Fluctuations of Attention and After-images.

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Whether, in view of recent investigation, the fluctuations which occur in the perception of sense-stimuli under certain well-known conditions, should be ascribed to the attention, is at best an open question. It is a question, moreover, that may eventually be settled as much by the weight of theoretical considerations as by evidence of an experimental nature. Where so many factors both psychical and physical are involved, and especially where a slight change in any one of these factors is found to parallel the variations in consciousness, the value of such a factor is apt to be exaggerated.

That an explanation should be sought in the organic conditions, peripheral and central, is quite natural; and the task is simplified when, by the exclusion of this or that process, the number of factors can be reduced. But this requirement of method by no means obliges us to assume that the attention itself is not the seat of the fluctuations. Much less can the assumption be justified on the ground that to refer the fluctuations to the attention would land us in the region of the transcendental. For if it be admitted that the attention is an empirically given process or state, and that stimuli the perception of which demands a high or even a maximal strain of attention, in some way fluctuate, it is permissible to infer that the attention is the wavering factor. The inference may, or may not be, correct: it may even involve a well-known fallacy; but it certainly does not imply that the attention is a transcendental somewhat. It is hardly a proof of the transcendental character of anything to maintain that it undergoes

rather rapid changes which are perceived in our empirical consciousness.

It would, moreover, be quite in keeping with the doctrine of psycho-physical parallelism (so far as this may turn out to be valid) to hold that the fluctuations are psychical no less than physical. For if it were shown definitely that they are due to variations in this or that organic function, it might also be inferred that a corresponding psychical change, either directly or indirectly, would be the accompaniment. And if it were furthermore shown that the variations occurred in some central process, the presumption would be that the parallel psychical fluctuation took place in the attention rather than in any sensory process.

On the other hand, if it be held that the fluctuations are purely organic, whatever be their seat, then two alternatives are presented: either the attention is ruled out as a mere name, superfluous for purposes of explanation and simply indicative of a certain phase of sensation; or, attention is treated seriously as a transcendental. For it is acknowledged to be somehow a function of consciousness and yet it is placed beyond the reach of change, or at least beyond any share in the changes that appear in consciousness. There is, no doubt, a third possibility, namely, that one shall speak of »so-called fluctuations of the attention«. This is a safe course and is, to some extent, in vogue just now. It is to be hoped that no future investigator will feel obliged to transpose the terms and describe »fluctuations of the so-called attention«.

So far as the discussion has been limited to the organic functions, the main issue has been that concerning the seat of the fluctuations. The net result of the evidence is in favor of a central, rather than of a peripheral, origin. The fact that fluctuations occur whether the stimuli are visual, tactile or auditory, plainly suggests that some centre common to the different senses is the source of the fluctuations. To this must be added, for visual stimuli, the argument from exclusion. It has been shown[1]) that when the ciliary muscles are paralysed by the injection of atropine, the fluctuations continue. More satisfactory

1) Pace, Zur Frage der Schwankungen der Aufmerksamkeit u. s. w. Philos. Studien, VIII, S. 388.

evidence in the same direction has recently been brought forward by Slaughter[1]) who cites the case of a patient operated upon for cataract. After the removal of the lens, the fluctuations could still be noticed. Now, strictly interpreted, these facts show merely that the fluctuations do not depend upon the changes in accommodation and adaptation. If they have received a larger interpretation it is partly because the presumption in favor of a central origin already existed, and partly because, in the other senses, such partial elimination of function is difficult or impossible. But, for the eye, the »peripheral« includes the retina; and, so far as I am aware, the retinal conditions as affected by the fluctuations have not been investigated.

A third line of proof which has been followed in the later investigations, consists in showing that the fluctuations correspond to changes in certain organic functions such as respiration and circulation[2]). The results thus obtained are obviously of great importance; and they are certainly open to various interpretations. In the first place, if the coincidence were in all respects perfect, there would still remain the problem as to the connection between the centres for these organic functions and the centre, whatever it may be, which is directly concerned in the conscious fluctuations. Slaughter, in his criticism of Lehmann, very correctly says: »But that the activity of the muscles of respiration should cause a greater flow of blood to the brain does not appear from this process of reasoning«. Similarly, we may say that Slaughtef's own conclusion as to the reinforcement of the activity of the nerve cell due to variations in blood pressure is not satisfactory so long as the reinforcement is considered as central only. For, on this view, it would be difficult to explain the fact that changes in the peripheral conditions, independent of any physiological rhythm, may cause a return of the stimulus which has vanished from consciousness. A slight movement, for instance, of a faint spot

1) Slaughter, The Fluctuations of the Attention etc. Amer. Journ. of Psychol., XII, p. 313.

2) Slaughter, l. c.; Mac Dougall, The Physical Characteristics of Attention. Psychol. Review, III, p. 158. Taylor, The effect of certain stimuli upon the attention wave. Amer. Journ. of Psychol., XII, p. 335.

which has momentarily disappeared from the visual field, will bring it back immediately. We cannot suppose that the physiological rhythms are, in this case, suspended or suddenly changed. Nor have we any proof that quick voluntary closing of the eyes, which, as Münsterberg has shown, prevents fluctuation, must have this effect by interfering with the rhythmic reinforcement of the nerve cells rather than by affecting the peripheral conditions.

In other words, the most convincing argument for the central origin of these fluctuations leaves, so far as further explanation is concerned, two possibilities. First, we may say that the conditions in the peripheral organ and in the afferent paths remain, during the entire series of fluctuations, unchanged, or so slightly changed that their respective functions continue. The stimulus is then transmitted steadily to the centre, e. g. to the cortical cells. Here, for a given interval, it produces its effect and appears in consciousness; but, in the next interval, owing to the reduced activity of the centre, the incoming stimulus is blocked or its effect is so minimized that it is not perceived. Second, we may say that changes take place simultaneously in the peripheral organ and in the brain, in such a way that the fluctuations are at once central and peripheral. This much was stated in my former article on the subject. The statement was vague; but, at the time, the evidence did not justify a more definite statement. It was, however, in accord with a view which has gained favor among physiologists, namely, that the distinction between peripheral functions and central functions should not be carried to extremes. If, instead of speaking of retinal changes as opposed to central changes, we should speak of changes in the cerebro-retinal mechanism, and employ a corresponding terminology for the other centro-sensory connections, we should probably be led to make greater allowance for the structural and functional differences in the several organs of sense. In the experiments which have so far been published, sufficient consideration has not been shown for the differences that present themselves as soon as we look into details. What this neglect implies will appear from a comparison between experiments on visual sensations and experiments on auditory sensations. For the most part, and even in the latest investigations, Masson's disk and the ticking watch have been used by all observers. How far they differ is easily

pointed out. The gray rings have a positive field or a background of white; the watch-tick has a background of silence. The rings, so long as they last, are constant stimuli; the ticks are intermittent. Each ring gets its ring-shape, not from a physical process or series, but from a peculiarity of the retina — i. e. from the persistence of impressions after the stimulation has ceased; whereas the sounds from the watch, however faint they may become, remain distinct.

These minor peculiarities may seem of little consequence in view of the significant fact that both visual and auditory perceptions fluctuate. And if all the facts pointed unambiguously to the central origin of the fluctuations, these details would be secondary. But they deserve more consideration in the sifting of evidence, especially if we assume that the fluctuations represent the interaction of the brain and the peripheral organ. It may be that the final explanation will get its chief support from these very peculiarities.

The present paper attempts to deal with visual fluctuations only. These, as a rule, are studied in series, each series comprising a more or less considerable number of fluctuations. It is to be noted, however, that there is no generally accepted time-limit for each series. Still, on the other hand, when a single record is very long, it is to be expected that the subjective conditions will vary to some extent. The strain implied is not, perhaps, severe upon the organs of hearing and touch; but for the eye it is considerable. Obviously, then, averages as to the length of the phases of visibility and the phases of invisibility, must be taken with some caution. The retina is not in the same condition at the close of a series which lasts seven or eight minutes, as it was at the beginning. Similarly, it is difficult to compare an entire fluctuation which occurs early in the series with another which occurs toward the end. We cannot say that the relation between the visible phase and the invisible phase has, in both instances, the same value. For, in any series, the number of fluctuations represents also the length of time during which the lateral retina has been steadily responding to stimulation while the central portions of the retina, during the same period, have, so far as perception can attest, passed through alternate intervals of activity and repose. While, therefore, the study of whole series is necessary when the periodicity of the fluctuations has to be determined, the exami-

nation of each phase may furnish at least a suggestion as to the causal relations. It may also be a step towards the final explanation of certain peculiarities which have been noticed by different observers and which, apparently, make it doubtful whether the fluctuations occur in regular periods.

In the selection of stimulus and apparatus, Masson's disk would naturally have had the preference, as its use would have made possible a direct comparison with results previously obtained. Several difficulties, however, are involved in its use when single phases are to be examined. Whatever mechanism be employed for its rotation, — clock-work, electric motor, water-power — its rate of rotation varies; and this means that the gray rings may be at one moment just at the threshold and, at the next moment, considerably above the threshold. Again, it would be extremely difficult to change the value of any given ring without affecting the value both of the other rings and of the entire field as shown upon the disk. Finally, it is questionable whether the presence of several rings in the field of vision is a help when the observer is required to note the disappearance and reappearance of the one ring which is, at the outset, judged to be barely visible. The distractions which inevitably arise from the rotating apparatus — usually in the form of sound and sometimes in the form of movement —, may be passed over here. Both the sound and the perceptible movement are subject to variation.

These objections have more force in view of the particular visual process which was intended for observation, i. e. the retinal variation. With the Masson disk, it is not easy to determine how far the retina, in each phase, either of visibility or of invisibility, may be fatigued. When a gray ring disappears, or when several rings disappear, as usually happens, their place in the field is taken by a sector, more or less regular in shape, that differs in brightness but little, if at all, form the general surface of the disk. There is no trace of an after-image. Nor is it possible to get the after-image, unless that particular portion of the field which fluctuates can be eliminated while the remaining portions of the field are kept constant.

To meet these requirements, the following arrangement was selected: A semi-transparent porcelain plaque was fixed in the side of a box

which contained a Welsbach gas burner. Between this burner and the plaque was inserted a plate of ground glass lined with paper. Between the paper and the porcelain plaque was a sheet of card-board with a horizontal slit 50×5 mm. Outside the box and at an angle of 45^{o} to the plaque was a second Welsbach light. This furnished the illumination for the field. By increasing or diminishing the distance of the outer burner from the plaque, it was easy to reduce or to increase the brightness of the field and consequently to regulate the relative intensity of the limited area formed by the light which came through the slit. Immediately behind the sheet of card-board was a movable screen with an opening large enough to permit the passage of light through the slit. This screen was held in position, the opening opposite the slit, by an electro-magnet. In the circuit controlling the magnet, a key was inserted which was under the hand of the observer. A slight pressure on the key sufficed to break the current and to drop the screen, thereby cutting off the light which came through the slit. The observer sat a distance of 1 m from the surface of the porcelain plaque. The entire apparatus was located in a dark-room in order to avoid the varying effects of daylight.

With this arrangement, it was possible to have either a band of light or a shadow for the stimulus. In place of the band, a spot of light of any desirable shape could be used. The size, position and brightness of the streak or spot could be readily altered by slight changes in the slit and the screens; and these changes could be made at any moment during the phase of visibility or during the phase of invisibility.

Preliminary experiments showed that the fluctuations of the luminous band are as easily perceived as those of the gray ring on the Masson disk. With the latter, it is sometimes difficult to observe the variations in the particular portion of the ring that one fixates, because the other portions of the ring and a number of other rings remain present to indirect vision. But the band of light, as it is the only area perceptibly different from the rest of the field, can be observed without any possibility of such distraction. It is, in this respect, equivalent to the single gray ring that would appear if one spot only were marked upon the disk, instead of a series of

spots, as is usually the case. The resemblance, of course, becomes closer when the slit is given a circular or semi-circular form.

The first series of experiments had for its object the study of the retinal conditions at the moment of disappearance. The method adopted was as follows: at a signal from the experimenter, the observer fixated the luminous band upon the plaque, allowed it to vanish and return, and finally, as it disappeared for the second time, released the screen from the supporting magnet. The second phase of invisibility was selected because it is much freer than the first from complications due to the effort at adapting and accommodating the eye for a portion of the field which is but slightly different from the rest. Any of the subsequent phases in a series might be chosen, but allowance should be made for the (presumably) progressive change in the condition of the retina. Whether this change takes place at the same rate in each and every series, is not yet determined.

Immediately after the fall of the screen, an after-image of the band appears in the place of the band upon the plaque, the rest of the field remaining apparently unchanged. The characteristics of the after-image may be noted here: a) for a luminous band it is dark, for a shadow-band it is bright, and for a spot or band of colored light it appears in the complementary color; b) it is strongest when it first appears and diminishes gradually until it can no longer be discerned against the white back-ground; c) there is no sign of fluctuation in the after-image itself, that is to say, it does not return once it has disappeared.

The essential feature lies in the fact that when the stimulus, which has ceased to be visible, is cut off, the after-image appears. This suggests, on the general theory of the after-image, that the disappearance of the primary stimulus, whatever be its cause, is accompanied by a decided alteration in the retinal condition, and, since the after-image is negative or complementary, it would indicate that the retina, at the moment of disappearance, is exhausted or fatigued. Under these conditions of the visual organ, the stimulus, though it persist, fails of its effect.

It must, however, be granted that the appearance of the after-image at this one point, that is, at the moment when the stimulus has just vanished, does not of itself furnish a parallel to the whole

fluctuation. For it gives us no information as to any change that may have previously occured in the retina, nor does it permit a direct inference as to what takes place during the phase of invisibility under ordinary conditions. Each fluctuation may be said to begin when the primary stimulus is first perceived and to end when the stimulus, after an interval of invisibility, returns to perception. What sort of curve will most accurately represent these changes is not known. Münsterberg, it is true, claimed that the records inscribed directly upon the kymograph drum by his subjects, were correct copies of the gradually sinking perception. This surely required a nice adjustment of the sensory and the motor processes. But, admitting the claim, we are as far as ever from knowing what the form of the curve is after the disappearance of the stimulus. It may drop at once to a low level and run on horizontally until it emerges, with a sudden rise, above the threshold; and, in this case, it would be fairly represented by the usual tracings. Or it may be more gradual in both its rising and its falling phases.

The difficulty will be somewhat lessened, if we can find an answer to these questions: Does the retinal fatigue come on gradually from the beginning of the fluctuation up to the moment of disappearance? Does it gradually pass off from this moment up to the moment of reappearance? And, consequently, does the after-image which may be observed at the moment of disappearance, represent the maximum of retinal fatigue?

One observation which was made in the course of our experiments, suggests an affirmative answer to these questions. If, instead of cutting off the light-band at the beginning of the phase of invisibility, we let the fluctuation take its course until the moment of reappearance and then drop the screen, no after-image, or at most a barely perceptible one, is seen. If any image at all appears, it vanishes immediately. This fact would seem to show that, at the close of the fluctuation, there is little or no trace of fatigue in that portion of the retina which receives its stimulation from the streak of light.

When, in addition, this terminal stage is compared with that which we find at the moment of disappearance, the difference is significant. In one case, there is a strong after-image which persists for an appreciable time after the stimulus has ceased to act; in the

other, though the stimulus, objectively regarded, has been continuously acting, there is hardly a vestige of its effect. An allowable inference is that, during the phase of invisibility, the retinal condition has undergone a change, and this change, on the general theory, may be interpreted as a restoration. So far as the after-image is a symptom of exhaustion, we may say that the exhaustion is greater at the moment of disappearance and that it reaches a minimum at the moment of reappearance.

Another comparison, on the same basis, is possible. The moment of reappearance, which marks the close of one fluctuation, is also the initial point in the next fluctuation. Now we cannot assume that the retina is in absolutely the same condition at every one of these initial points; for, though the stimulus is of equal intensity all the way through, we are unable to say whether the sensation it produces or the difference between that and the sensation produced by the larger field, is constant. The fact that the light-band is visible at the beginning of fluctuation b does not necessarily imply that its brightness subjectively considered, is the same as its brightness at the beginning of fluctuation a: and much less can we conclude that it is still the same in fluctuations x and y. The intervening phases of visibility and invisibility render a comparison between one initial point and another impossible or worthless. Similarly, we have no means of ascertaining whether the after-image, if it appear at all, at the beginning of one fluctuation is of exactly the same quality and strength as that which is seen at the beginning of another fluctuation. Still, since we cannot get the after-image at the beginning and at the end of one and the same fluctuation, we may reasonably assume that the conditions at both points are relatively or approximately the same; for at both points the stimulus has just become, or is just becoming, visible.

On this assumption, however, it is clear that we have the after-image determined for these three moments: the beginning of the fluctuation, the moment of disappearance, and the end of the fluctuation. At the two extremes it is at its lowest value, while, at the critical point, the vanishing of the stimulus, it is very strong. And this would point quite naturally to the conclusion that it gradually increases during the phase of visibility, attains its maximal value at

the moment of disappearance and then decreases to the moment of reappearance. So far, therefore, as the retinal condition is concerned, we seem justified in saying that it is, in the first phase, one of increasing fatigue and, in the second phase, one of diminishing fatigue.

This still leaves room for the question whether, in either phase, there may not be one or more minor variations. Just as we see in many plethysmographic tracings, certain slight oscillations within the larger sweep of, e. g., the volume curve, so we might suspect that secondary changes, on a much smaller scale, of course, would occur in the rising or in the falling portion of this fatigue-curve. It is conceivable, in other words, that the increase in strength of the after-image is directly proportional to the length of the period of stimulation; and, conversely, that its decrease is directly in proportion to the period of invisibility. Or, it is possible that neither phase is a function of the time only — that other factors have to be considered, the effect of which would tend to make the curve, in both phases, more complex.

Reference has already been made to the fact that the conditions of stimulation are not the same in all portions of the retina: and it is known that the sensibility to brightness varies according to the portion that is stimulated. Although, for the purposes of experiment, the modifications of the central retina have been considered apart from any changes that may occur at the same time in the lateral portions, it is likely that one set of changes is influenced by the other. While the fatigue-effect in the central portion is alternately rising and falling, as the fluctuations proceed, there must be a similar effect, though not perceptible, in all the other portions. Whether this also is a periodical process is a question that cannot be settled on evidence from perception, since the larger field, during a series of fluctuations, does not, apparently, vary in brightness.

That the fluctuations depend not only upon the absolute value of the stimulus but also upon its relative value, has been shown by several investigators. Marbe[1]) found that the fluctuations continue when the difference in intensity between the ring and the field

1) Marbe, Die Schwankungen der Gesichtsempfindungen. Philos. Studien, VIII, S. 615.

increases to a certain point above the threshold; but that, beyond this point, they cease. He also suggested that fatigue of some sort exerts an influence; but the special character or location of this fatigue he did not determine. His results, it would seem, might be explained on the hypothesis that the retina is the seat of fatigue. A relatively weak stimulus will not produce its full effect upon an organ that is more or less exhausted; whereas a stronger stimulus will be felt in spite of fatigue, even though the fatigue which it causes be more complete than that which is due to weaker stimulation.

The results obtained by Wiersma[1]) offer, at first sight, greater difficulty. He found that as the difference between stimulus and field increased, the average length of the phase of invisibility diminished, so that, in his own case, it became zero when the proportional intensity was 2,5. This would agree, in general, with Marbe's results. But if the fluctuations are ascribed to retinal fatigue, it is not so easy to see why a stimulus differing but slightly from the field, should remain longer out of perception than one which is relatively stronger. Wiersma does not indicate the corresponding phases of visibility, and consequently does not compare the phases in regard to their duration. It is to be noted, however, that the length of the invisible phase depends upon the proportion which the primary stimulus bears, in point of intensity, to the condition which it has produced in the retina before it disappears. A comparatively faint stimulus may require a considerable time to produce a perceptible impression upon the retina that is fatigued even to a small degree; and a stronger stimulus may act more rapidly, though it has to overcome more complete fatigue.

Finally, those changes in other functions should be taken into account which accompany the fluctuating retinal condition. Heinrich[2]) found that accommodation ceases when the attention is directed towards other than visual impressions. Hence he concludes, with Münsterberg, that the fatigue which brings about the fluctuation

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1) Wiersma, Untersuchungen über die sogenannten Aufmerksamkeitsschwankungen. Zeitschr. f. Psych. u. Phys., XXVI, S. 168.

2) Heinrich, Die Aufmerksamkeit und die Funktion der Sinnesorgane. Zeitschr. f. Psych. u. Phys., Bd. IX, S. 342.

must be muscular. The more obvious inference would be that the origin of the fluctuations is central and that the changes in accommodation result from those processes which correspond to the changes in the attention. It would seem, at all events, that the accommodation apparatus is to some extent controlled by the direction of the attention.

In the fluctuations as they are usually observed, there is no voluntary change in the direction of the attention: it is not directed to other sorts of stimuli than the visual which are acting upon the sense-organ. Nevertheless, it must undergo change of some kind when the stimulus disappears. It cannot be, in all respects, the same function in the absence of the stimulus that it is in presence of the stimulus. When the gray ring or band of light vanishes, the attention is divided between the memory-image of that which has disappeared and the impression actually received from the general field. Again, while it may be said that the attitude of the attention in both phases of each fluctuation is one of expectancy, it is also true that the term of this expectation varies: in one phase, the observer awaits the disappearance of the stimulus, in the other, he looks for the reappearance of the stimulus. In all probability, this variation of the attention must affect, though in a small degree, the processes of accommodation.

The entire series of changes, on this hypothesis, might thus be described: observation of a stimulus that differs but little from the larger field, produces a condition of fatigue in the retina, the degree of which is determined by the relative excitation of the central and the lateral regions. As a consequence of this fatigue, the stimulus under direct observation disappears. Its disappearance involves central changes which affect the process of attention. The variation, in content and in function, to which the attention is subjected, influences the accommodation-process. This, in turn, must produce some variation in the effect of the stimulus upon the visual organ, more especially its effect upon the retina. Reappearance, therefore, of the stimulus, implies not only that a particular portion of the retina has recovered from its fatigue, but also that this recuperation is facilitated or impeded by the changes which occur in the accommodation-process.

This would explain, partially, the interaction of the central and

peripheral functions. It would also do away with the necessity of treating the attention as a transcendental activity.

There still remain for explanation those peculiarities which have been observed e. g. in the perception of tones. Granting that the auditory sensations fluctuate in some cases and in others show no fluctuation, we are not thereby compelled to infer that the attention is free from fluctuation. The anatomical and physiological relations are obviously different for the several sorts of sensation. Hence, while we admit that the attention is conditioned by changes in the brain centres, we may still hold that its constancy or variability depends upon the particular relations, in structure and in function, which exist between the centre and the several organs of sense.