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ART. XI.—*On the Observation of Sudden Phenomena;* by S. P. LANGLEY.

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BY a sudden phenomenon is here meant one of that large class where the occurrence is awaited without the observer's previous knowledge of its exact instant, and of which familiar examples may be found in the bursting of a rocket, the appearance of a meteor, or the emergence of a star from behind the moon. A great part of all the phenomena of daily life, as well as of scientific observation, are of this kind, though the importance of a special instance of another class, (I refer to the gradual and foreseen approach of a star to a wire), has drawn to this latter such particular attention that we are apt to think of it only when "personal error" is in question.

When in an observatory, we study the means taken to record the precise time of the transit of a star, we find that the precision of modern apparatus has reduced the error which we may expect in almost any part of the mechanism to an extremely minute amount, which may be calculated to the fractional part of the one hundredth of a second. I say "almost" for, as we are all aware, there is one notable exception, at least until photography can be made to intervene. The human brain and nerves, and behind these the inscrutable processes of the will, themselves form an inevitable link in the chain of apparatus of observation, and here an error may and does arise enormously greater than that of all the rest put together.

We all know that this error varies with the individual and the occasion. It is most constant in the experienced observer, but even in his case it varies with the daily accidents of the human organism, and even with him it is presumably constant only for the particular observation to which the experience applies. There is not even a presumption, I think, that the personal equation belonging to an experienced transit observer would apply to the same person's notation of the occultation or emergence of a star, and still less, if possible, to any phenomenon outside his ordinary professional experience; for we must, of course, recognize that we carry this fallibility with us in every act of life, and that it is just as present when we attempt to determine the instant at which a race horse passes the winning post, as when we seek to note the particular hundredth of a second at which a star passes the wire.

The very words "personal equation" imply that the errors due to this fallibility can be ascertained and allowed for, and may lead us to think (if we think carelessly) that there is a personal equation always ascertainable; whereas, as we in fact know, it is only possible to apply the correction where long habit has settled the amount of error to be expected with regard to some one special phenomenon.

The number of devices for obtaining and correcting the personal equation, even in the special case of meridian observation, is, as those who have studied the subject know, surprisingly great. I think I have myself examined more than fifty such, and with hardly an exception they all exhibit variations on one idea—the idea, that is, that the error must have been committed *first;* the committing of the error being assumed to be an inevitable necessity for which subsequent correction is to be made.

I have thought, then, that it might be interesting if I were to ask you to consider with me what may seem at first the somewhat paradoxical suggestion, that means may be found by which any individual, skilled or ignorant, may make, not only meridian observations, but an observation of any sudden visible event, of whatsoever nature, so accurately that we need apply no correction, because the precision may be, if not absolute, at least such that no correction will in ordinary practice be needed. I may deceive myself in thinking that what I have to suggest involves a novel idea, but I am led to suppose so from the fact that I have met no application of it in a somewhat extended reading on this point.

Let me first remark that while such error as that in question doubtless belongs to all the senses in some degree, we are at this moment considering it in connection with the sense of sight only.

When we see anytbing in motion (let us suppose for instance a passing train on the railroad) we have the well-known facts that—

First. An instantaneous photograph is made by the optic lens upon the retina, there being a picture formed there, which is perfectly distinct, but which fades out upon the retinal plate in from one-tenth to one-quarter of a second, while the perception of this image is under ordinary circumstances * sensibly instantaneous; but—

Second. Nerves convey the distinct impression of every part of the picture to the brain, and it is here, if we have to act on this impression, that a certain time is lost, not only in the carrying of the message along one set of nerves and the bringing back the answer on the other, but in the decision that is being made by that unknown and inner self, which appears to us to exert here a more or less conscious act of will.

In the case of a sudden and startling event, the time elapsed may be almost indefinitely great; and in some cases, probably several entire seconds may pass without the consciousness of the observer. A very imperfectly appreciated interval must occur in all cases, for what we have just said applies to every event of our daily lives, and the professional observation is only a particular instance of it.

Now, I ask your attention to the practical instantaneity of the *formation* of this visual picture, which is known to be obtained where the duration of the phenomenon to be observed is much less than the one thousand-millionth of a second, while where we have every reason to believe that the actual formation of the image on the retina under known ordinary conditions requires a time of like order.

We may say, then, that the casting of a picture on the retina is instantaneous. It is its fading out that requires time, and it is while this fading out takes place, and even long after it, that the work of perception, decision, and action is going on behind the retinal curtain in the chambers of the brain. Notice then, that while to determine *when* a phenomenon occurs may require, under some circumstances, several seconds, and under all ordinary circumstances a notable fraction of a second, to determine *where* it occurs requires (sensibly) no time at all, for one single impression remains on the retina

* The writer's observations (this Journal, Nov., 1888) show that appreciable time is required for perception of the retinal impression, with certain excessively faint lights; but these are not here in question.

long enough to obtain full recognition and to be reproduced by processes of memory.

I can make my meaning clearer, perhaps, by using the same specific instance as before. Let us suppose that an accident to a passenger on the passing train is the phenomenon, the time of whose occurrence is to be noted, and that this accident is seen from a room in which there are two windows looking on the track. We must have seen the accident, if it be instantaneous, either through the first window or the second. If we had been led to anticipate that we should be called upon to say through which window we saw it, I think we may all admit that there would be no discrepancy on this point between different observers, for in this case we are considering only the element of position, and the element of time does not directly enter at all, so that observers in the same position who had been bidden to note through which window they saw it would all agree on this point.

Now a connection can here obviously be established between the place and the time, from which to infer the latter, if we are granted the knowledge of two facts: the time at which the carriage could have first come into view from the first window, and the time at which it must have passed out of view behind the second; for if we suppose the speed of the train to have been uniform, we have the means of deciding the fraction of the time when we know the fraction of space. Here then, as in the case of a common clock or chronograph, or any device where time and space are proportional, we can infer the latter from the former; only let it be observed that we here need no recording apparatus. What we use is the memory of where the event occurred; in other words, we recall the impression on the retinal screen and have no need to bring into use what we may call the time-perception apparatus of the brain which lies behind it; *nor do we in fact need that the object of our observation shall be really in motion, but only that it shall be made to appear to be so.*

This last point is all important, and what I ask your attention to is an experiment heretofore, I think, untried, and which is perhaps a novel application of the fundamental horological idea that time and space must be made proportional, for it seems to me it must be theoretically possible, not only in the case of the clock or the chronograph, but always, to so connect the former with the latter that the essential task of the time observer is only to say *where* any visible event apparently occurred, and then let some mechanism outside of himself say when.

That at least is the idea, and if it has, as I hope, been clearly apprehended by you, I will now ask your attention to a working plan for carrying it out. Numerous different devices have been under my consideration. I will take one which is primarily designed for the observation of any celestial phenomenon, though it could very well be adapted to terrestrial ones; and in order to fix our ideas, I will suppose that we have an event which we know the approximate time of, but which may burst upon us at some fraction of a second which we want to determine. I will assume (merely to fix our thoughts) that we wish to note the time at which a star emerges from behind the dark body of the moon, with an accuracy which ensures us that we have not made an error so great as one-twentieth of a second.

You see I hold in my hand a peculiar eye-piece, which has been made to observe this or any other terrestrial or celestial phenomenon of sudden occurrence. It can also be used for meridian observation, but its special field seems to lie in noting an event where no ordinary correction for personal equation is applicable. This event may be anything celestial or terrestrial, from the entrance of Venus on the disc of the sun, to the explosion of a mine; but, for the purpose of illustration merely, let us take it to be the sudden appearance of the star.

On looking into the telescope we see, in the first place, two prominent wires crossing each other at right angles, dividing the field of view into four quadrants. Now, by a simple mechanism, which I shall shortly explain, any object that our telescope is directed on—any fixed star for example—seems to be revolving in the field, passing successively through the first, second, third and fourth quadrants. If the star is hidden the mechanism is working just the same, and when the star appears it must evidently first be seen in some particular one of these four quadrants, and experience shows that we shall have no difficulty in telling in which one. The mechanism itself has recorded for us by an electric contact the limiting instant between which it is possible to see the beginning and the end of the cycle during which revolution may be supposed to be made. It is not necessary that this cycle should last just a second; but supposing it (still for illustration only) to be a second, if it was seen in the first quadrant, it was seen in the first quarter of the second; if it was seen in the second quadrant; some time in the second quarter of the second; in the third, in the third quarter; in the fourth, in the final quarter. All that we have to do in this case is to know in which second it occurred; for the quarter of a second we may say is noted for us by the purely automatic action of the optic lens and retina, since the first image on the retina must be that of the star as seen in some particular one of the four quadrants.

Going a little farther, we will now suppose each of the four quadrants, which in turn correspond to quarter seconds, to be divided into five parts, so that the whole circle is divided into twenty. All the observer has to say is in which quadrant and in which subdivision of the quadrant the star appears, to say in which twentieth of the second (or other brief cycle) it emerged.

The reticule I have just described is fixed in the focus of the eye-piece and does not revolve. What does revolve is a minute double prism of total reflection just before the reticule, the middle of whose reflecting face lies in the optical axis, and by whose means this axis is twice broken at a right angle, so that when the telescope is directed on a star the image of the star is not seen at the center of the field, but on one side of it. If the prism is revolved, the star must appear to revolve in a circle whose radius is nearly that of the side of the prism.

The little prism is turned by a small piece of watch-work, but it is not at all necessary that this should be exact, since all we demand is that the rate shall be constant during a second or so—a condition easily secured with the most ordinary mechanism.

The sketch and the apparatus exhibited sufficiently indicate, I think, the simple means by which this is brought about.

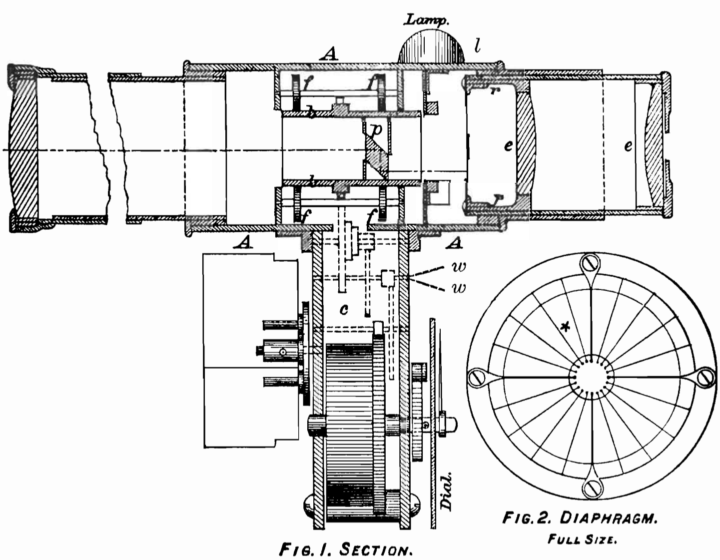

FIG. 1. SECTION.
½ FULL SIZE

FIG. 2. DIAPHRAGM.
FULL SIZE.

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Figure 1 is a section one-half full size. A A is the outer tube, which can be fitted, if desired, into the eye end of a telescope. *b b* is the inner tube, resting on friction wheels *f f*, revolved by the clock-work *c c* about once a second, and recording the time at which a key in the observer's hand may be pressed to indicate the particular second. This record may be made electrically by the wires *w w* on a chronograph, or more simply and directly on a little attached dial like that of a recording stop-watch.

p p is the prism of double total reflection, *r r* is the position of the fixed reticule (shown independently as it appears to the observer and of full size in figure 2).

e e are the lenses of a positive eye-piece. The lamp is for giving wire illumination, if desired, when a telescope is employed.

Field illumination is readily obtained otherwise by making the diaphragm in which the prism *p p* is set of translucent material.

Finally it should be remarked that on removing the eye-piece events may be observed without using any telescope. In this, its simplest form, the chronograph may also be dispensed with, and the record of the second made on an attached stop-watch dial and the instrument may thus carry its own complete recording apparatus and be more portable than an ordinary opera-glass.

I have not found opportunity to use this apparatus on the moon or occultations, but I have, what is possibly more to the purpose now, tried it on an artificial star, the instant of whose appearance and disappearance was independently recorded on a chronograph by an electrical contact. Different observers, entirely unskilled and ignorant in the use of the instrument, were invited to look into it and to determine the quadrant and section in which the star appeared and disappeared.

I have momentarily mislaid my notes containing in full detail the results of four observers but I can summarize them approximately by saying that after being simply told what to note; the average probable error (that is, for any single observation) was rather less than one-twentieth of a second. As far as I can judge from the limited number of instances, the younger the observer the better the observation. The worst of the observers (the oldest), however, had a probable error considerably less than one-tenth of a second; the youngest, a probable error of something like one-fortieth of a second, which implies, as you will observe, that he not only readily noted the quadrant and the subdivisions of the quadrant, but, also as a rule, even the part of the subdivision in which the star was first seen. None of these observers had so much as one hour's practice.

The plan in question is easily adapted to meridian observations, but for these we have numerous plans for correcting personal equation, and the writer may also direct attention to the fact of the existence of a distinct device (this Journal, July, 1877) which practically eliminates the personal error in the very act of a transit observation. It is more elaborate than the present one, which is so simple that it may be useful even in longitude work with the transit, though its proper field seems to be the observation of sudden events; but, to whatever purpose it is applied, I beg leave to present it to your attention less for any interest that attaches to the particular mechanism exhibited than as an illustration of a principle which seems to me to have not been employed before, at least in this way, and which I trust may have useful applications.