Are the intensity differences of sensation quantitative? (1) / by Charles S. Myers.

ARE THE INTENSITY DIFFERENCES OF SENSATION QUANTITATIVE? I.

BY

CHARLES S. MYERS.

FROM THE BRITISH JOURNAL OF PSYCHOLOGY, VOL. VI. PART 2, OCTOBER 1913.

CAMBRIDGE
AT THE UNIVERSITY PRESS.

[From THE JOURNAL OF PSYCHOLOGY, Vol. VI. Pt. 2, October, 1913.]

ARE THE INTENSITY DIFFERENCES OF SENSATION QUANTITATIVE?[1] I.

By CHARLES S. MYERS.

I. Introduction.

II. The Nature of Intensity Changes.

III. Conclusions.

I.

§ 1. I assume at the outset that the three following propositions will meet with general acceptance[2]. The first is that, whereas Weber's law is a direct expression of the data of sense experience, Fechner's

[1] A contribution to the Symposium presented at the Joint Meeting of the British Psychological Society, the Aristotelian Society, and the *Mind* Association in London, 7 June, 1913.

[2] Reasons for accepting them will be found in my *Textbook of Experimental Psychology*, 2nd ed. 1911, I. 249–253.

law has no such immediately psychological basis, being derived from the application of mathematical symbols and processes to those data. The second is that we are incapable of *measuring* the intensities of sensations, *quâ* sensations; we cannot say that the sensation evoked by an arc light contains so many units of the sensation evoked by a candle light,—we can only range sensual intensities in a graded series. The third proposition is that *intensity* experiences and intensity *difference* experiences are fundamentally similar in their dependence on past experience and (unconscious or conscious) comparison, and in the conditions governing their respective (absolute and differential) thresholds. What may follow from the discussion on intensities in this paper will therefore apply also to intensity differences which are the subject of this symposium.

§ 2. From the acceptance, however, of these three propositions, it by no means follows that differences in sensual intensity (or that sensual intensities themselves) are qualitative and not quantitative. It may well be that sensual intensities are dependent for their increase or decrease on an increase or decrease in the quantity of sensation, notwithstanding our inability to isolate the component units of which any intensity may really be the sum.

Even in the case of a given experience of *extensity* of sensation, we can only say that one sensation is more or is less extensive than another. We can hence only arrange sensations in the order of their extensity; *quâ* sensation we cannot say that one is twice as extensive as another. But we *can* conclude that one line or area (not the *sensation* of a line or area) is twice as extensive as another; and here lies the difference between extensity and intensity. Whereas, on the basis of extensity, we can directly measure the 'extensiveness' of objects[1], we can only measure their 'intensiveness' indirectly in terms of 'extensiveness'—*e.g.* we express the intensity of visual or auditory stimuli in terms of units of amplitude (extensiveness) of wave movement, and the intensity of a weight or taste stimulus in terms of units of matter (extensiveness) of the lifted or tasted object.

Now just as sensual extensity, when conjoined with movement, assumes the form of quantitative extensiveness (spatiality), so sensual protensity, though immeasurable *quâ* protensity, is capable of giving rise to a quantitatively measureable 'protensiveness' (time). Indeed

[1] I agree with Ward: "...before and apart from movement altogether, we experience that massiveness or extensity of impressions in which movements enable us to find positions, and also to measure" (*Encycl. Brit.* Article).

extensity and protensity differ strikingly from intensity and quality, in that the experiences of space and time, to which the former give rise, are lived *through*, whereas those corresponding to intensity and quality are lived *in*; the one pair of experiences are essentially transitional, the other pair punctual. We can at the outset integrate extensity and protensity with movement in a way impossible in the case of intensity and quality.

§ 3. But nevertheless the connexion of intensity with movement is obviously intimate. Power and intensity are practically synonymous. The very word intensity means a state of tension or strain. What, then, is more natural than to suppose that our experience of intensity depends ultimately on the muscular strains exerted to resist force—or even, with Münsterberg[1], to deduce intensity experiences from kinaesthetic sensations?

But if differences in intensity, say of visual sensation, are to be traced to differences in intensity of kinaesthetic sensation, it is difficult to see why we should be able to appreciate, as we can, a difference between 100 and 101 units of intensity of two lights, whereas we are hardly able to appreciate the difference between 100 and 103 units of mass in two lifted weights[2]. Moreover, the explanation is only pushed a step further back; we have yet to consider how sensations from the locomotor apparatus can vary in intensity.

§ 4. It is true that the sensations of muscular strain have in the past been held wholly responsible for the 'sense' (or 'feeling') of effort in all self-activity. Unquestionably afferent impulses of motor origin are of prime importance for our experience of activity, just as they and other (*e.g.* visceral) impulses are of prime importance for our experience of emotion. But there is now, I think, a growing consensus of opinion

[1] *Beitr. z. exp. Psychol.* 1890, Hft. 3, 23.

[2] I have perhaps unconsciously adopted this argument from A. Aliotta's *La misura in psicologia sperimentale* (Firenze, 1905, second footnote, page 106), which since writing the above I have re-read after a long interval. I may add that Aliotta criticizes Bergson's contention in *Les données immédiates de la conscience* (Paris, 1889, 32 ff.) that to determinate values of a stimulus correspond particular qualities of sensation, and that from experience we are led to associate with each such *quality* of the effect (sensation) the idea of an intensive *quantity* of the cause (stimulus). But, asks Aliotta (pp. 105, 106), how do we know that the intensity of the stimulus is changing except by previous sensations of different intensity? How can we transfer the magnitude of *physical* objects to our *mental* experience unless the idea of intensity has already arisen in consciousness? Cf. also Knight Dunlap (*Psychol. Rev.* 1912, VI. 425, 426) for his criticism of Titchener's view (*Textbook of Psychology*, Pt. 2, 140) of the connexion between kinaesthesis and the perception of relation.

that the acts of the self are, in themselves, conscious, apart from sensations of peripheral origin, and that we should make two main divisions of consciousness—the consciousness of 'acts' or 'processes' (*e.g.* the 'acts' of attending, imagining, remembering, thinking, willing) and the consciousness of 'contents' or 'products' (*e.g.* 'what' we attend to, 'what' we imagine, 'what' we remember, 'what' we think, 'what' we will).

II.

§ 1. Consciousness makes its appearance in life whenever a choice on the part of the organism is possible between two or more reactions to a given stimulus. So long as behaviour is fixed (in living matter it is of course never *absolutely* fixed), there is no consciousness—or at all events no consciousness in which the organism's 'self' shares. But with the development of instincts, fixity gives places to plasticity; a certain choice of reaction is open; a certain improvability is possible by practice and imitation; whereupon (as I have before insisted[1]) a rudiment of intelligence at once comes into play.

Now the correlate of differences in *quality* of a sensation consists in differences in *type* of reaction. A sweet taste corresponds with one type of reaction, a bitter taste with another; similarly with the sensations of colour and pitch, different types of reaction are evoked from longer or shorter waves. In their most primitive form, reactions are mainly those of approach and withdrawal. Certain stimuli cause positive, others cause negative 'taxis.' So long as the taxis is fixed, sensation is useless. But with the evolution of the nervous system, as soon as plasticity replaces fixity, vague 'affections' of pleasure and pain enter, followed at a later epoch by the evolution of 'sensations,' the number of possible reactions to the same class of stimulus being simultaneously increased. At bottom, differences in type of movement must be the cause of differentiation in the quality of sensation; it would be of no advantage for the organism to experience different qualities of sensation, unless those differences were serviceable in promoting different types of response[2].

[1] This *Journal*, 1909–10, III. 209–218, 267–270.

[2] Of course, in the developing adult we have to distinguish between the *inherited* physiological basis of sensual qualities (and intensities) and his successful differentiation of those qualities (and intensities) which is improvable by *practice*. That is to say, we have to distinguish between the primary influence of heredity and the secondary influence of education (environment), though the latter is ultimately dependent for its effects on heredity.

§ 2. If the qualities of sensation correspond to different types of reaction, we may be inclined to attribute the intensities of sensation to different degrees—moreness or lessness—of the same reaction. This, however, leads to the consideration of what is involved in moreness or lessness of a reaction. There are some reflex actions of the cord which apparently cannot be graded in strength. For example, by pressing or stretching the skin between or beneath the pads and cushion of the dog's hind foot, a reflex known as the 'extensor thrust' reflex is evoked; the leg is reflexly extended. (Reflexes can be best studied in the 'spinal' animal, in which the connexion between the cord and the higher parts of the central nervous system has been severed.) Now the extensor thrust reflex of the spinal preparation is little, if at all, altered by the strength of the external stimulus. So long as the external stimulus is adequate, whether it be relatively weak or strong, it produces practically the same strength of response[1]. It is an instance of 'all or none' in reaction. The reflex thrust is of very short duration, being easily fatigable.

Hence, in the case of the extensor thrust reflex, a stimulus of suitable strength and of suitable character, applied in a given situation, evokes in the nervous tissue within the cord a certain pattern of response, the issue of which is the discharge of efferent impulses along certain nerve fibres supplying certain muscles; and within fairly wide limits, the movement resulting from this efferent discharge is independent of the strength of the ingoing stimulus.

Now if in the spinal animal these limits are grossly overstepped, we do not get an increased extensor thrust reaction; quite another type of reaction appears,—an immediate and well-marked flexion-reflex. In other words the afferent impulses, on reaching the cord, evoke quite another 'mechanism.' They evoke quite another pattern of nervous response within the cord, so that we get a very different discharge, causing the contraction, not of extensor, but of flexor muscles.

As we have seen, the extensor thrust reflex is an instance of an 'all or none' reaction. The reaction is either obtainable or unobtainable: the stimulus is either effective or not; there is no grading of the reaction comparable to the grading of the stimulus. Nor is this 'all or none' effect manifested in a reflex only. There can be little doubt that muscle fibres and peripheral nerve fibres follow the same principle.

§ 3. In the case of the *cutaneus dorsi* muscle of the frog (which is particularly suitable for investigation owing to its peculiar nerve

[1] C. S. Sherrington, *The Integrative Action of the Nervous System*, London, 1906, 74.

supply), Lucas[1] has been able to prove that the force with which the muscle contracts as a whole is due simply to the number of the individual muscle fibres involved in the contraction.

§ 4. Next, as regards nerve fibres (which are of more immediate interest)—thanks mainly to the work of Gotch[2] and Adrian[3]—there can be little doubt that the principle holds good for them as it does for muscle fibres. Gotch found (i) that the rate of propagation of the wave of excitation (as shown by the concomitant electrical changes within the nerve trunk) is the same whether the excitation is strong or weaker; and (ii) that the effects obtained by exciting only a portion of the nerve fibres of a nerve trunk closely resemble those evoked by a weaker stimulus applied to the entire nerve trunk. These results suggest that a stronger stimulus to a nerve does not increase the strength of the impulse passing down any one nerve fibre but merely leads to a greater number of nerve fibres being involved. It is corroborated by Gotch's observation that the electro-motive force in a stimulated nerve trunk always takes the same time to show itself and to reach its height and to disappear, however it be made to differ in amount by employing different strengths of stimulation.

Adrian's experiments point to the same conclusion. He finds that the time needed to narcotize a nerve trunk by alcohol or by other means, so that the passage of the nervous impulse is blocked, depends not merely on the length of the nerve trunk which is narcotized, but on the disposal of that length. For example, if in one preparation 9 mm. of nerve be narcotized, and if in another two lengths of 4·5 mm. of nerve be narcotized, these shorter lengths being separated by a non-narcotized interval of normal nerve, the times taken to narcotize one and to narcotize both of the 4·5 mm. lengths are the same, while they are considerably longer than that taken to narcotize the 9 mm. length. "The disturbance [corresponding to the nervous impulse] has much greater difficulty in passing one length of 9 mm. of affected nerve than it has in passing two lengths of 4·5 mm." We must assume "that the disturbance [corresponding to the nervous impulse] increases in size in the normal area between the two lengths of 4·5 mm." And Adrian brings forward evidence that "the increase of a subnormal disturbance on entering normal nerve tissue is certainly complete before the disturbance has travelled 5 mm. in the normal region, and it may be instantaneous"; and that "the disturbance increases to a fixed size on entering

[1] *J. of Physiol.* 1908–9, xxxviii. 113–133.
[2] *Ibid.* 1902, xxvii. 395–416.
[3] *Ibid.* 1912, xlv. 389–412.

normal tissue no matter what its size may have been at the end of the region of decrement[1]." For these reasons he concludes that the nervous impulse in the normal nerve fibre must obey the 'all or none' principle.

§ 5. So far as regards muscle and nerve. Their increase in *intensity* of function seems to depend on a greater *quantity* of elements (muscle fibres or nerve fibres) taking part in the action. With a weak stimulus only a few elements respond: with a stronger stimulus, other (less sensitive) elements are also involved. Each element follows the 'all or none' principle, which we have seen exemplified in the extensor thrust reflex.

How now in regard to sensations? Have we any sensations which behave similarly? Owing to the careful work of Head, Rivers and Sherren, the sensations afforded by the heat and cold spots of the skin can now be shown to afford an excellent instance of this behaviour[2]. Different heat and cold spots are in different degrees sensitive to heat and cold. But each apparatus acts explosively and is easily fatigued. If the stimulus is strong enough, it reacts; if a still stronger stimulus is employed, it does not react differently. Hence we have here a clear instance of the 'all or none' principle. We have relatively sensitive and relatively insensitive heat and cold spots, and presumably these reflexly produce relatively considerable and relatively weak reactions. The differences in sensual intensity are correlated on the reflex level with differences in the strength of individual reactions. We may suppose that the nervous impulse from a more sensitive heat spot spreads centrally and hence efferently to a greater number of nerve fibres than are reached by the stimulus of a less sensitive heat spot.

§ 6. Thus the heat and cold spot sensations (and probably the other sensations belonging to the 'protopathic' system of sensibility), appear to be analogous instances of the 'all or none' principle. Each heat or cold spot, like the provocative of the extensor thrust reflex, gives a reaction which, within wide limits, is independent of the strength of the stimulus, provided that it is effective. But suppose these limits are overstepped. We have seen (page 141) that, with excessive increase in the strength (or with change in the character) of the stimulus, the extensor reflex suddenly gives place to the flexor reflex. So too, with like changes in the thermal stimulus, the quality of the sensation alters. The threshold of a new quality of sensation is overstepped: pain enters and quickly suppresses the temperature

[1] *Op. cit.* 399, 402, 412.

[2] *Brain*, 1905, XXVIII. 105.

sensation[1]. We cannot stay here to discuss whether the same end organs can give rise to pain and, with weaker strengths of stimuli, to heat, cold and touch. The important point now to observe is that the quality of the thermal or tactual sensation at once changes, just as the quality of the spinal reflex changes. A relatively innocuous 'exteroceptive' reaction, to use Sherrington's useful terminology, gives place to a 'nociceptive' reaction. And, just as in the case of the reflex, the pattern of impulse within the cord is different, so in the case of the sensation, the paths of the impulses as they pass up to the brain are (sooner or later) changed. At all events we have a hint that a difference of 'specific energy,' as it used to be called, may depend not (or not only) on peripheral conditions at the sense organ, but on more central conditions, say at the first synapses with which the impulses meet; in other words, difference of sensual quality may depend not merely on functional differentiation of end organs and peripheral fibres, but also on the mapping out of different patterns of response within the nervous system.

§ 7. But it will be objected that neither all reflexes nor all sensations obey the 'all or none' principle; and that what we have been considering are exceptions to the general rule. The question at once arises whether—inasmuch as muscle and nerve obey this principle, inasmuch as the extensor thrust reflex follows it, and inasmuch as the lowly protopathic system of sensibility shares it—we are not justified in assuming that higher reflexes and higher forms of sensibility are really governed by the same principle. Let us take, for instance, the 'scratch' reflex. Clearly this reflex, at first sight at least, disobeys the 'all or none' principle. The strength of the reflex can be graded according to the intensity of the stimulus. As the stimulus increases in strength, the clonic twitching movements of the scratching leg increase in amplitude, force, and number, although their frequency is practically unchanged. On the afferent side we may conjecture that more and more nerve fibres are being stimulated; on the efferent side that more and more nerve and muscle fibres are being stimulated. But what is going on at the spinal centres, that receive the afferent and emit the efferent impulses? May we not suppose that, shooting across the synapses, the disturbance preserves a constant 'type' of pattern of excitation, that pattern constituting a functional unit for evoking the reflex? When the stimulus is increased, the

[1] Cf. Rivers and Head, "A Human Experiment in Nerve-Division," *Brain*, 1908, xxxi. 381.

pattern of excitation changes. The additional afferent impulses shoot across into new synapses, which become integrated with the old. The old pattern becomes, so to speak, the nucleus of a more comprehensive pattern. But, despite these additions, the 'type' of the pattern is unchanged. The pattern functions in precisely the same manner as before, *i.e.* as a mechanism adapted for evoking the same kind of reflex. The central neural pattern changes, therefore, not in intensity but in extent; and it changes in extent in such a way that the type of reaction movement is still maintained. That even in graded reflexes the 'all or none' principle is followed is shown by the observation that the latent time taken to manifest the efferent effects of a sudden increase in an original afferent stimulation is practically identical with the latent time taken to produce the efferent effects of that original stimulation[1].

§ 8. Corresponding to the graded strengths of such reflex twitches we have, I suggest, such graded strengths of sensation as occur among auditory sensations. We can imagine that the reflexes caused by a tone of constant pitch of changing intensity vary in much the same way as the scratch reflex changes with strength of stimulus. The number of nerve fibres carrying the incoming nervous impulses increases with the growing strength of stimulation. Each nerve fibre follows the 'all or none' principle, while the central pattern, despite its growth, preserves its functional reaction unaltered in aim. So long as the pitch is kept constant, the type of reaction is practically constant, and hence the sensation is practically unchanged in quality. Further, the reaction, whatever its extent, preserves its character of indivisible integrity; for which reason, perhaps, an intensity cannot be analysed into component units of lesser intensity.

In certain respects, however, auditory sensations (indeed all forms of sensations other than protopathic) are distinguished from such a reaction as the scratch reflex, viz., by the apparent absence of refractory periods, and by the virtual lack of fatigability. The movements of the scratching limb are clonic; they recur with a periodicity which is practically fixed and independent of the frequency of the stimuli applied to the afferent path of the reflex. An additional stimulus, inserted with the object of evoking an additional reflex movement interpolated between these movements, is ineffective. The reflex centre thus shows refractory periods, during which stimuli are inoperative. The reflex centre is also fatigable. But auditory

[1] C. S. Sherrington, *The Integrative Action of the Nervous System*, London, 1906, 24.

sensations, on the other hand, are not intermittent, there appears to be no refractory period; nor are they sensibly fatigable. A prolonged sound is heard uninterruptedly; and it may be heard for minutes, days, or years, without appreciable alteration, so long as we choose to listen to it[1]. The reasons for such continuity and indefatigability we shall examine more closely in the following paragraph. Having regard to their wide difference in complication, we should not expect too close a parallelism between the reflex spinal mechanisms and the far higher mechanisms concerned in sensation. It might be objected, too, that what holds on the 'physiological' side need by no means hold on the 'mental' side of a reaction. But this paper has been written from a diametrically opposite standpoint. Based on the hypothesis of psycho-physiological parallelism, it aims at indicating the light that may be thrown on the fundamental character of the psychical attributes of sensation by physiological considerations[2].

§ 9. There remain a third class of reflex, and corresponding to it a third class of sensation, which we have yet to consider. If we may describe the extensor thrust reflex as a 'gradeless' reflex, and the scratch reflex as a 'clonic' (or 'twitch') 'graded' reflex, we may term the remaining form of reflex a 'tonic graded' reflex. The reflexes, termed by Sherrington 'proprioceptive' reflexes, afford excellent instances of this form of reflex. They are based on the integration of a pair of antagonistic reflexes. The two centres of these reflexes are fed simultaneously by the same unceasing proprioceptive impulses, *i.e.* by impulses arising from within the body, especially from the muscles, tendons, etc., of the limbs concerned. These afferent impulses act reflexly so as to keep the muscles in a postural condition of perpetual tonus,—a condition which may be described as a state of active equilibrium of the double reflex. In this condition it rests as on a knife edge, from which it may be made to swing in one or other of two opposite

[1] If very weak, a continuous sound stimulus is only heard intermittently. (Into the responsibility of inhibitory processes or refractory periods for such fluctuations I cannot here enter.) If strong overtones are present, one or other of them may successively attract the attention (cf. C. Stumpf, *Tonpsychologie*, I. 361).

[2] A caution may be added against supposing that in the complete differentiation of sensations the efferent side of central reactions must necessarily show itself *visibly*, by altered muscular contractions. In the first place the efferent side of a reaction may lead not only to skeletal but to visceral movements; in the second place, not only to muscular but to glandular and other activity; and in the third place, not directly to outgoing peripheral activity at all, but to further central changes in virtue of the connexions of the main efferent limb of the reflex arc with other arcs.

directions, as between two poles. Broadly speaking, afferent impulses which cause (or are set up by) reflex *contraction* of a group of muscles governed by one centre of the double reflex simultaneously cause reflex *inhibition* of contraction in the antagonistic group of muscles governed by the other centre of the same reflex. It is the special rôle of such reciprocal graded inhibition to procure an exact adjustment between the strengths of incoming stimuli and outgoing discharges.

The tonicity of this class of reflex seems continuous and within certain limits indefatigable. The continuity, the lack of refractory period, probably depends on the phenomenon of after-discharge. The efferent impulses are not cut short (or inhibited) periodically as in the step reflex. They outlast the stimulus, and so, if the stimulus be repeated sufficiently often, a continuous instead of an intermittent reflex movement, a condition of 'posture,' results.

The tonic reflexes are especially prominent in the 'decerebrate' animal; the refractory periods, so characteristic of 'decapitate' and 'spinal' preparations, are suppressed. Decerebrate rigidity is entirely proprioceptive in origin; it is abolished by 'deafferentation[1],' and is produced by the action of the proprioceptive impulses on a central mechanism, situated above the spinal cord, these impulses abolishing the refractory periods which are so characteristic in the 'spinal' animal[2].

§ 10. Corresponding to this class of tonic graded reflexes, we have a class of tonic graded sensations, well exemplified (i) in the sensations of warmth and coolness obtained from the epicritic system of cutaneous sensibility and (ii) in the sensations of light obtained from the cones of the retina. Adaptation, contrast and indefatigability are the distinguishing characteristics of this class of sensation. Just as the extensor thrust reflex is fatigable, so we have seen the heat and cold spot system to be fatigable; just as neither the extensor thrust nor the scratch reflex can exhibit a condition of equilibrium, so neither the heat and cold spot system of sensation[3], nor an auditory sensation (nor perhaps the retinal 'rod' sensations), is amenable to adaptation or contrast. There is no middle or 'indifference' point in heat, cold, or

[1] *I.e.* cutting off all afferent impulses.

[2] C. S. Sherrington, *Proc. Roy. Soc.* 1906, B. LXXVII.; *Quart. J. of exp. Physiol.* 1909; *J. of Physiol.* 1910, XL.

[3] Cf. Rivers and Head, *op. cit.* 406–410. In point of fact, the scratch reflex is not a pure example of its class; the scratching leg assumes a definite 'posture,' besides executing a series of scratching movements.

sound intensity as there is in warmth and coolness, or luminous intensity. In place of fatigue we have, in the class of tonic graded sensations, a variable neutral point of adaptability, a 'tonic' sensation, which is neither warm nor cold, neither bright nor dark, from which it is possible to change in the direction of warmth or coolness, brightness or darkness, and to reach (within certain limits) a new state of adaptation. In place of two isolated mechanisms for heat and cold, we have an integration of the two 'incopresentable' polarities for warmth and coolness, within a single mechanism[1].

§ 11. In the case of the class of tonic graded sensations, it is far more difficult to discriminate between changes in intensity and changes in quality. Who shall say whether the gradations of the warm-cool (or white-black) series of sensations change in intensity or in quality?

Nor is the confusion merely between intensity and quality. With the class of tonic graded sensations a new element enters, that of 'extensity.' One sensation appears to have more extensity than another; it appears to come from a wider sensory area. But, as on the spinal reflex level, if the same stimulus is applied to a wider sensory area the sensation must alter at the same time in intensity and often in quality. A vessel of warm water, in which the whole hand is immersed, feels warmer than when a single finger is introduced. The intensity and hue of a luminous sensation depend not merely on the strength of the stimulus at the point of stimulation but also on the area, the number of points, of application of that stimulus.

So close a connexion between extensity and intensity has been supposed to be correlated anatomically with the mode of termination

[1] How sensation, like a reflex, leaps from plane to plane has been already exemplified (p. 143) in the passage from heat, cold and touch to pain. The plane of the protopathic system is in turn distinguished, as we have just mentioned, from that of the epicritic system of cutaneous sensibility by its gradation, by its power of adaptation, by its (relative) indefatigability, and, further, by its freedom from diffusion and radiation and by its power of accurate localisation and of estimating relative size. So, too, the vibrations of a tuning-fork applied to the skin (*a fortiori* when applied to the ear) evoke a central reaction different from a mere series of touches. Thus Head and Holmes record a case of Brown-Séquard paralysis in which "the vibrations of a tuning-fork were appreciated badly or not at all over the right arm and leg, in spite of the complete integrity of tactile and pressure sensibility" (*Brain*, 1911–12, xxxiv. 111). So, too, a flickering light, as soon as the rapidity of the flicker is so great as to produce an uninterrupted sensation, establishes a new sensation, behaving, as Sherrington has shown (this *Journal*, 1904, i.), very differently from a series of flicker sensations; that is to say, a new 'type' of central neural pattern is at once initiated.

of afferent nerve fibres at the periphery. Any given fibre divides into fibrils and supplies a relatively wide sensory area, which is also supplied by similar divisions of other neighbouring fibres on either side of the given fibre. Hence it has been thought that extending the area of stimulation involves stimulation of a greater number of fibrils of the same fibre, and so leads to increase in the intensity of the nervous impulse along the nerve fibre. But if, as we have seen reasons for believing, nerve fibres act according to the 'all or none' principle, this explanation of the connexion between extensity and intensity falls to the ground, and we must seek some other—preferably in the close similarity of reaction, *i.e.* in the partial identity of neural pattern, which a more intensive stimulus and a more extensive stimulus reflexly call forth. Both the extensive and intensive series affect a greater number of nerve fibres as they are increased; both therefore call forth at first almost the same central changes of neural pattern, and almost the same efferent changes in outward reaction.

§ 12. We have seen that, so long as the reaction is of the same 'type,' pursuing the same plan and purpose, the corresponding sensation alters only in intensity; but that, when it begins to alter in type, differences of quality make their appearance. It is not surprising, then, that when sensations are made to increase in intensity, they so often show more than changes in mere intensity. Indeed it is probable that no sensation can be increased in intensity without at the same time undergoing some change in quality.

But this consideration alone hardly helps us to understand why the warm-cool and bright-dark series of sensations approach so much closer to changes in quality than do those belonging to the other two systems of sensation we have considered. We have also to take into consideration the manner in which the qualities of a given stimulus are differentiated in the evolution of sensibility. We start, I think we may assume, with a vague 'whole' of sensibility, which is differentiated into an increasing number of constituent 'parts.' Auditory stimuli of different vibration-frequencies at first give rise to a vague appreciation, merely perhaps of high and low pitch; we come ultimately, by superadded reactions, to have an enormous number of different types of reaction corresponding to different vibration-frequencies of stimulation[1].

In the case of colour sensations, it is, I think, generally agreed that they have been differentiated from the colourless series of sensations.

[1] Cf. H. J. Watt, this *Journal*, 1911, IV. 146.

But even prior to such differentiation, I venture to conceive a time when the various colour stimuli produced *vague* sensations of colour and of white (evolved from the still more primitive phenomena of taxis) by their action on three different neural centres. These centres, each with its appropriate pattern, correspond respectively to red, blue and yellowish-green sensations when excited individually, and to orange, yellow, purple, etc., or to white when two or more of them are excited simultaneously. At such a stage we may suppose a fairly close correspondence between visual and auditory sensibility. The reactions of both are due to the excitation of a group of *single* centres. Any one neural pattern is variable in a single direction only, the extent of variation corresponding to the degree of sensual intensity.

In this system of three-colour sensibility sensual contrast, adaptation and brightness are unknown[1]. Upon it a more complex system of sensibility, giving rise doubtless to new and 'higher' sensual qualities, has been erected. All colour stimuli come now to act on *double* centres corresponding to reflexes of the tonic graded type and giving rise, in the first place, to a series of sensations of graded brightness. Brightness replaces intensity now that the reaction swings from pole to pole, instead of, as before, from zero to the maximum of reaction. The corresponding sensations vary from white through grey to black and are characterized by contrast, adaptation and lack of fatigability.

From within this paired system of colourless sensibility two similar paired systems of colour sensibility become differentiated. The yellowish-green component of the lower three-colour system is now divided into yellow and green elements, and the red and green form the one, while the yellow and blue form the other, of the two new paired centres. It is as if from an axis of up- and down-reactions (corresponding to the white-black series of sensations) there had arisen two opposite to- and fro-reactions, each in a plane at right angles to the original up- and down-reaction (one to- and fro-reaction corresponding to the red-green, the other to the yellow-blue series of sensations). We must suppose that each colour stimulus acts not only on the white-black but also on the red-green or yellow-blue system (or on both systems) of sensibility. We must further suppose that when either of these two colour systems of sensibility is in equilibrium there is

[1] Of course contrast (and adaptation) of a sort are never absent; there is a contrast effect in a heat-followed-by-cold experience, or in a noise-followed-by-whisper experience. But such instances differ not in degree but in level from the sensual contrast (and adaptation) we are here considering.

no sensation save the grey which results from the ever simultaneous action of the colour stimulus on the white-black system.

Thus we are able to start from a (variable) neutral balancing point of equilibrium, a state of tone, from which we may progress in one direction or the other, from any grey either towards red, green, yellow or blue (or any intermediate shade of colour). Or, perhaps largely in virtue of the more primitive three-colour system, we may start from red and proceed to green by orange and yellow, or by carmine and violet. This mode of evolution of the colourless and colour series of sensation may help us to understand our difficulty in determining whether gradations in either series represent variations in quality or intensity. Quality and intensity appear to meet here; it becomes as difficult to be certain that, as we pass from red through shades of orange to yellow, we are passing through changes not of intensity but of quality, as it is difficult to be certain that, as we pass from black through shades of grey to white, we are passing through changes not of quality but of intensity. The same holds good for the evolution of our sensibility to warmth or coolness, although here (and possibly also in vision) the co-existence or the precedence of a more primitive 'spot' system of varying sensibility may have been psychically helpful. As Sherrington has said of the corresponding reflexes,—propriospinal reflexes normally fuse with other reflexes as adjuvant to them.

The close connexion we have traced between the colourless and the colour series of sensations is also shown in our ability to express the latter in terms of the former, *i.e.* to estimate in terms of greyness the *brightness* of a colour sensation. The *intensities*, on the other hand, of two very different colours we can only vaguely compare, either by their physiological action (so we may vaguely compare the intensities of two tones of very high and very low pitch), or by objectively imagining what amounts of colour there are in the respective stimuli (so we may vaguely compare the intensities of two different qualities of gustatory or olfactory sensation).

Our neurological considerations have led us to trace our experience of intensity back to a stage when it was possible only by a comparison of experiences corresponding to the neural patterns of two or more quite separate sense apparatus. At this first stage there were in question but two opposite qualities, two types of reaction,—one, *e.g.*, a heat reaction obtainable from scattered heat spots, the other a cold reaction obtainable from scattered cold spots, of varying sensitivity.

At this stage the gap between heat and cold sensations was not bridged.

In the second stage of sensibility, we find both quality and intensity far more advanced. Not only can intensity within a given sense apparatus be delicately graded, but also quality admits of further gradation by the simultaneous excitation of two or more elementary reactions in different degrees. Thus, given two colour qualities red and yellow, every shade of intermediate quality is obtainable by simultaneously presenting the two stimuli in different strengths.

In the third or last stage, quality is still further developed; it rises into 'modality.' It is no longer possible to pass from one quality (*e.g.* bitter, red, or warm) to another (*e.g.* sweet, green, or cool, respectively) without passing through a quality which belongs to neither. Such antagonistic qualities, 'modalities' as Helmholtz called them, are incopresentable; when simultaneously excited, they either 'neutralise' one another (giving rise to a new sensation) or show rivalry. What remains of intensity at this stage is a relic from the second stage in the evolution of sensibility, when we are dealing with one (or more) single centres in action, each starting from zero; whereas at this third stage we have one (or more) double centres in action, inclining to one or other side of a variable point of active equilibrium.

III.

The conclusion, to which we have been led, is that the ultimate difference between the quality and the intensity of sensation depends on the nature of the underlying reaction. Broadly speaking, when the reaction changes its fundamental type, it alters in quality and the sensation changes also in quality. So long as the reaction preserves its fundamental type, it can be said to vary only in quantity, and the sensation changes also in intensity.

In this sense sensual intensities are quantitative. But intensities are *not* quantitative in the sense that there is a moreness or lessness of excitation within the same anatomical area; for we have seen reason to believe that any given neural tissue, central or peripheral, follows the 'all or none' principle. Nor are intensities quantitative in the sense that the stronger sensation *contains* the weaker, as a large quantity may be said to contain a smaller; this is obviously contradicted by introspective experience. But in so far as they fail to answer to these requirements, it does not follow that sensual intensities are qualitative,

unless we merely mean that they resemble sensual qualities in behaving differently from quantities (which after all are not in the same sense sensual).

We cannot even say that intensities are quantitative, merely in the sense, and for the reason, that they show a moreness or lessness of the same sensory character. Otherwise we must term the differences in any series of colour sensations, ranging say from red to yellow, differences of intensity. We can speak of colour sensations as differing in moreness or lessness of hue; we can describe olfactory or auditory sensations as having more or less of a certain quality. But we do not in general confuse such variations in quality with variations in intensity, of the sensation.

Sensual intensity thus means, at bottom, *how much* reaction; sensual quality means *what type* of reaction. That is to say (if only we can legitimately translate neurological into psychological process) intensity and quality of sensation are dependent on variations of mental activity in one or other of two directions[1].

Now when the present activities of higher systems look back on the past activities of higher systems, we get a differentiation of the activity consciousness into consciousness of mental 'processes' or 'acts,' on the one hand, and of mental 'products' or 'contents' on the other. If the lowly sensual levels could but look back upon themselves, their activities would be similarly differentiated into 'acts' of sensing and 'contents' of sensation. But this is not possible. We experience 'acts' of apperception, thinking, willing, imagining, etc., in all of which the self is involved; but we have no experience of the 'act' of sensing. It is true that intensity and quality are *derived* from the activity of the sensual level. But they come to us as contents of consciousness, not merely by virtue of such lowly activity (itself undifferentiated into act and content), but also by virtue of our possession of higher and still higher forms of experience culminating in comparison, relation and abstraction. We are able to compare and to relate individual reactions differing in 'moreness' or 'lessness' or in 'type'; and thus finally we reach the abstract forms (the *Gestaltvorstellungen*) of intensity, quality and quantity generally[2].

[1] That these directions are fundamentally different is shown by the limitation of Weber's law to intensities.

[2] This is well shown in certain parietal cortical lesions, where our powers of unconscious comparison, relation and attention seem at fault, and in consequence not only the differential, but also the absolute, thresholds of sensations (as judged by the uniformity of correct answers) suffer, although sensibility itself may be relatively little affected (H. Head and G. Holmes, *Brain*, 1911–12, xxxiv. 102–254).

If pressed to give a definite answer to the question whether intensity differences are quantitative or qualitative, I decline to be bound to either horn of the dilemma. To me the question seems *mal posée*, since it is capable of every conceivable answer. Thus it is open for anyone to call a change in sensual intensity qualitative,—in so far as it is not directly measurable; in this sense, a change in any other sensual attribute (in quality, extensity or protensity) is also qualitative. Or a change in sensual intensity may as legitimately be called quantitative,—in so far as (even like changes in sensual quality as contrasted with sensual modality) it depends on 'more or less' of a given complex of reaction, and in so far as (even like changes in sensual quality or modality) it is indirectly capable of measurement in spatial and temporal terms based on sensual extensity, sensual protensity and movement. On the other hand, since changes in sensual intensity occur in a specific direction quite different from that of quality changes, they may be called non-qualitative. Indeed it is thus arguable that intensity differences are neither qualitative nor quantitative, but strictly *sui generis, i.e.* intensive.

(*Manuscript received* 20 *March*, 1913.)

The *British Journal of Psychology* is issued in parts at irregular intervals; four parts will (usually) constitute a volume of about 450 pages, Royal 8vo.

Papers for publication should be sent to Dr C. S. Myers, Great Shelford, Cambridge, or to Dr W. H. R. Rivers, St John's College, Cambridge.

Contributors receive twenty-five copies of their papers free. Additional copies may be had at cost price: these should be ordered when the final proof is returned.

The subscription price, payable in advance, is 15*s.* per volume (post-free); the price of single numbers will depend on the size of each number. Subscriptions may be sent to any Bookseller, or to the Cambridge University Press, Fetter Lane, London, E.C.