

more likely to be useful in connection with military exercises than if applied to industrial labour.

(2) No law connecting heat production and work performance can be properly formulated until the range of experimental observations under uniform conditions has been carried below the starting point of existing records. It is desirable to define muscular efficiency more strictly than has been usual, and it is possible that the results of Macdonald which the present extended analysis of Benedict and Cathcart's data verifies, are open to more than one interpretation.

### *The Galvanometric Measurement of "Emotive" Physiological Changes.*

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*Object.*—The object of these experiments was to determine whether or no in the absence of the ordinary visible signs of emotion (muscular, secretory, etc.), electrical signs of emotive discharges are demonstrable by galvanometer.

Affirmative results reported by previous observers\* have not, to my mind, fully established the reality of the ground fact, independently of the slight and ordinarily insensible muscular movements that can be perceived by a thought reader or recorded by suitable apparatus, and, as a first step in the inquiry, I thought it necessary to take simultaneous records of galvanometric and muscular movements.

The following communication deals only with the large and sudden electrical responses that are unmistakeably independent of muscular contraction. The smaller and more gradual fluctuations of more debatable nature will be dealt with in a future communication. For the present state of the subject it is, in my opinion, necessary, in the first instance, to establish as clearly as possible the chief actual facts by actual demonstration.

\* Veraguth, 'Das Psychogalvanische Reflexphänomen,' Berlin, 1909. Petersen and Jung, 'Psychophysical Investigations with the Galvanometer and Pneumograph in Normal and Insane Individuals.' Goldscheider, "Der sogenannte psycho-galvanische Reflex und seine physikalisch-chemische Deutung," 'Pflüger's Archiv,' vol. 162, p. 489 (1915).

For this purpose there were projected upon the screen:—

1. On the upper scale the galvanometer spot, arranged to move to the + side with increased electrical conductivity due to emotional excitement (and returning to the — side with diminishing conductivity accompanying the subsidence of excitement).
2. On the lower scale the shadow of a delicate myograph to show the fluctuations of muscular contraction.

For the purpose of the demonstration, strong (disagreeable) stimuli are used, viz.:—

1. An unexpected loud sound (motor horn).
2. An expected burn (lighted match under hand, the striking of the match being, if possible, utilised as the warning signal).
3. A disagreeable pungent smell, under control of subject.
4. A painful thought, in some degree under control of subject.

*Method.*—Simultaneous photographic records of the movements and of the electrical resistance (skin) are taken from the extremities (hands and feet) of a subject as quiescent as possible. The subject reclines in an armchair reading an unexciting book, and often becomes somnolent; a stimulus calculated to arouse "emotion" is now made and signalled on the records. The muscle recorder is of sufficient delicacy to show the pulse, and to respond to the slightest unconscious movement. The electrical circuit consists of an accumulator cell (2·5 volts), or of 2 Leclanché cells (2·8 volts), two galvanometers, a resistance (1,000 or 10,000 ohms) that can be put in or out of circuit for the purpose of calibration, and the subject of observation, with unpolarisable electrodes applied to the dorsal and palmar surfaces of the hand or of the foot.

The galvanometric spot of light indicative of current strength wavers under the influence of fluctuations of imbibition, and of contact pressure with slight (unconscious) muscular movement, but also, and quite independently, with altered states of consciousness, especially with such alterations as are sufficiently intense to be attended with subjective, or it may be objective, signs of emotion.

The effect is best demonstrated on the hand or foot; on other parts (forearm, arm, leg, thigh) under similar conditions it is imperceptible. As regards the hand and foot, the palmar surface is effective, the dorsal surface ineffective.

*Results.*—From these facts a correlation with the presence of sweat glands suggests itself.

But atropin (atropin, four trials by local application of liq. atropiæ, followed by a belladonna plaster for 24 hours) was found not to affect the skin response.

The application of an indiarubber band rendering the limb pulseless and ex-sanguine did not appreciably affect the emotive response.

The most remarkable fact is the response to an idea. In this connection it

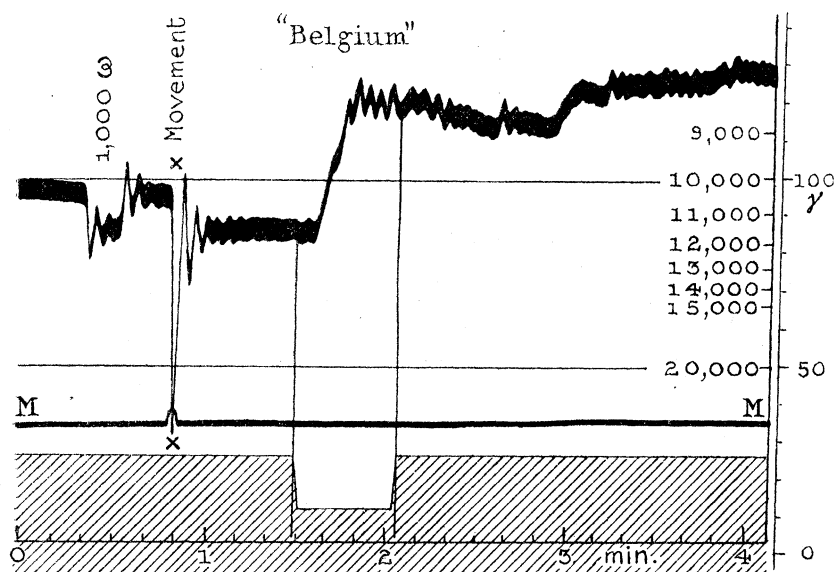


FIG. 1.—The emotive response in this instance has a resistance value of 4000 ohms (i.e., a fall of  $R$  from 12,000 to 8000, or a rise of conductivity on the record of about 20 mm. = about 40  $\gamma$ , i.e., 0.000040 mho).

At the point marked X the subject raised the little finger, causing a rise of the myograph lever and a momentary increase of resistance in the circuit.

The emotive effect of the idea aroused in the subject in response to the sentence "Pensez à la Belgique" was far more permanent than that shown in fig. 2, in which the exciting idea was aroused by the phrase "Pensez aux Gothas." The subject, G. de D., is a Belgian lady, who was an eye-witness of episodes in the German occupation of Belgium in 1914.

is further remarkable that the most effective ideas are such as are accompanied by disagreeable or painful emotion. The threat of a burn is often more effective than the burn itself.

Lighting a match may give a larger effect than the application of a match to the free hand.

The apprehension of a bad smell that has just been experienced has proved to be particularly effective.

The expected prick of a needle has produced more effect than an unexpected prick.

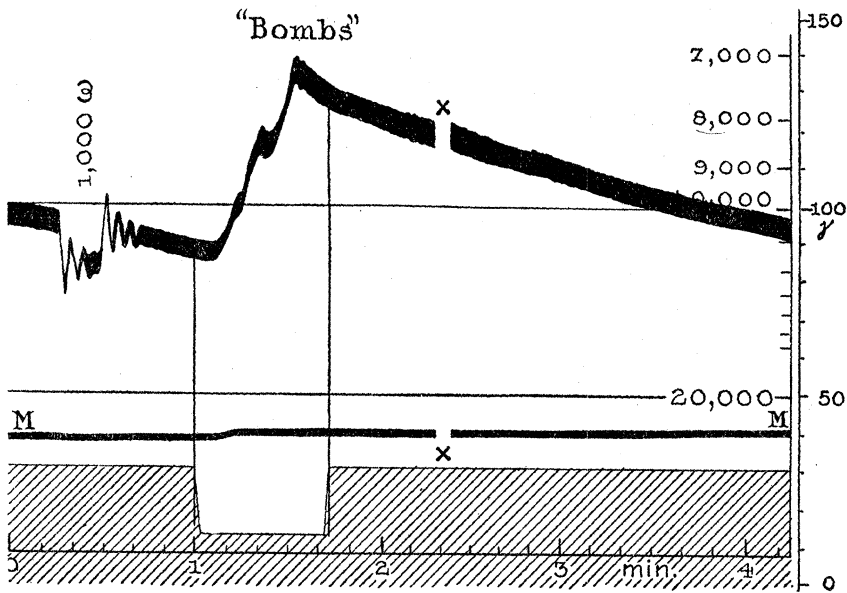


FIG. 2.—Emotive response to the suggested idea of an air-raid. The brief interruption of light marked X was made for the purpose of testing the record for parallax.

In both records the battery (two Leclanché cells), patient, and galvanometer (shunted) are in series.

In other observations I have followed the more convenient method of placing the patient in the  $x$  arm of a Wheatstone bridge and calibrating by 0.14 volt whatever departure from zero (lowered resistance of  $x$ ) is produced in response to the emotive stimulus.

Different subjects react differently to different stimuli, and the same subject in different states of health and at different times of day reacts differently to identical stimulation.