

AN ELECTRO-MECHANICAL CHRONOSCOPE

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Provided that certain changes are made in its electro-magnets and that it is skilfully handled the most reliable chronoscope known is the Hipp chronoscope. But for want of skilful handling it is not unusual to see a dust-coated copy of the instrument stored away in a museum for apparatus that looks nice but is rarely used. Nevertheless the Hipp deserves more respect. After having invested in the costly piece with its control-hammer additional, the experimenter should fit it for service by rewinding its electro-magnets with coarser wire, by insuring a steady current with a good gravity battery of 12 cells, by discarding the control-hammer and employing some type of gravity chronometer for control tests.¹ It is the fineness with which the instrument is designed to record times that makes it unsatisfactory in inexperienced hands but that insures reliability when correctly operated.

Even after the corrections indicated are made the instrument must be constantly watched and tested, as a fluctuation of the current or a slight change in the adjustment of the delicate parts of the apparatus may produce a chronoscope variation that will entirely obscure the variations in reaction time. The instrument responds to all irregularities and is never popular when operated in a hit and miss manner. Many attempts have been made to devise a simpler chronoscope than the Hipp. The special aim has been to construct one that will eliminate the constant care of control and minimize

¹ The manner of making these changes and the reasons for them may be found in the *National Academy of Sciences*, 7, 397 ff., 1893 (Cattell and Dolley). After correcting the instrument as indicated these writers found average variable errors for seven series of ten single tests of the chronoscope as follows: 0.96, 0.8, 0.42, 0.4, 0.64, 0.64, and 0.56 σ . Using the same instrument corrected by Cattell the present writer in making several thousand reaction tests found an average variation of the chronoscope in control tests of about 1 σ ("Reaction to Multiple Stimuli," *Archives of Psychology*, No. 25, 8, 1912).

the possibility of getting out of adjustment. The simplest chronoscope is one so designed as to harness the force of gravity for marking off units of space that may be given time values. This arrangement eliminates delicate clockwork propelling devices and reduces the number of adjustable parts three fourths. Even after the chronoscope is reduced to its simplest terms three difficult problems remain, First, to devise a reliable chronoscope release; Second, to construct a sufficiently accurate reaction recorder, and, Third, the greatest problem of all, *to put down a chronometric scale that is trustworthy.*

The chronoscope described in this article consists of a

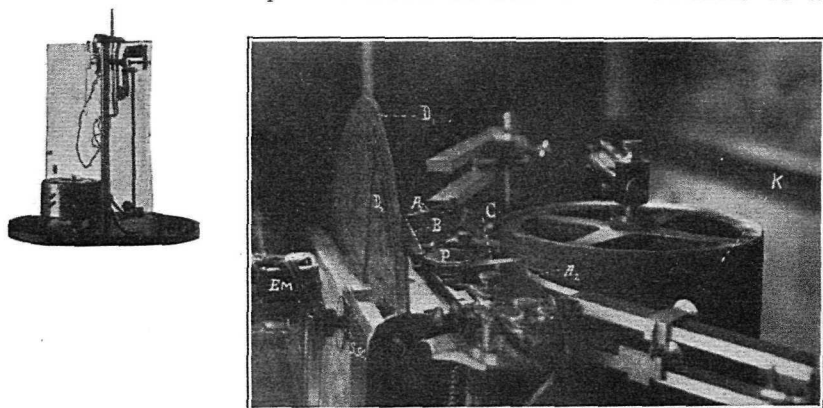


FIG. 1.

disc compounded of two adjustable parts (D_1 and D_2 , Fig. 1), which are two circular planes of $1/16$ in. brass, 11.5 in. in diameter, with a concentric semicircle of each having a radius of 4.75 in. cut away, leaving in each case a marginal area 1 in. in width. One of the discs is constant with respect to a pendulum attached to their common axis while the other is adjustable to allow the various apertures of a tachistoscopic attachment described later in this article. These discs are held rigidly together by a set-screw (*S. sc.*, Fig. 2) and rock with the vibrating pendulum. In making a chronometric reading with the electrical arrangement the initial position of the pendulum, *i. e.*, horizontal, is maintained by the force

of an electro-magnet (EM , Fig. 2) upon the armature (A_2) carried near the base of the pendulum whose socket ($P.S.$) is shown. To minimize friction the shaft carrying the discs and the pendulum has cone bearings (Fig. 2). The pendulum weights are two cylinders of lead set in brass. The gross relations of the various parts of the apparatus are shown in the upper left corner of Fig. 1, a lateral photograph of the apparatus.

Fig. 2 is a diagram showing the details of the chronoscope

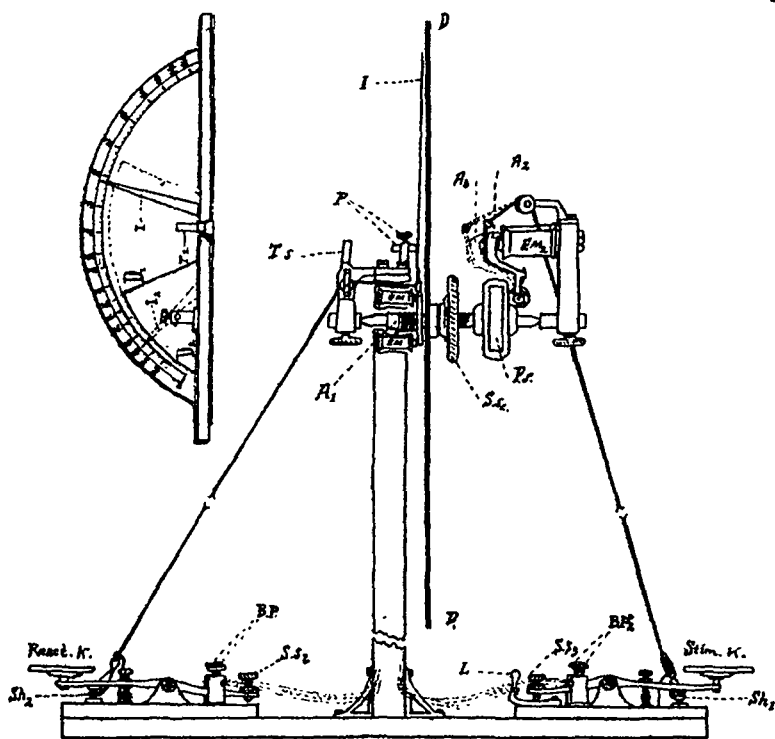


FIG. 2.

arranged for both *mechanical* and *electrical* stimulus key and reaction key. The figure shows the apparatus set for *mechanical* operation. Sh_1 is a copper shoe held firmly between the contact points of a stimulus key by means of the insertion of the inclined surface of the lever, L , and the resiliency of the key shaft, supporting by means of a cord over a

pulley the armature, A_2 , which holds the pendulum in the initial horizontal position. Sh_2 is likewise a copper shoe between the contact points of the reaction key held firmly by the reagent's finger upon the button, and holding the armature (A_1) of the reaction index to its initial position against the arm of the post, P . The armature, A_1 , to which the reaction index (I) is attached moves freely upon the spindle bearing the chronoscope disc, and by means of a coiled spring flies against the disc when release is made and is carried with it allowing the index pointer to escape the arm of the post, P , by which it is held during the reaction interval.¹ When the pendulum is in the initial position the index point rests upon the zero point of the chronometric scale. The index may be thrown back to the zero point from any position on the scale by pulling upon the cord to which Sh_2 is fastened.

When the stimulus lever (L) is suddenly pulled the stimulus hammer ($S.S_2$) by virtue of the resilient shaft which carries it and the rebound of the strong coiled spring near its fulcrum strikes the solid metallic base a blow emitting a sound which serves as a stimulus, and whose intensity is variable by means of set screws. With the drop of the stimulus hammer upon the metallic base and the emission of the sound the shoe actuated by the strong spring of the release armature flies from between the points, while the armature flies back to position A_3 . This releases the pendulum and carries the chronometric scale in the negative direction counting against the reagent until the index flies upon the disc marking the close of the stimulus-reaction period.

The difficulty in attempting to devise a mechanical chronoscope is to give it versatility. It is not hard to provide a release that at the same time serves as a sound stimulus, and that offers no resources for the presentation of touch and light stimuli. With the mechanical device described above, however, it is possible to give all three stimuli. This is shown by Fig. 3, a diagram of the three-stimulus key. The method of giving the sound stimulus is described above.

¹ This type of armature although employed in a somewhat different manner was first used by Bergström in a pendulum chronoscope figured and described in the *PSYCHOLOGICAL REVIEW*, VII., 1900, 438 ff.

When it is desired to present a light stimulus with the mechanical chronoscope a light wooden arm long enough to extend beyond the base of the chronoscope is attached to the shaft of the reaction key. This wooden arm carries a small black square (*A*) operating as a shutter to a 1 cm. aperture (*Ap*) in a black screen large enough to conceal the movements

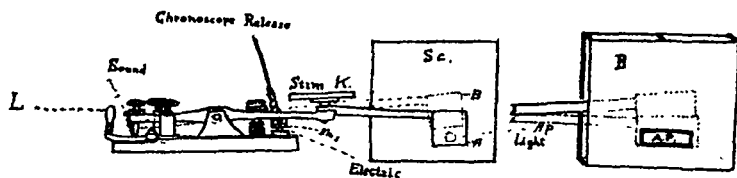


FIG. 3.

of the experimenter. When it is desired to use tactual stimuli the stimulus key, by means of the binding posts, is inserted into the primary circuit of an induction coil preferably with condenser. The reaction key is introduced in the secondary circuit in such manner that the cathode is in the button of the key and the anode in a shallow vessel of salt water. If the vibrating armature of the current interrupter of the induction coil is tied back securely against its adjustable contact and the reacting finger rests upon the cathode and the fingers of the other hand rest in the vessel, a shock is felt in the reacting finger when the primary circuit is broken at *Sh*₁. As the key is figured above it is set for all three stimuli which would be administered simultaneously with the sudden pull toward the experimenter of lever *L*.

By removing the arrangement for light stimulus the pair of stimuli, sound and shock, may be given together; or by getting out of series with the induction coil, the paired stimuli, sound and light, may be given. Likewise it is possible to eliminate any two stimuli and administer a third singly. When light is presented singly a small rubber plate is attached to the posterior side of the stimulus lever (*L*) to eliminate the sound. In all these cases it is seen that the chronoscope release is mechanical, by means of *Sh*₁. Fig. 2 by means of dotted lines from the binding posts suggests the wiring arrangement for electrical operation of the chronoscope. When

the current is used the two cords are serviceable to set the pendulum armature and to throw the reaction index back to zero.

It is seen that the mechanical device can be operated only when the experimenter and reagent are at close range. When, however, it is desired to give stimuli from a distance or to have the reaction from another room the electrical arrangement mentioned above must be employed. The reaction movement called for by the apparatus is in all cases of the break-circuit variety. The chronoscope may be put to the same tasks that are attempted by any type of electrical chronoscope, at the same time affording a mechanical arrangement that would seem to meet the objections of those opposed to the electric chronoscope.

METHOD OF LAYING THE CHRONOMETRIC SCALE

A chronoscope is a device for visualizing intervals of time by freely initiating or terminating the regular movement of either a point along a graduated scale or a graduated scale past a point, each division of the scale being the space traversed in a given unit of time. Many a chronoscope has been devised with perfect balance and bearings but failed because its scale was too largely a matter of speculation. *The chronometric scale is the real chronoscope*—propelling the scale or moving an index uniformly along it are comparatively easy accessories.

The possibility of laying a definite chronometric scale was one of the factors that prompted the present device. Fig. 1 shows the method of deriving the scale and of placing it upon the chronoscope disc. One of a pair of synchronized differential tuning forks of 256 v.d. frequency is loaded with a small aluminum feather (A_1) by means of a stiff wax. It is then sounded with its companion, the number of beats per second counted and its vibration-rate calculated. Then by means of wax another aluminum feather (A_2) is attached to the second fork, and small increments are made to the wax until the beats disappear. The forks are again synchronical and their vibration-rate is that formerly calculated. They are mounted

as shown in Fig. 1 in such manner that feather A_2 touches the smoked drum of a kymograph and feather A_1 rests upon the smoked edge of the chronoscope disc. Into this arrangement a third member is brought, a Morse key rearranged for break-circuit contact, and bearing two aluminum feathers at the end of its shaft beneath the button (P). One of these feathers is adjusted to lie within the same radius of the disc as the tuning fork feather, A_1 , and the other is squared with the point of the feather upon the kymograph.

After the disc is brought to its initial position and the circuit to the electro-magnet (EM) is closed, it is seen that a pressure upon the button (P), which short-circuits the current to EM , will release the disc. At the same time a mark will be recorded upon the kymograph and another upon the smoked edge of the chronoscope disc. The entire procedure is as follows: Start the forks, and with the hand suddenly revolve the drum of the kymograph, having disconnected it from the clock-work mechanism, and with the other hand press upon the button (P) at least twice in quick succession.

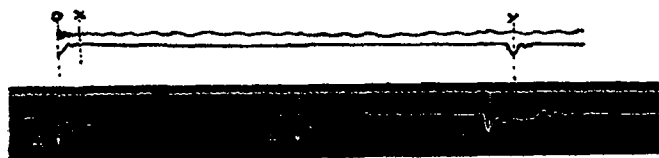


FIG. 4.

Lower Fig. 4 is the kymograph record of the pressures, and upper Fig. 4 is a diagrammatic view of the disc record straightened and brought into relationship with it. The time value of the distance o - y on the chronoscope scale is readily counted off from the distance on the kymograph scale, A - B . In laying the chronoscope scale it is necessary only to read toward o from the point y to establish the first distinguishable chronometric value from o . There will always be the space o - x whose time value *in toto* is known but whose individual waves are too close together to be distinguished.

After setting the chronographic records with shellac the scale of time values is engraved upon the chronoscope disc

at grade points located by producing a radius of the disc through the crest of each tuning-fork wave. The time value of each wave-length was 4° which save in the case of waves near π is graded in four equal parts, or to the 1° . This chronographic method of laying the scale is superior to the method of employing sparks produced by an induction coil with a tuning-fork interrupter because the sparks deviate considerably in making the aerial gap, and fail to indicate the true location of the scale.

In order to test the reliability of the chronoscope a control

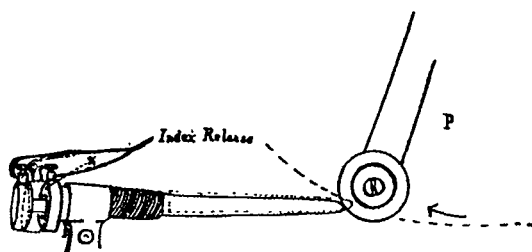


FIG. 5.

apparatus (Fig. 5) is used consisting of a shaft with a polished metal point so poised that its axis if produced is a secant of the pendular arc. This shaft is carried by a comparatively facile spring in a rigid base. When the pendulum strikes the shaft it is pushed back breaking the circuit at x , thus releasing the chronoscope index and recording upon the scale the interval between the release of the pendulum and its striking the shaft. The values given below are the averages of 12 groups of control tests of 10 trials each, or 120 tests. The mechanical release was used in the tests.

Average Interval	Average Variation
519.4 $^\circ$	0.84 $^\circ$
520.2	1.08
520.4	0.64
520.1	0.18
520.4	0.64
521.4	0.80
519.5	1.00
519.0	1.00
520.3	0.42
519.8	0.48
519.9	0.72
522.0 $^\circ$ Gross Av. 520.2 $^\circ$	0.42 $^\circ$ Gross Av. 0.68 $^\circ$

The present device by means of its adjustable discs (D_1 and D_2 , Fig. 1) affords a tachistoscope that is fairly serviceable.¹ The point-exposure time may be read off from the chronometric scale, and affords a maximum point exposure of 420°. The stimuli are held by a clip behind the discs and are seen through the sector of the compound disc. B , in Fig. 3, is a diagram showing a tachistoscopic attachment for the stimulus key (*Stim. K*) making it possible to expose words, colors, etc., in a rectangular aperture for reaction experiments in discrimination, cognition, choice and association. The screen is large enough to conceal the operations of the experimenter from the reagent. By using the rubber plate under the sound hammer the exposures are made almost noiselessly.

SUMMARY OF THE SPECIAL FEATURES OF THE CHRONOSCOPE

1. It allows either mechanical or electrical release of the time scale, involving in each case the same parts, and making it possible to work where a steady electric current is not available.
2. The reaction mechanism may be operated either mechanically or electrically.
3. The device makes it possible to lay a chronometric scale whose units can be exactly placed to within a short distance of the zero point, and whose total value is exactly known.
4. By means of an attachment time exposures may be made that are measured off on the chronometric scale, and the variety of compound-reaction stimuli can be given.

¹ In his "Mental and Physical Tests—Simpler Processes," 1914, pp. 263 ff., Whipple figures and describes a disc tachistoscope of his own construction and one now commonly in use. In his instrument the point-exposure times are calculated from the relative positions of weights upon the two counterbalancing arms that rotate the disc. In the present arrangement the times are shown on the chronometric scale.