

EXPERIMENTAL INVESTIGATIONS CONCERNING THE DEPTH OF SLEEP.¹

BY DR. SANTE DE SANCTIS AND DR. U. NEYROZ,
University of Rome.

The question of the depth of sleep has already been discussed in a book by one of the present writers² from both the critical and the experimental standpoints. The curves of depth constructed by Kohlschütter, Mönninghoff and Piesbergen, Michelson, and Lambranzi were there given, and the methods used by these and other investigators criticized.³

In general, auditory stimuli were used as means of wakening; but Michelson and Czerny experimented with electricity also, and Lambranzi with auditory, visual, and olfactory stimuli, used one at a time or simultaneously. In the above-mentioned book one of us described some experiments performed with tactile and pressure stimuli, using Griessbach's esthesiometer with sharp and blunt points.

This method had the great advantage of producing in the sleeper (at least where normal subjects were concerned) a single and continuous excitation, instead of a series of excitations separated by a more or less extended interval of time. Note was made not only of the degree of pressure at which waking was effected, but also of the degree at which the sleeper made defensive or withdrawing movements; so that, constructing a diagram with the values obtained, two curves were obtained: one of conscious reaction, representing the curve of the points of complete awaking, or *curve of the depth of sleep*, the other the curve of *subconscious reaction*. Some figures were there given⁴ which it is deemed advisable to reproduce here.

¹ Translated from the authors' MS. by Professor Howard C. Warren, Princeton University.

² S. De Sanctis, 'Die Träume,' etc. Durch zahlreiche Nachträge des Verfassers erweiterte Uebersetzung, von O. Schmidt. Halle, Marhold, 1901, pp. 207 ff.

³ For bibliography, see the work cited.

⁴ S. De Sanctis, op. cit., p. 214.

EXPERIMENTS ON A BOY OF EIGHT YEARS; DURATION OF
SLEEP, FROM 9 P. M. TO 8 A. M.

SERIES 1.

Hour: 10	Subconscious reaction: 15	Waking-point: 60
11	35	70
4	10	25
7	10	30

SERIES 2.

Hour: 10	Subconscious reaction: 15	Waking-point: 60
11	30	60
4	15	30
7	15	25

SERIES 3.

Hour: 10	Subconscious reaction: 15	Waking-point: 65
11	35	65
4	15	35
7	10	40

These tests show that in the child experimented upon the depth of sleep was greatest at 11 p. m. and became lighter in the early hours of the morning. They also show that the subconscious reaction maintained approximately the same proportion to the degree of depth of sleep throughout.

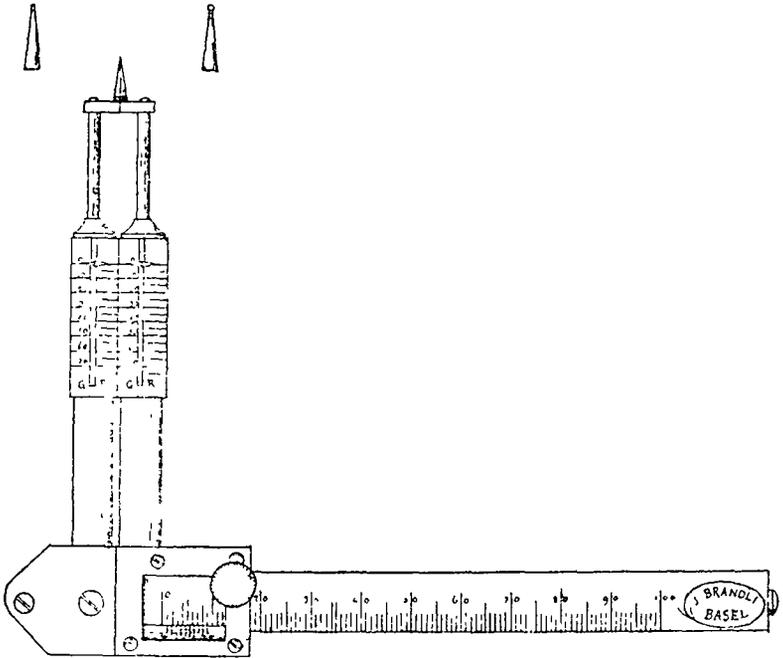
The experiments referred to were meager, however, and hence far from conclusive. We desired to carry them out on a much larger scale and to attempt by means of the method of tactile excitations to construct the *curve of the depth of sleep* for various subjects.

The instrument employed was the *Griessbach esthesiometer* (made by Brandli of Basel), adapted to admit of using stimuli given by a single point. For this purpose a metal cap was fitted over the two points of the instrument brought close together, but in such a way that the action of the moving shafts was perfectly free; the extremity of the cap terminated in either a rounded surface or a blunt point. (See Fig. 1.)

We were soon compelled to discard the rounded point, for the reason that the stimulation was generally insufficient to produce awakening when the depth of sleep had attained a certain intensity; we therefore made use of the blunt point, or of the two sharp points of the esthesiometer brought together so as to

form a single point. However, as basis of experiment with all subjects the blunt point was chiefly employed, as it best answered our purpose, being able to bring about awakening without pain, and at the same time doing away with the danger of the instrument's slipping and inflicting injury, in the event of a sudden movement by the sleeper. Moreover, in cases of light sleep, if the awakening were effected suddenly by means of a painful stimulus, it would not have been possible to construct an exact curve, especially for the periods during which the depth of sleep was at a minimum.

FIG. 1.



The experiments were carried on for about six consecutive months, one or at most two per night, so that the normal course of sleep might not be in any way altered, as would evidently have been the case had the tests been made too close together. The experiments were always performed at different hours on successive and irregularly alternated nights; several observations were made in hours already used, in order that a more exact value might be obtained, and at least four different periods

were selected for each hour of sleep, so that we might find the waking-points for every ten or fifteen minutes, in order to make the curve as complete as possible.

In our notebook we recorded all the observations as they were made, and any influences which might have effected a modification of the physical or moral well-being of the subject of experiment.

The four normal subjects upon whom experiments were made were relatives of one of the writers; two were of mature age, the other two young people; all were sound and in the best of health. They slept in separate rooms. One of us, taking his station in an intermediate room, could keep close watch of the moment at which they fell asleep, determining it from the cessation of movement, the rhythm of breathing, etc. We had previous knowledge of the habits of each of the subjects in falling asleep.

The hour at which they fell asleep being thus ascertained, the experiment was performed at the time selected. One of us entered in bare feet and without making the slightest noise approached the sleeper's bed, which had beforehand been moved out from the wall to enable him to move around it easily. The head of the bed was low, so as to present no obstacle to his movements. Having ascertained that the subject gave no sign of waking, he threw a dim light upon his forehead by means of a small dark-lantern, provided with a screen below and having the luminous aperture reduced to a minimum, so that the light should not strike the subject's eyes at all, but illuminate only the part under examination and the scale of the esthesiometer. Then the point of the instrument, held vertically in the right hand, was placed gently on the forehead, in contact with the left frontal protuberance at its upper extremity near the borders of the hairy part of the scalp. (The forehead was selected to avoid the necessity of uncovering the sleeper, the left side in order that the stimulation might always be at the same point and because it was more accessible, owing to the general custom of sleeping on the right side.) Pressing the instrument down in a uniform and continuous manner, so that the spring passed along the graduated scale from end to end in twenty seconds, the ob-

server watched carefully for the instant when the sleeper first made a movement—a wrinkling of the forehead, slight movement of the head or limbs, change in the rhythm of respiration, etc.; he then read on the scale the number opposite the point where the indicating needle was situated at that instant; the pressure was continued without interruption until the subject awoke, and note was made of the point at which the waking occurred.

If, as occasionally happened, the reflex movements of the sleeper were somewhat energetic, such as a sudden movement of the head or a change of position of the body, so that it was impossible to keep the instrument applied continuously to the forehead, it was withdrawn and the excitation recommenced after an interval of ten seconds, in such a way that the pause and the duration of the new excitation should together occupy not more than thirty seconds.

The experiments on the abnormal subjects were made in the months of March and April, 1901. There were five such subjects: two epileptics of long standing (E. B., T. R.), one case of epilepsy due to a wound (G. G.), one hysterio-epileptic degenerate (F. B.), and one case of paralytic dementia (L. M.).

These tests also were made on irregularly alternated days (the subjects never knowing whether they would be wakened in the night or not) and at various hours, a couple of times per night with an interval of three or four hours between the two tests.

On account of the many practical difficulties not more than 25 or 30 esthesiometric readings per subject could be made, on the average, giving the waking-points for every twenty minutes, or thirty at the most; these points, however, were more than sufficient to give us an amply complete curve, the variations in the depth of sleep being quite large, as we were convinced from the experiments on the normal subjects.

On the nights of experiment one of us, taking his station in a room near that in which the patients slept (at the Psychiatric Clinic of the University of Rome), determined the time at which each of them fell asleep. The subjects under examination, not more than three of whom were used at a time, slept together in a large dormitory, but in beds situated so far apart that the experiments made on one patient did not disturb the slumber of

the others. One of us softly entered the dormitory, and standing behind the bed, which was placed at a distance from the wall, cast the light of his lantern, as before, on the forehead only, and pressed on this part with the instrument, always upon the left frontal protuberance, observing and writing down at once the degrees corresponding to the first reflex reaction and the complete awaking of the sleeper—proceeding, in a word, as with the normal subjects.

The observations made each time, together with the data obtained from questions put on the morning following each night of experiments, were recorded in a notebook in which was also recorded anything which might have happened during the preceding day to any of the patients experimented upon.

The following tables give the values obtained in the particular experiments for each of the normal subjects. It is to be observed that for the first two normal subjects the figures represent the average of tests repeated several times, for the sake of verification, in each particular hour of sleep and as frequently as possible.

The first column indicates the hour of sleep at which the experiment was made, the second gives the value corresponding to the first *subconscious reaction*, the third, that corresponding to the *waking-point*.

Cases were found where the entire range of the esthesiometer was insufficient to produce awakening. In such cases it was necessary to bring a second excitation to bear upon the subject; that is, it was necessary to recommence the pressure and continue it until, as a result of the summation of excitations, the awakening was effected. Similarly, it sometimes happened that the regular course of the esthesiometer was interrupted by a vigorous (unconscious) withdrawing movement on the part of the sleeper; it was then necessary, as in the other cases, to recommence the pressure after a short pause and proceed with it till he awoke. The former case is indicated in the third column by numbers joined by a plus sign (+), the latter by figures separated by a comma. Finally, in the fourth column are placed the data respecting dreams obtained from questions put at the time of the experiment, that is, as soon as

the subject was awake; affirmative answers are indicated by a plus sign (+), negative by a minus sign (-), doubt by an interrogation point (?).

From these experiments, by joining the several waking-points, we were able to obtain a *curve of the depth of sleep*. With this curve we give another, which shows the manner in which the *subconscious reaction* varies; and we might easily have added still a third, the *curve of dreams*, had it not seemed to us somewhat inappropriate to place numerical data and data gathered from the putting of questions in one and the same graphic representation.

Normal subject O. N., male, aged 15; rather delicate constitution, but healthy. Temperament excitable, somewhat impulsive. Sleep usually deep and regular. Seldom wakes up in the night. Is accustomed to fall asleep soon after going to bed. Is not a good dreamer; always remembers his dreams, which are, however, for the most part trivial.

TABLE I.—NORMAL SUBJECT O. N., MALE.

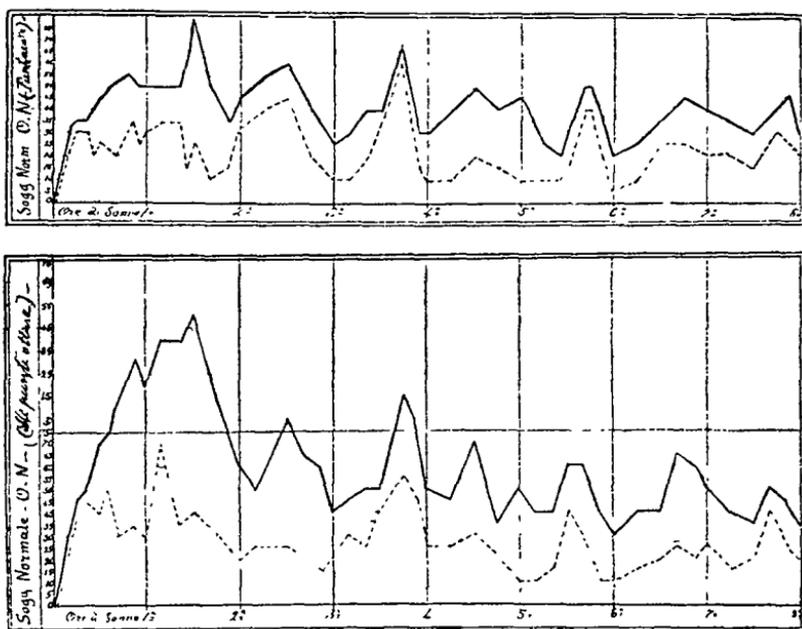
EXPERIMENTS WITH SHARP POINT OF THE ESTHESIOMETER.

Hour of Sleep	Subcon Reaction	Waking Point	Dreams	Hour of Sleep	Subcon Reaction	Waking Point	Dreams
0.10	20	30	—	3.40	60	65	+
0.15	30	35	—	3.50	15	30	?
0.20	30	35	—	4	10	30	—
0.25	20	40	—	4.15	10	40	—
0.30	25	45	—	4.30	20	50	—
0.40	20	50	—	4.45	15	40	—
0.50	35	55	—	5	10	45	+
0.55	25	50	—	5.15	10	25	+
1	30	50	—	5.25	10	20	+
1.10	35	50	—	5.30	15	30	?
1.20	35	50	—	5.40	40	50	—
1.25	15	65	—	5.45	40	50	?
1.30	25	25, 55	—	5.55	10	30	+
1.40	10	50	—	6	5	20	?
1.50	15	35	+	6.15	10	25	+
2	30	45	—	6.30	25	35	?
2.15	40	55	?	6.45	25	45	+
2.30	45	60	+	7	20	40	+
2.45	20	40	—	7.15	20	35	+
3	10	25	?	7.30	15	30	+
3.10	10	30	—	7.45	30	40	—
3.20	20	40	—	7.50	25	45	—
3.30	35	40	+	8	20	30	—
				8.15	20	30	+

TABLE II.—NORMAL SUBJECT O. N. (THE SAME).
EXPERIMENTS WITH BLUNT POINT OF THE ESTHESIOMETER.

Hour of Sleep	Subcon Reaction	Waking Point	Dreams	Hour of Sleep	Subcon Reaction	Waking Point	Dreams
0.10	20	30	—	4	25	50	?
0.15	40	45	—	4.15	25	45	?
0.20	45	50	—	4.30	30	70	?
0.30	40	70	—	4.45	20	35	+
0.35	50	75	—	5	10	50	+
0.40	30	30, 55	—	5.10	10	40	+
0.50	35	35, 20, 50	—	5.20	15	40	—
1	30	30, 20, 45	—	5.30	40	60	+
1.10	70	70, 30, 15	—	5.40	30	60	+
1.20	35	35, 45, 40	—	5.50	10	40	+
1.30	40	40, 30, 20, 35	—	6	10	30	+
1.45	30	75 + 15	—	6.15	15	40	+
2	20	60	—	6.30	20	40	+
2.10	25	50	?	6.40	25	65	+
2.30	25	25, 35, 20	+	6.50	20	60	—
2.40	20	20, 45	—	7	25	50	+
2.50	15	60	—	7.15	15	40	—
3	20	40	—	7.30	20	35	—
3.10	30	45	—	7.40	40	50	+
3.20	25	50	—	7.50	25	45	—
3.30	40	50	+	8	20	35	+
3.45	55	55, 20, 15	+	8.10	25	30	—
3.50	45	45, 25, 10	—	8.20	35	50	+

FIG. 2.



Note in subject O.N. that the maximum depth is reached in the first half of the second hour. Note also the infrequency of dreams in the first half and their relative frequency in the second half of the sleep period. (Compare Fig. 2.)

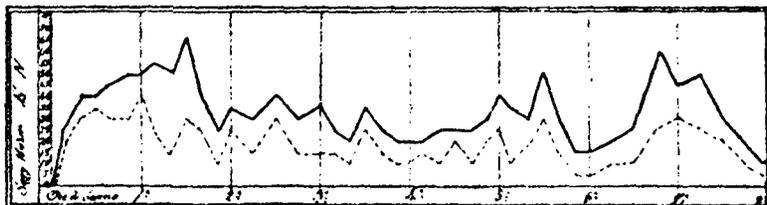
Normal subject E. N., female, aged 21; good constitution, at the time slightly debilitated from study, somewhat emotional; intellect and memory very good. Sleeps rather lightly; wakes up easily during the night; ordinarily falls asleep a considerable time after going to bed. Has frequent dreams and remembers them well.

TABLE III.—NORMAL SUBJECT E. N., FEMALE.

Hour of Sleep.	Subcon. Reaction.	Waking Point.	Dreams.	Hour of Sleep.	Subcon. Reaction.	Waking Point.	Dreams.
0.10	20	25	—	4.10	15	20	—
0.20	30	40	—	4.20	10	25	+
0.30	35	40	+	4.30	20	25	+
0.40	30	45	—	4.40	10	25	+
0.50	30	50	?	4.50	20	30	+
1	40	50	—	5	25	40	+
1.10	25	55	+	5.10	10	35	+
1.20	15	50	—	5.20	20	30	+
1.30	30	65	?	5.30	30	50	+
1.40	25	30	+	5.40	15	30	+
1.50	10	25	+	5.50	5	15	+
2	25	35	—	6	5	15	+
2.15	15	30	+	6.15	10	20	+
2.30	30	40	+	6.30	10	25	+
2.45	15	30	?	6.45	25	55	+
3	15	35	?	7	30	45	+
3.10	15	25	+	7.15	25	50	+
3.20	10	20	+	7.30	20	30	+
3.30	25	35	+	7.45	10	20	+
3.40	15	25	+	8	5	10	+
3.50	10	20	+	8.15	10	15	+
4	10	20	+	8.30	10	15	—
				8.45	5	10	+

Note in normal subject E. N. that the depth of sleep attains its maximum after an hour and a half of sleep; that in the period between six and a half and seven and a quarter hours the depth is considerable. Dreams vary at first and become frequent in the succeeding hours until morning. (Compare Fig. 3.)

FIG. 3.



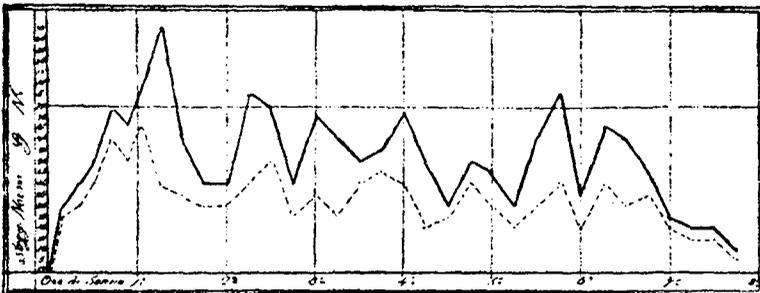
Normal subject G. N., male, aged 60; very robust constitution, mentally normal. Sleeps soundly during the early part of the night. In the latter part of the night wakes easily. Falls asleep soon after going to bed. Is a good dreamer and remembers his dreams fairly well.

TABLE IV.—NORMAL SUBJECT G. N., MALE.

Hour of Sleep.	Subcon. Reaction.	Waking Point.	Dreams.	Hour of Sleep.	Subcon. Reaction.	Waking Point.	Dreams.
0.10	25	30	—	4	40	70	+
0.20	30	40	?	4.15	20	50	+
0.30	40	50	+	4.30	45	30	+
0.40	60	70	+	4.45	40	50	+
0.50	50	65	+	5	30	45	+
1	65	65, 15	?	5.15	20	30	+
1.15	40	40, 60, 10	+	5.30	30	60	+
1.30	35	60	+	5.45	40	40, 40	+
1.45	30	40	—	6	20	35	+
2	30	40	+	6.15	40	65	+
2.15	40	40, 40	—	6.30	30	60	+
2.30	50	75	+	6.45	35	55	—
2.45	25	40	+	7	20	25	—
3	35	35, 35	+	7.15	15	20	+
3.15	25	60	+	7.30	15	20	+
3.30	40	50	+	7.45	10	15	—
3.45	45	55	+				

Note in normal subject G. N. that the maximum depth is attained at the beginning of the second hour; that it is quite marked also in the period between five and a half and six and a half hours. Dreams were noted in almost every experiment. (Compare Fig. 4.)

FIG. 4.



Normal subject An. N., female, aged 55; robust physical constitution. Quiet temperament. Sensibility and intellect normal. Is accustomed to fall asleep soon after going to bed. Generally sleeps well; her sleep does not ordinarily extend

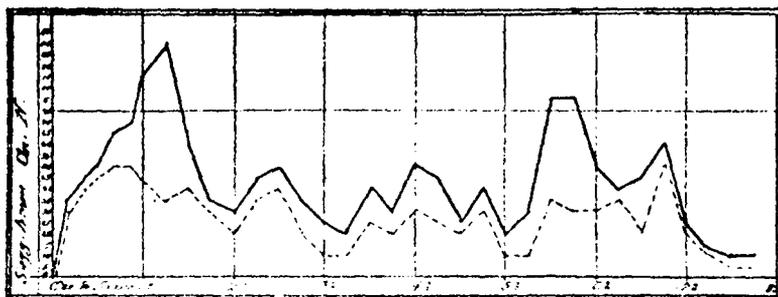
beyond eight hours. Dreams frequently and has a good memory for dreams.

TABLE V.—NORMAL SUBJECT AN. N., FEMALE.

Hour of Sleep.	Subcon. Reaction.	Waking Point.	Dreams	Hour of Sleep.	Subcon. Reaction.	Waking Point	Dreams.
0.10	30	35	+	4	30	50	+
0.20	40	45	+	4.15	25	45	+
0.30	45	50	+	4.30	20	25	+
0.40	50	65	+	4.45	30	40	+
0.50	50	70	?	5	10	20	+
1	45	45, 45	+	5.15	10	30	+
1.15	35	35, 40, 30	+	5.30	35	35, 45	+
1.30	40	60	—	5.45	30	30, 50	+
1.45	30	35	+	6	30	50	+
2	20	30	+	6.15	35	40	+
2.15	35	45	—	6.30	20	45	+
2.30	40	50	+	6.45	50	60	+
2.45	20	35	+	7	20	25	+
3	10	25	+	7.15	10	15	+
3.15	10	20	+	7.30	5	10	+
3.30	25	40	+	7.45	5	10	—
3.45	20	30	+				

Note in normal subject An. N. that the maximum depth is reached at the beginning of the second hour of sleep, and that it is also considerable in the sixth and seventh hours. Dreams are very frequent; they occur even when the depth of sleep is at its maximum. (Compare Fig. 5.)

FIG. 5.



The tables dealing with the measure of sleep in the five pathological subjects are very complex, since it seemed desirable to note (1) not only the moment at which the first reflex movement on the tactile-pressure excitation appeared, but also the nature and extent of such movement; (2) the phenomena accompanying complete awaking; (3) recollection of dreams

and, where recalled, their content; (4) convulsions and any other pathological phenomena observable in the subject on the day preceding the night of experiment, etc.; besides many other matters which are of no direct interest to the readers of this REVIEW.

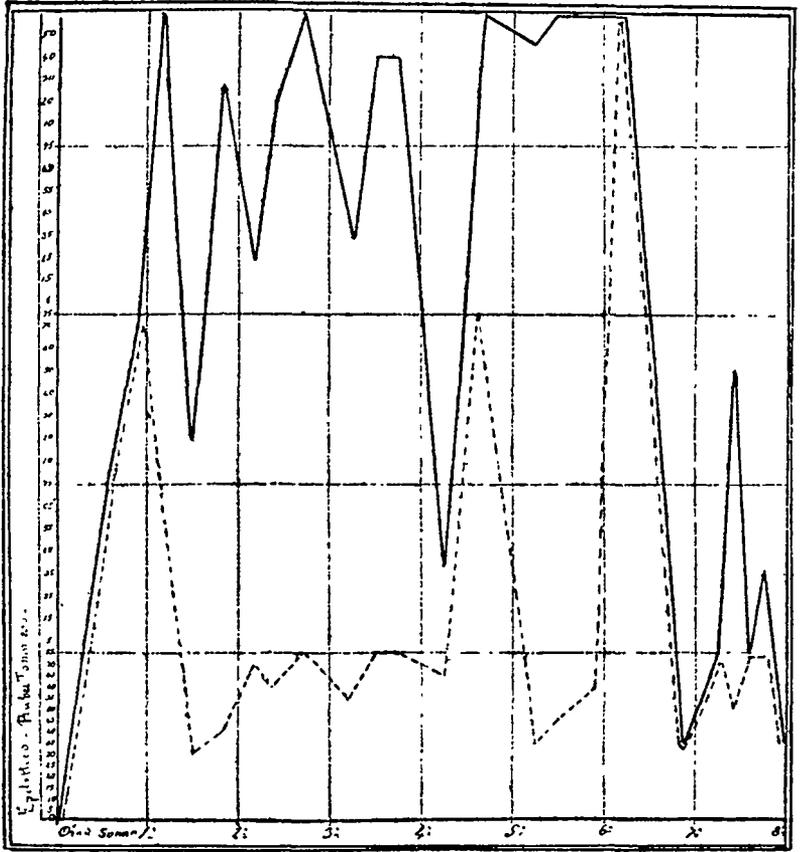
For this reason we shall make a descriptive report of the observations without giving tables, and shall reproduce here the graphic representation only, showing the curves of the depth of sleep and subconscious reaction.

Tommaso Rubei, aged 33. In childhood he had typhoid; was early given to self-abuse. About his eighth year he began to have attacks of vertigo, but without loss of consciousness. At the age of 15 he experienced a great fright, and two years later began to have convulsions, which at first were very frequent and closely connected with atmospheric changes, and which gradually became rarer. For several years they have appeared every 20, 30 or 40 days; but attacks of petit mal and vertigo are also not infrequent. These attacks occur almost without exception at night and are sometimes preceded by a feeling of tightening at the throat; the attack consists of tonic and clonic convulsions lasting from 5 to 8 minutes followed by coma and deep sleep. Movements and sensibility are normal, secretions of sweat abundant and easily provoked; the pupillary reaction is slightly tardy; the knee-jerk is more pronounced on the left side, while the epigastric reflex appears only on the right. His demeanor is ordinarily quiet, temperament somewhat depressed. Outbursts of anger are frequent, memory somewhat feeble. His intellectual gifts are slight.

Rubei usually sleeps well and without waking up in the course of the night; his sleep is quiet and sound. According to patient's report he dreams every night, generally of pleasant things, sometimes about matters connected with his daily life, members of his family, etc. Formerly he was often troubled with erotic dreams, followed by pollution. He does not remember whether previous to his illness his sleep exhibited any phenomena of special interest. Ordinarily he does not notice any alteration in sleep before an attack; but in the past he sometimes had terrifying dreams.

His recollection of dreams generally varies much, especially with atmospheric conditions (?); he declares that he can not recollect them at all on mornings after wet or rainy days. At other times, he says, he remembers them very well and to the minutest particulars, but he is seldom able to relate them with any great clearness.

FIG. 6.



See Fig. 6. The curve shows that Rubei's sleep is of extraordinary depth, and that it continues deep with few oscillations till he awakes.

The line representing subconscious reaction shows great differences of proportion with the curve of depth in the third and fourth hours of sleep.

It is a noteworthy fact that to awaken him it is almost always necessary to employ a number of stimuli and to push them to the maximum several times, while in the other subjects this is only exceptionally the case. Moreover, the subconscious reactions were for the most part feeble and entirely out of proportion to the intensity of the stimulus—slight movements of the head, more or less marked wrinkling of the brow, sometimes movements of the hand, as if to brush the stimulus away from the head. Awakening did not occur generally till several seconds after the last stimulation; the subject was unable to state the number of times he had been touched, but several times he declared that he had been aware of a vague feeling of discomfort on the forehead. He usually fell asleep again a few minutes after the awakening was accomplished.

In contrast with the other patients, who generally fall asleep soon after going to bed, Rubei usually remains awake for half an hour or longer. As regards the effect of the epileptic attacks upon his sleep little can be said, inasmuch as in the month of experiment they occurred but three times during the night; from experiments made March 11, 1901, at 10:35 p. m., twenty minutes after an attack (after 1 h. 30 m. of sleep), and March 22, 1901, at 1 a. m., fifteen minutes after an attack (after 4 h. 15 m. of sleep), it appears that the waking-point is lowered in comparison with the same hour on other nights without attacks. On the other hand, the waking-point remained very high when the experiment was made 1 h. 25 m. after the attack (March 23, 1901, after 4 h. 45 m. of sleep).

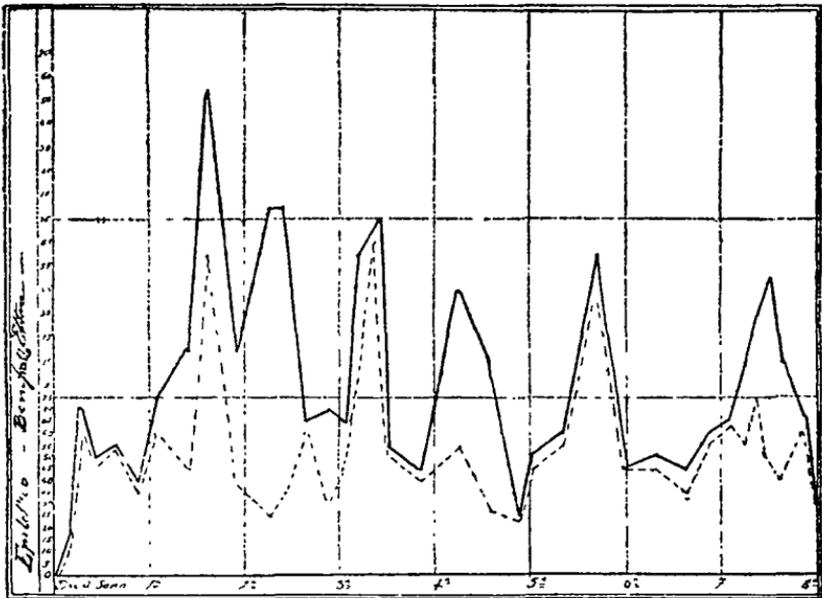
From questions put to him regarding his dreams it appeared that, even when Rubei declared that he dreamed, he was unable for the most part to relate at all in detail the subject of the dream. Altogether, in a total of 28 experiments, twice he was able to relate his dream, 9 times he recalled the subject in a general way, always as 'pleasant' in character, 7 times he did not dream at all, and 10 times he was uncertain whether he had dreamed or not. The strangest feature is that the two times when he recollected the dream fairly well were in experiments following close upon the beginning of sleep. Of the other dreams, three occurred in the first four, and six in the last four hours of sleep.

Ettore Benefalle, aged 24. In childhood he was subject to rather frequent convulsions, the attacks at times lasting throughout the day. Later they became less frequent, but were supplemented by attacks of petit mal (vertigo and sudden loss of consciousness). At present the severe chronic attacks occur very seldom; on the other hand, mild attacks are more or less frequent. The attack is preceded by an aura consisting of a tingling sensation in the right hand with clouding of vision. It lasts 4 or 5 minutes with tonic and clonic shocks, more powerful on the right side than on the left, followed by a state of coma; there is generally no frothing at the mouth. The mild attacks consist in a clouding of vision—‘the light goes away from his eyes’—he sees, as it were, a ball of white flame, which hovers before his eyes, causing much discomfort; he feels as if his body were split in two in the middle. All this generally lasts for a few seconds. Afterwards he feels torpid, and if the attack occur at night he dare not go to sleep afterwards, ‘for fear the trouble might come on again.’ The attacks occur by day as well as at night, but more frequently at night. There is a slight defect of hearing, and of smell on the right side. The tactile sensibility appears to be less on the right side. Visual acuteness is also inferior, especially on the right. The knee-jerk is normal. Mental capacity inferior. Temperament liable to variations without apparent reason; B. is quiet and very devout; he is addicted to pederasty.

B. usually sleeps well; his sleep is quiet and sound; if he happens to wake in the course of the night he falls asleep again immediately; he says that he has sometimes waked up with a start as a result of terrifying dreams, crying out in fear and calling to the attendants for help. He ordinarily dreams every night, but when he has one of the severer attacks during the night he does not dream at all. In general his dreams are pleasant, sometimes they are strange and terrifying; quite frequently, especially in recent times, erotic dreams occur, which are repeated several times in succession, almost always in the same way, followed in the majority of cases by pollution, and he wakes up with a pleasant impression. He also dreams, though not often, of things that have happened in

the course of the day or in preceding days. He says that he has always dreamed, and that he observes no difference in his manner of sleeping on account of the disorder to which he is subject. When his dreams are terrifying he retains a vivid impression, and continues in fear during the day, dwelling on them often. He generally remembers his dreams well; but when attacks occur, even the milder ones, and he chances to dream, he does not remember the subject of his dreams at all.

FIG. 7.



See Fig. 7. The curve for the depth of sleep throughout its course is high as a whole, but does not reach the elevation of Rubei's. The course of the line of subconscious reaction maintains a fairly constant proportion to the curve of depth; the least constancy of proportion occurs at the beginning of the third and fifth hours of sleep. In his case also the first reaction to the stimulus was almost always slight. In waking, the return of consciousness was rapid, so that the subject was always in condition to answer pertinently the questions asked him as soon as he was awake.

During the month and more in which B. was subject to our experiments the epileptic attacks occurred but once in the classic form, and this was at night; the other times they were mild and of very short duration. In an experiment made 20 minutes after the severe attack his sleep was found to be much deeper than in the corresponding hour of other nights free from attacks (after 30 minutes of sleep). In five other experiments also made after attacks the depth was notable (after 2 h. 15 m., 3 h. 20 m., 4 h. 15 m., 5 h. 20 m., and 7 h. 15 m. of sleep), but without much deviation from the normal mean. The patient, on the other hand, asserts that his sleep is not so sound after the attacks.

From the observations made with reference to his dreams it appears that, contrary to what Benefialle asserts, namely, that he dreams every night, 22 times he did not dream at all, while 16 times he claims to have had dreams; the dreams were in general trival, sometimes erotic; his recollection of them at the time was very cursory, but on the following morning he was able to describe the dream in greater detail (*parannesia onirica?*). The greatest frequency of dreaming occurred between the second and fourth hours of sleep; there were no dreams (except once, after 1 h. 5 m. of sleep) in the first two hours; there were very few in the latter half of the sleep period, though they were somewhat more frequent towards the end.

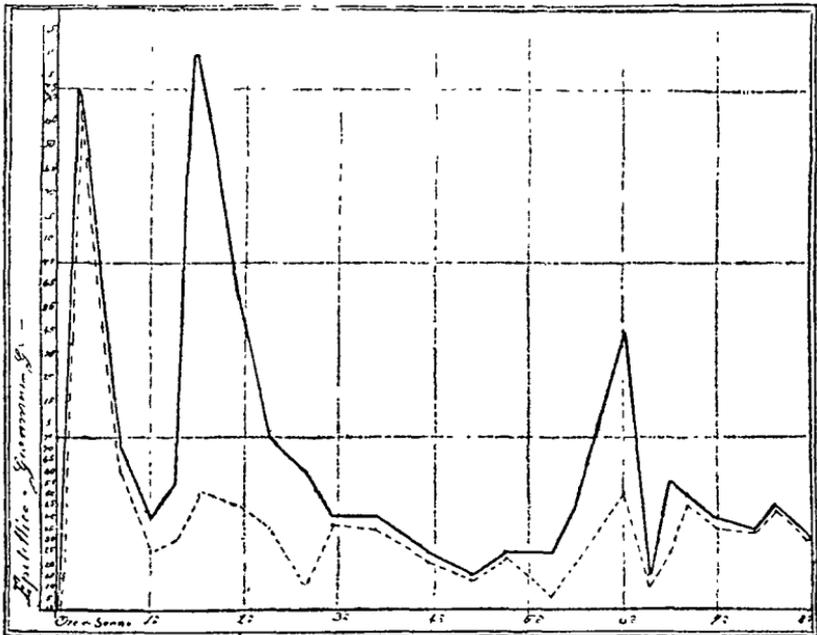
Gioacchino Giannini, aged 18. About his sixth year, in trying to avoid the wheel of a cart, he was caught between it and the guard, receiving a rather severe injury on the head; taken to the hospital, he recovered consciousness after 48 hours and did not suffer any ill-effects during the 25 days which he spent at the hospital. For seven or eight years he was perfectly able to pursue his work, when suddenly one night, without any reason for it, he was seized, while in bed, with tonic and clonic convulsions on the left side; a week later the attack was repeated in the same way, and from then on they recurred every 30 or 40 days. At the end of two years he was operated upon. Following the operation (raising of the right parietal bone which was somewhat depressed) there were no more attacks for about three months. But as the result of an injury received upon the scar the convulsions reappeared in the same

form as before, once or twice a month, and have recurred incessantly since. The patient says that he feels himself drawn sharply toward the left, he calls for help and lies on the bed or sits down so as not to injure himself during the attack; the latter is generally severe and always more violent on the left side, but of short duration, with rapid return of consciousness. In general the attacks occur by day or about evening while he is going to bed, almost never during sleep. Nothing else worthy of note.

Giannini is a sound sleeper; according to his report he seldom wakes in the course of the night; only once in 5 or 6 days do dreams occur; their content is generally of little interest; they are sometimes terrifying, occasionally erotic. He says that when he has had one of his attacks during the day he sleeps more soundly and does not dream at all. He is not aware of any differences in his sleep since he has been subject to the attacks from when he was in good health.

See Fig. 8. In this case the curve of sleep shows a course which is quite unique; it quickly reaches a very high point

FIG. 8.



within the first half hour, descending quite as rapidly in the second half hour. It rises again, reaching the maximum after an hour and a half; it then falls gradually, only to rise again to a notable height about the end of the sixth hour, thereafter maintaining itself at a medium level till the time of waking. In the majority of tests, except in the periods of greatest depth, the subconscious reactions were rather marked, even for slight stimuli, and preceded the awaking by a small margin only. Patient had but two epileptic attacks, which occurred, as usual, in the day time, and did not affect his sleep. There is little to note with respect to his dreams, Giannini not being a good dreamer, and giving affirmative answers three times only.

Luigi Moriggi, aged 51; contracted syphilis at a very early age. In June, 1899, the symptoms of the present disorder set in; pains in the head, continual somnolence during the day, neglect of his duties, foolish outlay of money, pilfering the property of others, exalted ideas of his own importance, disorders of memory and speech, etc. He entered the asylum at Rome, October 19, 1899.

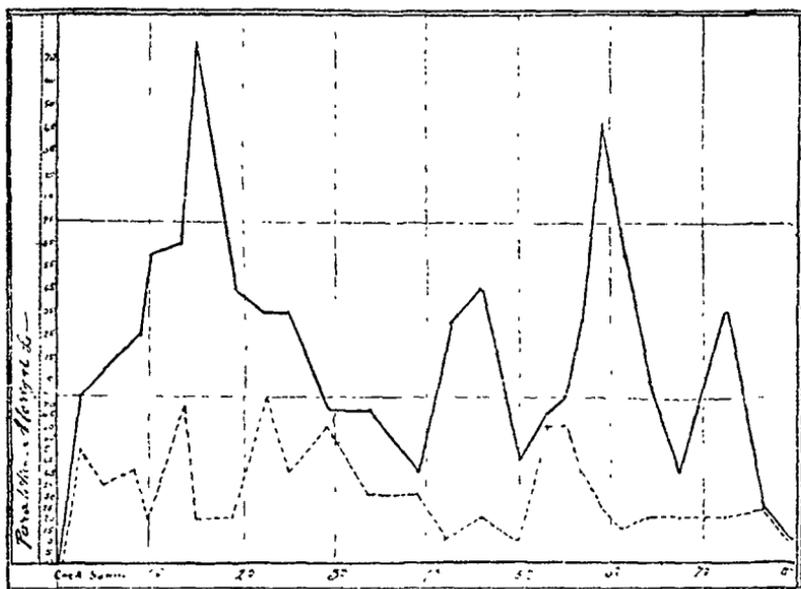
The pupils are unequal in size, reaction slow, tremors, rapid exhaustion of the facial muscles, tongue, fingers, etc.; slight indication of Romberg's sign, exaggeration of the deeper reflexes, diminution of the superficial ones, normal tactile sensibility. Demeanor apathetic, mild euphoria, wild ideas (hazy and vague) of his own greatness, affective side deficient, critical side exceedingly deficient; memory weak. Diagnosis of *dementia paralytica*.

M.'s sleep is usually light and often interrupted; he dreams but seldom, sometimes about members of his family or trivial matters. Before his illness he slept well and without interruption; he says that he dreamed more frequently then than now, but without ever being much of a dreamer. The few dreams which he has at present he does not remember at all.

See Fig. 9. The figure shows that the depth of sleep mounts rapidly at the beginning of the first hour of sleep, keeps on increasing slowly and continuously till the first half of the second hour, and then decreases with oscillations till the sixth

hour, at the end of which there is a decided rise. The depth is above the normal in this subject also.

FIG. 9.



Somewhat more variable is the line of subconscious reaction; it is conspicuously low in the second half of the sleep period, except in the fifth hour. The reactions were generally few and feeble; but before awakening was effected it was necessary to repeat the excitation at least twice. There is nothing to note regarding his dreams, Moriggi never having mentioned a single dream during the period of experimentation.

Francesco Bechelli, aged 16. His mother suffers from hystero-epileptic convulsions. He is very capricious; has always shown a perverse and unruly character, resisting his mother and sister, going even so far as to draw a knife upon them. He often runs away from home, after stealing some objects and selling them for a few *sous*, which he spends in amusement. He often sleeps in the street or a gateway, resisting the police when they endeavor to take him back home. Has several times attempted suicide. The pupillary reaction is good, the conjunctival and pharyngeal reflexes are wanting;

the knee-jerk is vigorous, other reflexes normal. There is hypesthesia of the right side of the trunk and also of the lower left limb. Amblyopia is present on the right side, hypacusia and anosmia on the left, hyperesthesia in the inguinal region. His demeanor is quiet. Decided deficiency in mental gifts, childish ideas, lack of capacity for concentration; ethical sensibility very blunt. He speaks with complacency of his own debauchery; of many of the deeds of which he is accused he has no recollection whatever, of others he admits the authorship and boasts of them. He is addicted to swearing and is exceedingly fond of indecent language. The patient has both mental and motor crises. Diagnosis of *degeneration and moral insanity*, probably *hystero-epilepsy with distinct crises*.

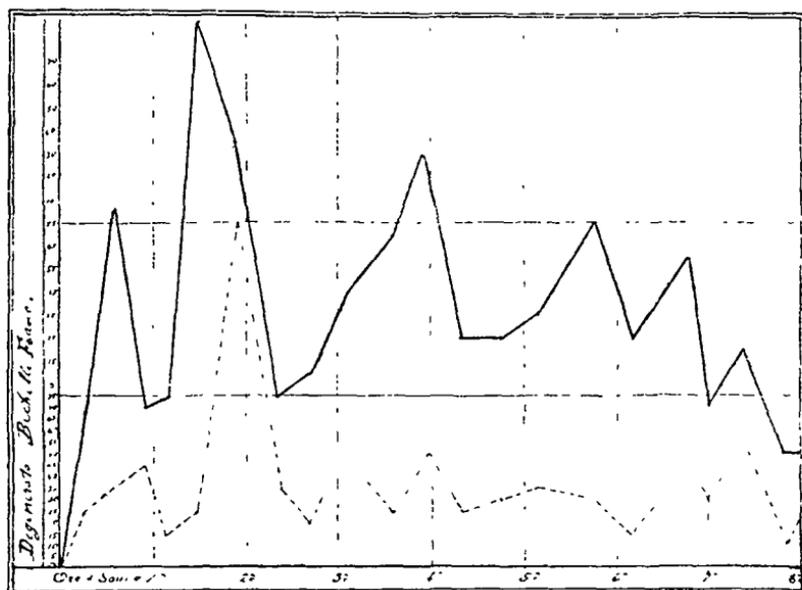
He is a sound sleeper; if he wakes up before midnight he goes to sleep again quickly, if it is near morning he remains awake and if at home gets up and goes out. For the past three or four years he has dreamed very little, previous to that more frequently; his dreams are generally pleasant, but formerly he often dreamed of being pursued by his parents seeking to beat him, or by the police, and would awake with a start. At other times he thought he saw wild beasts under the bed seeking to attack him: then he would feel, as it were, a blow on the head and wake up terrified (*De Sanctis's dream equivalent of attack*). At present, he says, when such a dream occurs he wakes up quickly, realizing that it is a dream, while if the dream is pleasant he remains asleep. His sleep has never shown any notable changes in connection with his disorder, except that, as mentioned above, dreams occur much less frequently, and that without being especially impressed by them he generally remembers them well.

See Fig. 10. His sleep increases rapidly in intensity during the first half hour; the curve attains its highest level in the second hour; then it descends, only to rise again and remain at a high level, but with oscillations which continually diminish in height till the time of waking, without exhibiting any noteworthy elevation in the second half of the sleep period.

The curve of subconscious reaction is seen to be less variable; except for a marked elevation in the second hour of

sleep it remains at rather a low level, with few oscillations. The reactions are somewhat energetic, but notwithstanding this there is no clear sign of waking until after repeated stimuli which, in the mean, if taken separately, would not reach a high degree of intensity.

FIG. 10.



His dream activity is very slight; only four times was an affirmative answer given—in experiments made after 2 h. 20 m., 5 h. 45 m., 8 h. 10 m., and 8 h. 45 m. of sleep—that is, once in the first and three times in the second half of the sleep period.

During the time when Bechelli was subject to experiment nothing was observed on either the mental or the motor side which seemed to exert a real influence on the course of his sleep.

Comparing the curves obtained from our normal subjects with the curves given by the authors cited at the beginning of this article, some rather notable differences appear at once.

As we have seen, the maximum depth falls, according to Kohlschütter, within the first hour of sleep, according to Mönninghoff and Piesbergen in the third quarter of the second hour,

according to Michelson at the end of the first, and about the same according to Czerny; while according to our observations it falls within the first half of the second hour. This would be in accord rather with the observations of Lambranzi. The diversity of results should be attributed, however, not so much to method as to individual factors, the authors mentioned having found that the point is sometimes earlier, sometimes later, according to the subject.

But where the curve of depth of sleep obtained by our method differs most notably from the others is in its later course; for while according to Kohlschütter and Michelson it descends continuously and rapidly till the time of waking, and according to Mönninghoff and Piesbergen, Czerny, and more especially Lambranzi it exhibits a marked elevation in the second half of the sleep period, according to our observations, on the contrary, the curve, although following in general a descending course, does not have a uniform path, but exhibits marked oscillations, with a maximum and minimum for each hour of sleep. The *secondary rise* of the curve appears clearly in three subjects and lasts for an hour and a half; it occurs earliest in the subjects G. N. and An. N., who are accustomed to sleep from 7 to 8 hours at the most, and later in the subject E. N., who habitually sleeps longer. The fact that we did not discover any such rise in the subject O. N., who is not much of a dreamer, appears to confirm Lambranzi's hypothesis, according to which the secondary rise is due to a real increase in the depth of sleep in connection with greater dream activity. But we shall see presently that Lambranzi's hypothesis seems to be contradicted by other facts. It appears evident, then, that each subject has a curve peculiar to himself, which differs both in elevation and in course from the others. That the depth of sleep is not the same in all individuals has been known, indeed, from the earliest times; age, sex, constitution, state of health, etc., are all factors which may cause it to vary, apart from factors extraneous to the organism which may act for a longer or shorter time on the sleeper.

Analysis of the curves of the abnormal subjects brings out noteworthy points regarding the general course of the depth of sleep and the intensity to which it attains.

The fact which stands out first of all is that in all five of the pathological subjects the depth of sleep is far greater than among the normal subjects. In the epileptic *Rubei* sleep is extraordinarily deep; in the two other epileptics, *Benefalle* and *Giannini*, although deep, it does not reach the level found in *Rubei*'s case. In the paralytic *Moriggi* and the degenerate *Bechelli* sleep maintains throughout its course a depth at least double that of the normal cases.

As regards the epileptics, these researches completely confirm some investigations made by one of us, who found that, contrary to the assertions of most authors that all neuropaths, including epileptics, have a restless and light sleep, as a matter of fact sleep was very deep in the majority (60 per cent.) of the cases of epilepsy with the classic symptoms. In the subject *Rubei*, moreover, confirmation is found of another fact also noted by one of us, that with increase in age of the patient and length of standing of the disorder sleep becomes much deeper. As a matter of fact, *Rubei* is the oldest of the three epileptics and has been the longest time an invalid.¹

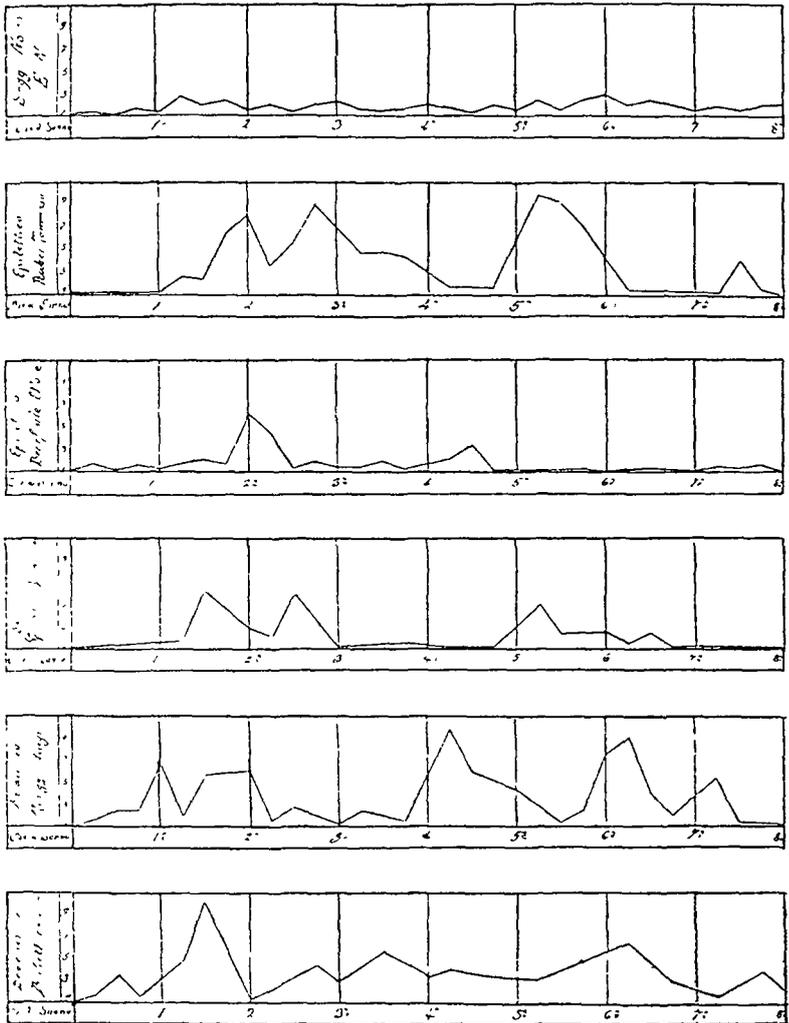
As to the maximum depth of sleep, in all the psychopaths, as in the normal cases, it falls in the first half of the second hour.

Examining the course of the curves for the psychopaths, we find that they differ among themselves much more than those of the normal subjects. In two only, *Benefalle* and *Bechelli*, does there occur a continuous lowering of height with continual oscillations, proceeding till the time of waking, while in the other three the curve presents peculiar characteristics. In the two epileptics *Rubei* and *Giannini* the oscillations are much fewer, but while in the former the depth is very great throughout, in the latter it remains at a much lower level. The curve of the epileptic *Benefalle* is the one which, as regards type, accords most with the normal, becoming continually lower, with oscillations, as the time of waking approaches; the curve of *Bechelli* comes next. In the paralytic *Moriggi* we find a type of curve which is more in accord with such normal curves as show a marked rise in the second half of the period. As to this rise, which we have termed *secondary*, the fact is to be

¹ Cf. De Sanctis: 'Die Träume,' etc.

noted that the two subjects in whom it appears most prominent are not dreamers at all, which does not bear out Lambranzi's hypothesis, at least for psychopaths; while, *per contra*, the two subjects who dream most frequently, *Rubci* and *Benefalle*, do not show it in any marked degree.

FIG. 11.



Relation between Subconscious Reactions and Waking-point in the Normal and Pathological Subjects.

TABLE VI.—RATIO BETWEEN SUBCONSCIOUS REACTION AND WAKING-POINT.

Hour of Sleep.	Normal				Psychopathic				
	E. N.	An. N	G. N	O. N.	Rubei.	Bene-falle	Gian-nini.	Morrigi	Be-chelli.
0.15	1.15	1.14	1.26	1.30	1.00	1.55	—	1.50	1.71
0.30	1.00	1.11	1.25	1.45	1.00	1.05	1.00	2.42	3.42
0.45	1.53	1.30	1.23	1.65	1.00	1.70	1.13	2.50	1.55
1	1.25	2.00	1.28	3.18	—	1.25	1.60	6.75	—
1.15	2.75	3.00	2.75	1.30	2.55	—	1.83	1.92	5.00
1.30	2.18	1.50	1.42	3.12	2.40	2.11	6.20	5.62	10.10
1.45	2.50	1.16	1.33	3.00	6.33	1.92	—	—	—
2	1.50	1.50	1.33	3.00	8.12	6.20	3.00	6.00	1.23
2.15	2.00	1.28	2.00	2.33	3.57	4.42	2.14	1.46	2.14
2.30	1.33	1.27	2.50	3.20	5.33	1.18	6.00	2.75	—
2.45	2.00	1.75	1.60	3.62	9.06	1.90	—	—	4.25
3	2.33	2.00	2.00	2.00	—	1.48	1.00	1.16	3.00
3.15	1.83	2.00	2.40	1.75	4.74	1.50	1.14	2.33	—
3.30	1.40	1.60	1.25	1.25	4.85	1.83	—	—	5.80
3.45	1.83	1.50	1.22	1.77	4.54	1.12	1.55	1.33	—
4	2.00	1.66	1.75	2.00	—	—	—	—	3.60
4.15	1.91	1.80	2.50	1.80	1.84	2.08	1.00	10.50	4.00
4.30	1.15	1.25	1.50	2.33	—	3.60	—	6.00	—
4.45	2.00	1.33	1.25	1.75	1.80	1.00	1.00	—	3.30
5	1.60	2.00	1.50	5.00	—	1.11	—	4.50	—
5.15	2.50	3.00	1.50	4.00	9.85	1.09	5.00	—	3.14
5.30	1.66	2.28	2.00	1.50	9.22	—	2.25	1.25	—
5.45	2.50	2.66	2.00	3.00	7.00	1.17	—	2.62	5.00
6	3.00	1.66	1.75	3.00	—	1.00	2.40	7.60	—
6.15	2.00	1.14	1.65	2.66	1.23	1.11	1.50	9.00	6.60
6.30	2.50	2.25	2.00	2.00	1.08	1.28	2.20	4.00	—
6.45	2.20	1.20	1.85	2.80	1.00	1.09	1.10	2.00	3.00
7	1.50	1.25	1.25	2.00	—	1.00	1.14	—	2.33
7.15	2.00	1.50	1.33	2.66	1.09	1.63	—	5.50	1.72
7.30	1.50	2.00	1.33	1.75	4.00	1.50	1.10	1.00	—
7.45	2.00	2.00	1.50	1.52	1.64	1.65	—	—	4.00
8	2.00	—	—	1.75	1.00	1.06	1.60	1.00	2.00

If, now, we turn our attention to the curves of subconscious reaction, we observe at once that they do not take a course constantly proportional to the curve of waking; now they approach, now they recede from the latter. Other observers have already noted that the reflexes have various modes of action during sleep; thus Marie de Manacéne maintains that in sleep the reflexes are more vigorous and quicker to act than in waking, being no longer 'réprimés et maîtrisés par la vie cérébrale consciente'; this view is contradicted by Tarchanoff, who, after cutting the spinal cord of young dogs above the lumbar region, found that the reflexes in the hind legs, which then depended on the cord alone, did not alter notably from the waking state, while

those of the front legs, which were still under the control of the brain, underwent very marked diminution. This hint will suffice to show how important is the analysis of the curve of subconscious reaction in all our subjects.

How much higher a ratio between subconscious reaction and waking-point is maintained in the psychopaths than in the normal subjects, is shown numerically in Table VI. and graphically in the curves. (Compare Table VI. and Fig. 11.)

It is readily seen that the disproportion between the curve of the waking-point and that of subconscious reaction does not become very accentuated in the normal subjects. During the first hour of sleep in all the subjects, both normal and psychopathic, the ratio between subconscious reaction and awaking is very small and nearly uniform for the entire hour, which would go to show that the reflex activity remains at a very high threshold; while in the next hour the ratio in every case takes a very much higher value, and it is precisely in this hour that the depth of sleep reaches its maximum. In the succeeding hours we find that the course of the curve of subconscious reaction is less regular among the psychopaths than among the normal subjects. In the epileptic *Ruberi*, in whom the depth of sleep is greatest, we also find the greatest difference between the two curves; it is worthy of mention that the ratio remains at a very high level for two thirds of the duration of sleep. In *Benefalle*, on the contrary, the differences between the two curves are, in general, not at all marked. They are rather more marked in *Bechelli*. In *Giannini* the greatest difference occurs between the first hour and a half and the second hour and a half; in *Moriggi* a maximum difference occurs not only between the first half hour and second hour of sleep, but also in connection with the secondary rise of the waking curve (sixth hour). As regards dreams, it is important to note that they occur in every period of sleep, even at the beginning, *i. e.*, when the depth is greatest; but they are more frequent and more vivid in the later hours of the night, particularly towards morning. As to the modifying influence of external stimuli on the course of dreams, we were several times able to note it. Thus the subject An. N. related that while she was dreaming of chatting with acquaint-

ances and was about to leave the house, of a sudden she was seized with a violent headache, so that she was compelled to turn back. (Precisely at that moment the experiment was being performed, as usual, with pressure on the forehead.) Another time the subject E. N. told of feeling as if she had just been bitten by a large spider. Similarly, O. N. dreamed several times of being engaged in a fight with other persons and of receiving a blow on the head with a stick or knife; etc.

The dream activity of the psychopaths, on the other hand, is slight. It is *nil* in the paralytic *Moriggi* and very small in the degenerate *Bechelli* and the epileptic *Giannini*; in the other two it is somewhat greater.

Further, in the psychopaths dreams occur more seldom in the first half of the sleep period and more frequently in the second; they are generally trivial in character, sometimes erotic, and the memory of them is for the most part very cursory. We were never able to observe any influence of the stimulation on the content of the dream.

It is worth while to note the tendency on the part of one subject to believe himself a greater dreamer than he really is. Are we dealing here, perhaps, with a fact of auto-suggestion?

As regards the influence of the epileptic attacks on sleep and dreams we can say little, as these occurred very seldom during the period of experimentation. They seemed to exert no noteworthy influence in the case of the psychopaths; in *Rubei* they appeared to produce a diminution in the usual depth, and in *Benefalle* a slight increase. The recollection of dreams is less on nights in which attacks occur.

But our cases are too few to justify our laying stress on general conclusions. Moreover, inspection of the tracings will speak more plainly than any comment which we can make.

A word, in closing, as to the method. It seems to us that the depth of sleep may be satisfactorily measured by the method of tactile-pressure excitations. However, in future researches it will be necessary to employ an instrument with a spring having a greater length of compressibility and bearing, in consequence, a finer numerical gradation. To obtain this it is of course necessary to make certain changes in the ordinary

graduated esthesimeters and algesimeters. One of us is at present engaged in this task, namely, that of constructing a rational and practical *Hypnometer*.

ROME, August, 1901.

NOTE.—An abstract of this article was read by Professor Sante De Sanctis at the Fifth International Congress of Physiology, held at Turin, September 17 to 23, 1901.