it were not rendered so difficult by the minuteness, incredible complexity, and delicacy of living organisms, and particularly of their nervous systems. It is desirable, however, to pursue it so far as is reasonably possible in order that our explanations may keep close to the structure and function of the organisms whose functioning we are trying to explain. Also, work upon the living organism, and particularly on man himself, is most likely to be of practical value in medicine (for example, in the understanding, diagnosis, and treatment of mental defects correlated with brain injuries, tumours, psychological trauma, or physical disease). On the other hand, the synthetic approach has the advantage of greater generality. We may find that modification of behaviour involves certain general principles which may be exemplified in various ways by plant and animal tissues or by hydraulic, mechanical, or electrical devices. Loeb[7], indeed, has pointed out that the essential features of reflex mechanisms—irritable and conducting elements—do not necessarily entail nervous tissue but are often exhibited by other tissues after destruction, or in the absence of, the nervous system.

The principles of irritability and of conduction are thus more fundamental than the particular mechanisms which fulfil them in particular cases. Similarly, the laws of optics and image-formation are more fundamental than the particular material from which the lens is made—glass, perspex, or protein—in a camera or in an eye. If this be granted, the synthetic approach—both theoretical and practical—has many advantages. We can use mathematical symbols or mechanical components

whose properties we know and which we can manipulate easily, and can disregard some of the immense complexities of the living organism which, necessary though they may be for other functions such as nutrition, growth, and reproduction, are not strictly relevant to the problems in hand. We can borrow freely from the theory and technological practice which has grown up in the attempt to simulate human behaviour and to solve what had previously been problems capable only of human solution —for instance, the nature of sensory elements (photocells, microphones, thermometers and strain gauges), effector elements such as relays and power units, and complete servo-systems such as automatic temperature and voltage regulators and automatic pilots for aircraft. As Clark Hull[8] emphasizes, this 'robot approach', as he calls it, also protects us against mistaking an anthropomorphic account of behaviour for a scientific account. The disadvantages of the method are the possibility of misleading analogies, and the prejudices of anti-mechanists.

There are, of course, a number of people, particularly in the ranks of the philosophers, who refuse to admit that any present or future knowledge derived from physiology or technology can possibly elucidate the relation between thought-processes and physical processes, or solve such problems as the status of mind and spirit and its independence of, or dependence on, mechanisms. Such persons are so convinced of the complete gap between mind and matter that they do not, as a rule, think it necessary to read any of the vast literature which has accumulated on the impairment of mental function by brain injury or physical disease or operation. They consider the gap so great that they do not think they need to specify exactly where one ends and the other begins; and this saves them from making many statements or predictions which might, in fact, prove to be wrong. It is of no use to point out to such people the numerous correlations between bodily and mental function; they insist that a lifelong correlation between two utterly different processes may occur, in some mysterious way, and be no indication of any relation of interdependence between the two. If it be pointed out that they do not apply this to physical events—that they do not, for instance, insist that a grain of dust in their watch cannot possibly be the cause of its stopping, however invariable the conjunction of events—and that no sciences of any kind would exist if all held their views, they still insist that mind or spirit is a completely new and different entity, whose presence absolves them from making the same inference from correlation to necessary connection and dependence.

I am the first to admit the reality of mental and conscious phenomena and their complete absence from the experimental results of physics. But this does not seem to me to solve the problem; it only intensifies it. The principle that two events which are invariably associated are in fact causally connected seems to me a greater one than the principle that if two

things seem to us to be different in nature they cannot be connected. For I could cite numerous cases where physical events which, to individuals of various intelligence-levels and creeds, seemed different and independent have in fact been proved to be related (for example, coal and plants) but I cannot think of any case where an invariable and constant conjunction of physical events has finally been found to be purely coincidental, that is, to be completely unrelated to the main body of physical knowledge of causal processes.

The pure vitalists, indeed, often fall into this inevitable trap; for they sometimes seek to disprove the dependence of mind on body by the same argument—by citing instances which seem to them to show a poor correlation between the two. Such are cases of courageous action, clear thinking, or artistic creation despite grave bodily disease or injury. But in the majority of these cases the physiologist can demonstrate that this is, in fact, quite consistent with his own theory, for the regions of the central nervous system which have been injured in these cases are not those which would have impaired the functions under consideration, and he could without fear of being wrong predict that if certain other regions had been destroyed such actions would not have been possible.

I am also aware, like the pure vitalists, of a strong wish to find that mind and spirit are independent of bodily mechanism, but I have never found any evidence that such a view is justified, nor that the wish is different in kind from the wish that some elaborate mechanical device would work, or from the inability to believe that it cannot work, though I know, rationally, that some small but essential part is broken.

Another objection raised by the extreme vitalists is based on the idea of freewill; they contend that a human being is not actuated by causes, like a machine, but surveys the situation and chooses to do what seems to him best. I should reply, first, that I think the extreme form of such indeterminism to be untenable, and secondly that a moderate form of it, asserting that man is actuated by purpose and requirements and is not just driven by external agencies, is indeed correct but can well be paralleled by the behaviour of certain machines. As regards the first point, few indeterminists would go so far as to say that a man, in his actions, is totally uninfluenced by his past experience or habits, or by the situation in which he finds himself; they would only postulate a certain degree of freedom to be influenced by the whole or by various parts of the situation and by previous experience in making his decisions. Although it is not, I think, possible to disprove at present the possibility of such a moderate degree of indeterminism, it is rather contra-indicated by phenomena such as post-hypnotic suggestion, in which the subject claims he voluntarily chooses to do some act which in fact he has been commanded to do while under hypnosis. Again, Penfield[9] found that if he stimulated electrically the motor region of the cortex in a patient whose brain was exposed he could

cause the patient to make a sound or voluntary movement which the patient then claimed he had voluntarily produced.

On the second point, as to whether a human being is driven blindly by external causes, like a leaf before the wind, or is able to take account of purposes and consequences, I think the indeterminists have justifiably drawn attention to a dissimilarity between human behaviour and the functioning of a limited range of machines which they had encountered, but have by no means indicated a type of behaviour which it is outside the scope of any possible machine to manifest.

Thus McDougall[10] rightly emphasizes that human behaviour is caused from in front, rather than from behind. But I do not think that he analyses this notion clearly. Again, Haldane, in his book *Respiration*[11], seems to imagine that the regulation of breathing by the *energy requirements* of the body lifts its functioning to a higher level, and indicates a life, or φῦσις,[1] unlike that of any machine. The difference, in my view, comes back to the very simple one between a mechanical device involving feedback, and one not involving feedback-notions which are well known in the fields of amplifier and servo-mechanism design, and to which we shall frequently recur. The movements of a leaf are explicable in terms directly of the wind which blows and of its own visible shape; we do not need to consider the leaf itself as a source of energy. Living creatures, and machines such as amplifiers and guns, on the other hand, liberate energy when suitably stimulated and behave in ways which cannot be explained without taking their stored-up energy into account. Further, machines like automatic regulators and servo-mechanisms show behaviour which is determined not just by the external disturbance acting on them and their internal store of energy, but by the relation between their disturbed state and some assigned state of equilibrium, for example, by the departure from the correct temperature which has occurred. This notion, again, we shall discuss in greater detail; at this stage I only want to suggest that such mechanisms do show a simple form of purposiveness or of being actuated by requirements.

For the correct temperature, or the correct course in the case of an aircraft controlled by an automatic pilot, is not a physical cause in the ordinary sense; it is a requirement to be fulfilled, and it is due to the special construction of the machine that the machine can show a wide variety of behaviour directed towards the end of restoring the correct temperature or course and ceasing only when that end has been attained. In other words, the indeterminists are quite right in asserting that purposive behaviour introduces some new principle over and above that of straight causation from behind, and a principle which is shown very little, or not at all, in inorganic nature apart from man-made machines; but it is not a principle which is peculiar to living organisms or conscious minds—it is

[1] 'physis' (Greek), nature, inborn quality, property or constitution. (Ed.)