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THE PRESENT STATUS OF EPICRITIC AND PROTOPATHIC SENSIBILITY AND A METHOD FOR THE STUDY OF PROTOPATHIC DISSOCIATION

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The division of sensibility in the peripheral nerves made by Head and Sherrin (1) into three forms, viz., epicritic, protopathic, and deep, has been attacked from many quarters. The onslaughts for the most part have centered on that form of dissociated sensibility in which the epicritic elements are suppressed, the protopathic elements being retained with their well-known characteristics, viz.: sudden entry into consciousness, poor localization, wide radiation, over-reaction, and inability to name the stimulus.

In the regeneration period after nerve section and suture Rivers and Head (2) found that this type of dissociation occurred as the result of the unequal rate of regeneration in two separate sets of systems, the one mediating the protopathic elements recovering function somewhat in advance of the set which mediates the epicritic elements.

The attackers,¹ chief among whom are to be mentioned Trotter and Davies (3) in England, and Boring (4) in America, have not

¹ Since the World War many articles have appeared in the literature attacking the dissociation hypothesis. A glance at these contributions shows that however useful they may be from the clinical standpoint, they fall far short of supplying a basis for scientific criticism of any theory of sensation. The only work so far submitted, in English and American literature, worthy of consideration in this respect is the work of Trotter and Davies and of Boring.

succeeded in disproving the dissociation hypothesis. Indeed when subjected to critical analysis the clinical studies of Trotter and Davies lend strong support to Head's main argument whilst the studies of Boring, notwithstanding somewhat extravagant claims on the score of introspective analysis, are grossly defective in many essential respects, not the least of which is an apparent predisposition to prove something against the dissociation hypothesis.

The writer has made numerous studies during the past decade upon regeneration in sensory nerves after all sorts of injury and has come to the conclusion that with some modifications Head's position, at least in regard to dissociation, is practically impregnable. The "protopathic stage" as Head calls it may not, it is true, always stand out without admixture of the epicritic elements. On this point Head's opponents, in the author's opinion, have achieved some success. The limits of the epicritic ranges for heat and cold are, moreover, not fixed and each of these forms seems to be an arbitrarily assumed entity since the specific element of heat (warmth) or cold, of all degrees, runs in a series that forms a continuum. Here again the attack of Head's opponents seems to have registered effectively. Spatial discrimination as tested by the compass points simultaneously applied is regarded by Head as the most delicate form of epicritic sensibility and the last of the "epicritic forms" to recover after nerve suture. Head's opponents regard this test as in reality a test for a form of deep sensibility and the author's studies (5), in which he made compass tests on the deep fascia of the thigh, show that, at least in part, this form of sensibility is mediated by infracutaneous mechanisms.

Head recognizes three forms of protopathic sensibility, pain (pricking), heat, and cold; each of which he regards as a simple entity. As a matter of fact, however, each of these, even when evoked by a punctiform stimulus, is a complex of hurtful (affective) and non-hurtful (critical) elements. Thus in certain dissociations the sharpness of pin-prick is shown to be an element separate and distinct from the *hurt* element since it may be preserved intact although the hurt element has been suppressed. And similarly warmth, and the specific sensation of cold, may be retained where the element of hurt or unpleasantness has been abolished. These forms of dissociation found by the author (5) in a case of syringomyelia show that the fundamental thing in protopathic sensibility is the *unlocalized, unmeasurable, uncontrolled hurt or affective element* (unpleasantness, change of state, etc.) as opposed to the *introspectively measurable, more or less well-defined sensation* of sharp-

ness or pointedness (e.g., of pin-prick), and of warmth and cold, each of which must be classed with the critical elements. Head's apparent failure to appreciate the significance of the dissociable elements found, even in what appears to be the simplest form of punctiform stimulation, has led him into a difficult maze of speculation. Thus he insists that once the peripheral nerves enter the spinal cord, i.e., at the first synaptic junction, epicritic and protopathic forms of sensibility are no longer encountered and yet in certain cases of syringomyelia the critical elements (pointedness and touch) of pin-prick may be retained unaffected, or but slightly impaired, where the affective (hurt element) is completely abolished. The similarity, moreover, between the type of sensibility retained in thalamic dissociation and that found in protopathic dissociation during the regeneration period after nerve section and suture is so marked as to warrant the conclusion that they are identical in nature as well as in the mechanism of their production, viz., abolition or impairment of function relative or absolute in the critical mechanism.

As the author (5) has pointed out, the dissociations encountered in syringomyelia and in thalamic dissociation clearly show that the critical pathways, both superficial (epicritic) and deep, retain their anatomical and functional individuality all the way from the periphery up to the thalamus. Head's contention, therefore, anent the intricate regrouping and integrations of afferent impulses, as one of the principal functions of the spinal cord, seems not only superfluous but in actual conflict with demonstrable facts. The sensation known as "heat" evoked by temperatures over 45° C. is a complex of the specific element *warmth* plus the affective element of *burning* or *stinging*, and each of these elements is dissociable from the other in both cord and thalamic lesions. Head nevertheless insists upon his epicritic form of heat in spite of the fact that in syringomyelia temperatures of 55° to 70° C. may evoke only the sensation of warmth. Cold is also a complex of the specific critical element *cold* plus the affective, unpleasant or hurt element and again the author has observed cases (unpublished) in which these elements were dissociated. The fact that cold is analgesic under certain conditions and algesic under other conditions seems to have baffled many observers including Head and Boring. Head makes a strong point of the pleasurable evoked by warmth as indicating a specific form of protopathic sensibility but it has long ago been shown that stimuli otherwise painless or even agreeable becomes painful when their intensity approaches a degree that threatens tissue injury. Change of state is the fundamental thing in all stimulation and the exaltation

consequent upon activation of any function, within limits not antagonistic to well being, local and general, sufficiently explains the agreeable features of warmth. In thalamic dissociation the over-reaction to warmth is not an indication of an exalted specific form of protopathic sensibility. It merely represents the response to an innocuous stimulus where the affective mechanisms have been released from critical control which, as the author has pointed out (5), is exerted directly and mainly at the thalamic level, and not circuitously through the cerebral cortex as Head and Holmes (6) insist. It should be kept in mind that the thalamus mediates only the grosser affective elements and that even these may be in part mediated also by the inner layers of the cerebral cortex. In the course of its development the thalamus should not be regarded as an isolated entity but as closely related structurally and functionally with more primitive elements in the cerebral cortex. Of the epicritic and protopathic forms of sensibility laid down in the original classification of Head and his colleagues only one form remains as a distinct entity, viz.:—light touch, and attempts have been made to remove even this from the category in which Head placed it by Trotter and Davies who regard touch as merely dynamic contact and introspectively distinguishable from pressure or static contact. It seems, therefore, that after fifteen years of trial Head's classification has little to recommend it. In the author's opinion it has retarded rather than aided progress in the clinical study of sensation on account of the confusion it has caused in the minds of students and teachers alike not only because of its fundamental defects as a classification but also, in great measure, because of its formidable ill-fitting terminology.

In Head's classification no mention is made of deep protopathic sensibility although this latter is a commonplace of clinical study and is the form *par excellence* found in the viscera. Compare intestinal colic, testicular pain, etc. This is further reason why Head's classification should be dropped although the tests employed by him might with benefit be retained as in the author's classification (5) and perhaps be made the standard for sensory examinations in hospitals and private practice throughout this country. Head's failure to distinguish between the fundamental affective element in his protopathic sensibility and the critical or specific elements led him to speak of protopathic heat and cold as distinct forms of sensibility with the result that psychologists and clinicians, unable to verify his findings, or to harmonize them with well-established facts, have been led to deny altogether the existence of protopathic sensibility as a distinct form. Had Head not insisted too stringently upon the oc-

currence of a "stage" of protopathic sensibility and had he appreciated the fact that the common fundamental purely affective element underlies all his protopathic forms, giving in each instance enhanced vividness to the superposed critical elements, his work would have been almost beyond criticism. As it stands, its great merit consists in the demonstration after a cutaneous nerve injury of protopathic dissociation, i.e., abolition or impairment of sensibility for the critical elements, the affective elements being retained and exhibiting protopathic characteristics.

A glaring defect in our clinical methods of studying sensation and one often complained of by psychologists is the absence of any attempt at introspective analysis. But even the psychologists themselves seem to have grown timid on this subject and have failed for once to come to the aid of the clinician. The author has found introspective evaluation such an important aid to clinical study, even when the introspections are of the most elementary kind, that he ventures to set forth in detail the simple method he has found useful in unraveling the vexed problems of dissociated sensibility.

METHOD OF STUDYING PROTOPATHIC DISSOCIATION

In the regeneration period after injury or division of a peripheral nerve the protopathic type of dissociation is the one most usually encountered, whereas in spinal cord lesions, the dissociation best known to clinicians is of the critical type, i.e., in which the affective elements are abolished or impaired, the critical elements being retained. Compare the dissociation found in syringomyelia and related conditions. This reversal of type in the dissociation found commonly in spinal cord lesions as contrasted with that so commonly found in peripheral nerve injuries points clearly to two separate systems of pathways, one for impulses representing the affective elements, and another for impulses representing the critical elements. But the evidence for the existence in the peripheral nerves of these two systems does not rest merely on the occurrence of protopathic dissociation, since direct evidence of critical dissociation like that found in syringomyelia is found in certain cases after nerve injury.

Compare the Horsley case in which, after removal of a small tumor from the nerves at the base of the brain by Horsley, Head (7, p. 108) found sensibility absent for pricking and for 55° C. but preserved for light touch and 43° C. Compare also the "Triangle" in the Human Experiment (2) in which Rivers and Head found sensibility for pricking and for the affective or hurt elements of

heat (above 50° C.) absent, that for light touch and for the critical element (warmth) of 43° to 49° C. being preserved. Compare finally the case reported to the New York Neurological Society by Dawbarn and Byrne (8) in which after division and suture of the radial nerve in the upper arm sensibility for light touch and for the compass points simultaneously applied returned in a considerable area on the dorsum of the hand far in advance of that for pricking and for temperatures of all ranges.

In these cases it will be noted that sensibility was found present or absent for certain groups of critical elements (superficial critical stimuli) whereas, for the gross affective elements of pricking, of heat above 55° C., and of cold of all grades (superficial affective stimuli), it was found absent not *fractionally* as in the case of the superficial critical elements but as a *whole*.

The last link in this chain of evidence was supplied when the author (5) was enabled to show that in lesions such as tumors causing compression of the spinal cord, dissociation of the protopathic type was by no means of infrequent occurrence. In the spinal cord and peripheral nerves, therefore, it must be admitted that there are at least two separate and distinct anatomical systems of pathways for the conduction of afferent impulses. One of these systems mediates, the more or less unlocalized, unmeasured, uncontrolled *affective* or *quality* elements (hurt, pleasure, change of state) and the other the introspectively measurable, well-localized, controlling *critical* or *quantitative* elements (sharpness, size, shape, warmth, specific sensation of cold and spatial discrimination, posture, passive movement, etc.).

The affective system has its main terminus in the optic thalamus whereas the main destination of the critical system is the cerebral cortex. Compare Head and Holmes (6). Each of these systems conducts afferent impulses not only from the skin and superficial parts but also from structures that are deeply situated, such as muscles, tendons, etc.; and as each system of necessity has receptor mechanisms not only at or near the surface of the body but also in the deeper parts it seemed desirable to the author (5) for clinical, if for no other reasons, to further divide each of the great systems with reference to the location of its receptor mechanisms. This makes four separate sets of afferent pathways in the peripheral nerves, viz. (1) *superficial critical*, (2) *superficial affective*, (3) *deep critical*, and (4) *deep affective*, each set representing some more or less distinct phase of development of the sensory system. Each of these four sets of pathways remains separate and distinct

from the others, each retaining in the spinal cord, brain-stem and optic thalamus, its functional and anatomical individuality if not a spatial allocation that is grossly or microscopically demonstrable.

This simple classification has been found by the author to be of great practical aid in sensory studies. It seems especially well adapted for the brief summarization of sensory findings so essential for diagnostic purposes. It also supplies a satisfactory means of correlation between physiological and psychological data, emphasizing as it does the radical distinction between the *critical* or *intellectual* elements on the one hand and the *affective* or *feeling* elements on the other.

Under normal conditions each critical system or set of pathways functions in conjunction with the corresponding affective system, the former controlling the latter in the interests of the more complex, cognitive or reasoned methods of adjustment whereby, through experience, memory, judgment, etc., aided by the proficient receptor mechanisms (e.g., of vision, hearing, etc.), injurious objects may be avoided by locomotion without risking possible injury from direct contact, as opposed to the more primitive, unreasoning, instinctive methods of reflex withdrawal by shortening (flexion-reflex) after direct noxious contact.

Many observers have failed to convince themselves that protopathic dissociation occurs regularly after nerve injuries because they attempted to institute comparisons between threshold values obtained in each of the two great general systems, affective and critical, without realizing that in practice every stimulus, whether it be punctiform or areal, makes appeal in greater or less degree to both of these systems. This holds especially for stimulation tests made in the random method which Boring (4) in particular used. Thus in cutaneous hyperalgesia the lightest von Frey hair may evoke a sensation preponderately affective, viz., hurt as opposed to contact, whereas, under normal conditions pricking at a low pressure, e.g., 1.0 or 2.0 grammes, and in certain cases of syringomyelia even at a pressure of 37.0 grammes or more, may evoke a sensation that is preponderately critical, viz., sharpness (pointedness) as opposed to hurt. Introspective analyses based on methods of stimulation which do not take into consideration differences in threshold values dependant on the situation in relation to the body surface as well as upon the nature (i.e., whether belonging to the affective or critical system) of the receptor mechanisms stimulated can have little value in determining the presence or absence of dissociation of sensibility. The absence or impairment of sensibility as a whole for the critical as well as for

the affective elements must be established more or less accurately by the determination of threshold values but a reliable basis for the immediate comparison of threshold values obtained by stimuli that are preponderately *critical* with those obtained by stimuli that are preponderately *affective* is wanting. In the author's opinion the classification of the sensory pathways on the twofold basis, viz., (1) according to the nature of the elements which each system mediates, i.e., affective or critical and (2) according to the nature and location of the receptor mechanisms, i.e., whether superficially or deeply situated, is a distinct help in the study of dissociation since it serves to keep before the mind of the examiner the mechanisms to which each stimulus makes particular appeal. But no method is complete which does not make provision for introspective analysis in one form or another. The procedure which the author has found most serviceable in testing cutaneous sensibility consists first in marking off a definite area within the affected skin area and then applying affective stimuli in a random manner and recording the introspective evaluations for the *critical* and *affective* elements represented in each stimulus. The evaluations are so recorded that comparison of the state of sensibility presented by the affected area with that presented by a corresponding area of normal skin is possible on a quantified basis. This can be readily done by using + marks in the manner set forth below. When water at 50° C., in a silver test tube with a definite area of contact, is applied momentarily and lightly to the normal skin, e.g., on the dorsum of the hand, appeal is made to several types of receptors. The first sensation experienced is that of contact which is felt at once. Next in order warmth is felt and beneath this appears the hurt or affective element which is overshadowed by, and under control of, the two other (critical) elements. In conditions exhibiting defective critical sensibility the hurt element overshadows the critical elements (touch and warmth) with resulting overreaction. These two conditions of sensibility can be contrasted by setting down the introspective evaluations for the different elements of the stimulus 50° C. as follows:

Elements	Normal area	Affected area
Touch	+++	+
Warmth	++	+
Hurt	+	+++

The evaluations for cold at 20° C. may be similarly contrasted as follows:

Elements	Normal area	Affected area
Touch	++	+
Cold (specific element).....	+++	++
Unpleasant feeling.....	+	+++

For pricking at 3.0 grammes, or more, pressure the evaluations might stand:

Elements	Normal area	Affected area
Touch	++	+
Pointedness (sharpness).....	+++	+
Hurt	+	+++

In doubtful cases tables such as these emphasize at once the presence or absence of the subjective overreaction (hurt element, etc.) so characteristic of protopathic dissociation. In addition to the subjective overreaction set down in the tables, the presence or absence of other protopathic characteristics may be recorded such as objective overreaction (withdrawal), radiation locally of the stimulus effects, reference, persistence, poor localization and impaired ability to name the stimulus. Such a table showing the typical characteristics of protopathic dissociation, e.g., for heat at 55° to 60° C., might run:

Elements	Normal area	Affected area
Touch	+	○
Heat (warmth).....	+++	○
Subjective over-reaction (hurt, etc.)	+	+++
Objective over-reaction (withdrawal)	+	+++
Localization	+++	+ or ○
Radiation	+	+++
Reference	○	+ or ○
Persistence	○	+
Ability to name stimulus.....	+++	○

It is well known that practice with any tests reduces the threshold value markedly in some instances even as much as fifty per cent. It is therefore advisable that in every case before testing, the patient should have some training in the threshold as well as in introspective studies so that in the final tests the answers may be promptly and spontaneously given. In the introspective tests each element should be reported in the order of its appearance and according to the degree of its intensity.

The applications of each stimulus may be few or many depending upon circumstances, the elements being evaluated and charted according to the scheme just outlined. At the end of the examination the

average of the evaluations is determined for each element by dividing the total numbers of +’s charted for each element by the number of applications of the stimulus. In the final chart the averages for each element are set down against each other for comparison. By the aid of this simple method, elaborated and adapted to circumstances, the author has found no difficulty in demonstrating to his satisfaction protopathic dissociation not only after severe lesions of the peripheral nerves but also in spinal cord lesions and in the ordinary conditions in which pain is associated with minor grades of nerve injury of mechanical or chemical origin, e.g., contusions, infections, etc.

Many investigators have fallen into error by assuming that in order to obtain dissociation of sensibility one of the two chief sets of elements, i.e., critical or affective, must be completely suppressed as a whole whilst the other remains practically unimpaired. After section of a cutaneous nerve if stimuli, such as very heavy von Frey tactile hairs, be used, sensibility may be found but slightly impaired since such stimuli make appeal to the deeply situated receptor mechanisms of afferent paths that may not have been involved in the nerve section. Just such an error was made by Trotter and Davies (3) who relied on introspection to distinguish between dynamic contact (light touch) and static or pressure-contact (pressure-touch). No wonder these observers found that sensibility for critical and affective elements became restored simultaneously in the affected area after nerve section and suture.

The author believes that the time is ripe for clinicians to come to a more thorough understanding of the significance of the sensory tests. As at present made and recorded they are practically worthless and represent just so much waste of time and effort. Witness the summaries containing such expressions as “hypesthesia (or hyperesthesia below the level of the umbilicus.” With our present knowledge of the multiple appeal of all kinds of stimuli, both punctiform and areal, and of the fundamental critical and affective components present in all forms of stimulation, it is amazing to find neurologists using such terms as hypaesthesia and hyperaesthesia to signify sensory impairment or exaltation. As such terms grossly misrepresent the actual sensory changes, they should have no place in our clinical histories or reports not to mention text-books. The employment of a method such as laid down in this paper would obviate all such difficulties and would give sensory tests a diagnostic value which under present methods they cannot possibly have. As

at present used by the majority of neurologists the sensory tests have little significance beyond the bare information that this or that form of sensibility is or is not lost or impaired. Interpretative evaluation is altogether missing. The method evolved by the author has, amongst other things, the great advantages that by it the sensory tests can be reduced to the extreme of simplicity so as to be available for the general practitioner in routine clinical examinations and for the neurologist's hurried preliminary or diagnostic examinations as opposed to the later, more painstaking examinations made possibly with a view to research. In the four divisions of the author's classification, viz., (1) superficial critical, (2) superficial affective, (3) deep critical, and (4) deep affective, only one type of stimulus need be selected as representative of each division. Thus taking light touch (cotton or the finger tip) as representative of superficial critical stimuli, pin-pricking of superficial affective, posture and passive movement of deep critical, and pressure-pain (pinching, etc.) of deep affective, we have a means of making a rapid sensory examination which, from the point of view of interpretative evaluation, far excels the majority of sensory examinations as at present made even by otherwise skilled neurologists. This simple plan calls for just four sensory tests, viz., light touch, pin-pricking, posture and passive movement, and pressure-pain, all of which can be made in a few moments without the use of instruments other than an ordinary pin. Hitherto, thanks to the failure of teachers of neurology to appreciate their significance, the sensory tests have been made a sort of Chinese puzzle for the general practitioner and as a consequence have been generally so far overlooked in routine examinations, inside and outside of our hospitals, as to find no place in the clinical records. The method here offered to the profession should mark the beginning at least of a movement in the direction of clinical progress.

Conclusions—(1) The division of sensibility into epicritic, protopathic and deep is incomplete and misleading. (2) The terms "epicritic" and "protopathic" in the sense in which Head, their originator, uses them, that is as including so many distinct forms of sensibility, are arbitrary and misleading and should be discarded. (3) The clinical study of sensory defects in addition to threshold tests should include some attempt at introspective analysis without which the various types of dissociated sensibility are likely to be overlooked. (4) Some simple standardized form or chart for the

clinical study of sensory defects should be adopted in the hospitals and medical schools throughout the country.

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