Illustrations to article by
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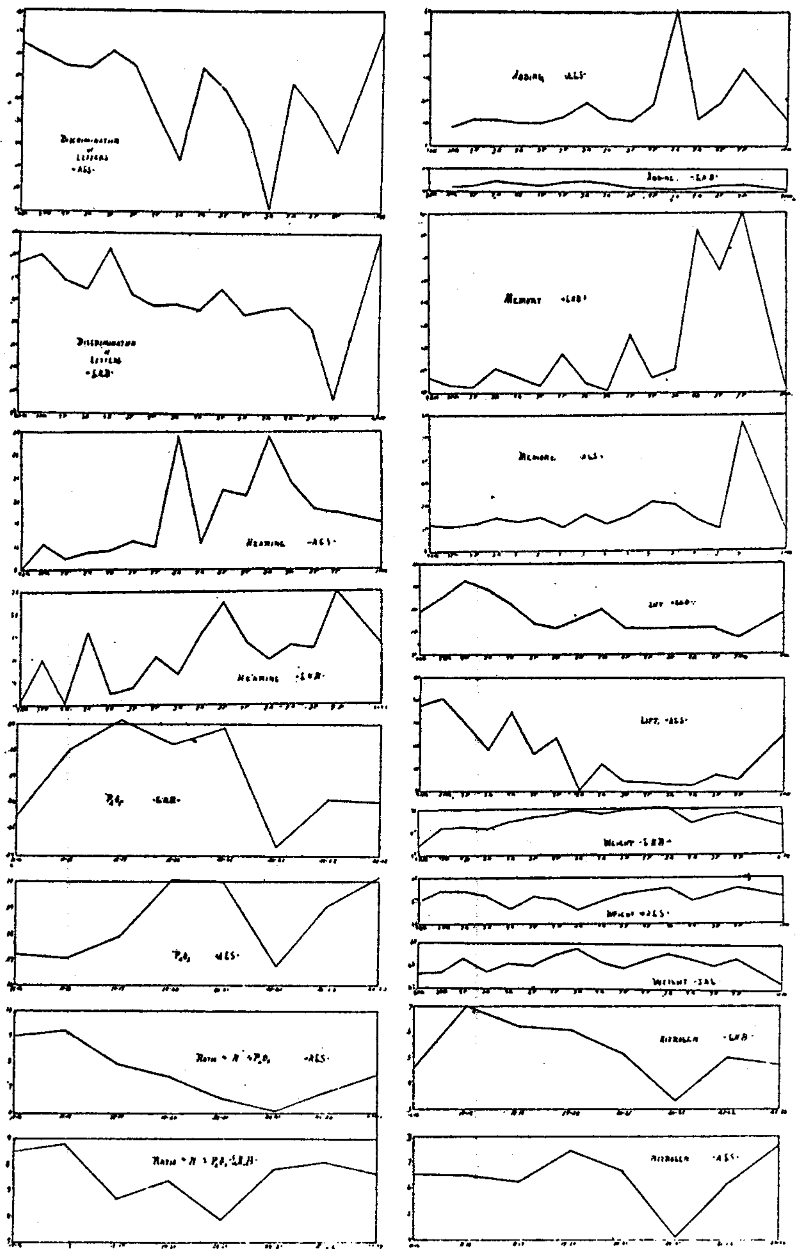

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THE PSYCHOLOGICAL REVIEW.

STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF THE UNIVERSITY OF IOWA.

ON THE EFFECTS OF LOSS OF SLEEP.[1]

BY PROFESSOR G. T. W. PATRICK AND DR. J. ALLEN GILBERT.

The object of the following experiments was to determine some of the physiological and mental effects of enforced abstinence from sleep. In an address before the International Medical Congress at Rome in 1894, M. de Manacéine reported some experiments upon young dogs on the effects of absolute insomnia. The animals were kept from sleeping, and died at the end of the fourth or fifth day. (*Arch. Ital. Biol.* XXI, 2. PSYCHOLOGICAL REVIEW II, 1, p. 81.) So far as is known to the present writers, no experiments upon human subjects have hitherto been made on enforced insomnia for psychological purposes. The plan of our experiments was as follows: It was proposed to keep the subjects awake continuously for about 90 hours, to make a series of physiological and psychological tests upon them at intervals of 6 hours in respect to reaction-time, discrimination-time, motor ability, memory, attention, etc.; to observe secondly, the general effects of insomnia, and finally to observe the depth, character and amount of sleep following the period of waking. This plan was successfully carried out with three subjects, the depth of sleep being ascertained, however, in the case of only one. The subjects were in each case constantly attended by either one or two watchers.

[1] One of the three experiments described in this article was reported in a paper by Professor Patrick at the December meeting of the American Psychological Association at Philadelphia.

They took their regular meals at 7 a. m., 12.30 p. m., and 6 p. m., the food being normal in character and amount. In addition they ate a very light lunch at 12.30 a. m. The days were spent in occupations conforming as nearly as possible to the usual daily work of the subject. The nights were spent at first in reading or playing light games, and toward the end of the experiments in any way best adapted to keep the subjects awake, such as walking, working upon apparatus, or playing active games. Each set of experiments, however, took nearly two hours, so that this occupation consumed almost one-third of the time both day and night.

We give first a general account of the subjects and experiments. The first subject, J. A. G., is a young man of 28 years, assistant professor in the University. He is unmarried, of perfect health, of nervous temperament, of very great vitality and activity. He is accustomed to about 8 hours of sound sleep from 10 p. m. to 6 a. m. He awoke at his usual time Wednesday morning, November 27, and remained awake until 12 o'clock Saturday night. The second night he did not feel well and suffered severely from sleepiness. The third night he suffered less. The fourth day and the evening following he felt well and was able to pass his time in his usual occupations. During the last 50 hours, however, he had to be watched closely, and could not be allowed to sit down unoccupied, as he showed a tendency to fall asleep immediately, his own will to keep awake being of no avail. The daily rhythm was well marked. During the afternoon and evening the subject was less troubled with sleepiness. The sleepy period was from midnight until noon, of which the worst part was about dawn.

The most marked effect of the abstinence from sleep with this subject was the presence of hallucinations of sight. These were persistent after the second night. The subject complained that the floor was covered with a greasy-looking, molecular layer of rapidly moving or oscillating particles. Often this layer was a foot above the floor and parallel with it and caused the subject trouble in walking, as he would try to step up on it. Later the air was full of these dancing particles which developed into swarms of little bodies like gnats, but colored red, purple, or black. The subject would climb upon a chair to brush them from about the gas jet or stealthily try to touch an imaginary fly on the table with his finger. These phenomena did not move with movements of the eye and appeared to be true hallucinations, centrally caused, but due no doubt to the long and unusual strain put upon the eyes. Meanwhile the subject's sharpness of vision was not impaired. At no other time has he had hallucinations of sight and they entirely disappeared after sleep.

The period of 90 hours being completed at 12 o'clock Saturday night, the subject was allowed to go to sleep, which he did immediately. He was awakened at intervals of one hour to ascertain the depth of sleep, but fell asleep again at once after each awakening, and slept until half past ten Sunday morning. He awoke then spontaneously, wholly refreshed, felt quite as well as ever, and did not feel sleepy the following evening. He slept, however, two hours later than usual Monday morning.

The special tests made upon this subject, 14 in number, are shown with the results in Table I. They were all repeated every 6 hours throughout the whole period, and repeated again finally after the subject had slept. The results of the latter tests are shown in the last column. In reaction-time and discrimination-time, the effects of practice were eliminated as far as possible by preparatory training preliminary to the experiment. A few words of explanation of methods and apparatus are necessary. The pulse was taken at the beginning of each set of tests and then again at the end immediately after the subject was fatigued by tapping with the forefinger as rapidly as possible for 60 seconds. The subject was weighed the same time after each meal and in the same clothing. Grip was taken with an ordinary hand dynamometer. Pull was taken with the same instrument, the subject using the second finger of each hand.

For reaction-time the stimulus was a telephone click, with signal, the reaction being the release of a key, the subject being in the dark room, away from the recording drum. Each reaction-time given represents the mean value of from 10 to 15 reactions. For discrimination a modification of the same apparatus was used, the subject reacting only to the loud stimulus.

J. A. G.

TABLE I.

	November 27.			November 28.				November 29.				November 30.				Dec. 1. After Sleep.
	9 a.m.	3 p.m.	9 p.m.	3 a.m.	9 a.m.	3 p.m.	9 p.m.	3 a.m.	9 a.m.	3 p.m.	9 p.m.	3 a.m.	9 a.m.	3 p.m.	9 p.m.	12 m.
1. Pulse	88	89	68	62	81	72	74	74	68	65	63	63	61	72	61	77
2. Temperature (Centigrade)	36.72	36.39	36.17	35.78	36.56	36.67	36.56	35.67	36.44	36.56	36.11	36.28	36.00	36.50	36.39	36.17
3. Weight (Kilograms)	67.70	67.75	68.30	67.78	68.19	68.04	68.52	68.83	68.27	67.99	68.35	68.60	68.41	68.13	68.47	67.39
4. Grip (Kilograms)	48.08	46.95	51.94	47.86	47.17	44.45	40.83		44.91	48.08	47.17	45.36	43.99	49.67	43.77	50.35
5. Pull (Kilograms)	27.22	27.67	28.12	26.31	26.76	25.86	22.68	22.68	26.31	25.86	24.95	23.59	22.68	26.99	23.13	27.67
6. Reaction-time. Mean (Sec.)	.122	.132	.129	.149	.133	.129	.139	.143	.146	.130	.144	.146	.139	.165	.148	.128
Mean Variation.	9	26	28	20	10	16	24	25	21	10	50	21	31	26	20	13
7. Discrimination-time. Mean (Sec.)	.258	.240	.242	.253	.225	.215	.216	.271	.207	.210	.213	.213	.206	.201	.158	.205
Mean Variation	50	56	51	48	38	32	43	67	63	63	40	65	62	36	43	52
8. Sensibility to pain. Lower threshold		3250	3000	3100	2750	3100	2650	2800	3150	2800	2750	2850	3300	3150	3250	3200
Upper threshold		4450	4350	4550	4050	4650	4450	4300	4600	4250	4200	4300	4550	4850	4400	4800
9. Acuteness of Vision (cm.)	137.2	132.1	139.7	134.6	142.2	156.2	150.5	120.6	137.2	143.5	137.2	152.4	148.6	156.8	171.4	125.7
10. Memory (Sec.)		540	260	159	290	330	200	105	240	70	262	290	123	190	545	125
11. Addition of Figures		228	254	248	238	249	223	215	205	216	196	210	200	250	224	277
12. Voluntary Motor Ability	42.2	42.2	40.1	39.0	40.0	41.2	38.6	35.5	39.5	39.0	35.0	38.9	41.0	39.0	39.7	41.3
13. Fatigue. Per cent. of Loss	24.1	24.6	22.6	20.5	18.0	24.0	13.7	12.1	17.0	13.9	11.4	20.6	17.6	17.9	13.6	17.7
14. Pulse after Fatigue	89	81	92	82	75	76	58	59	62	62	54	58	63	59	52	84

Sensibility to pain was tested by a specially prepared algometer, arranged to bring any desired pressure upon the middle of the fingernail of the first finger, the finger being inserted between two horizontal bars, the one pressing upon the fingernail being a very dull wooden knife edge. The figures record the pressure in grams, the lower threshold representing the first feeling of pain, the upper threshold the point at which the pain could no longer be endured. Acuteness of vision was tested in the dark room by finding the greatest distance at which the subject could read a section of a page from Wundt's *Studien* by the light of one standard candle at a distance of 25 cm. The memory test consisted in committing to memory 10 of the Ebbinghaus nonsense syllables. These were used in the ordinary way, but we consider this test of very slight value, for it is impossible not to learn these lists by association, and impossible to get different lists which offer equal ease or difficulty in association. The effects of loss of sleep upon attention and association we attempted also to ascertain by determining the greatest number of figures in prepared columns that could be added in three minutes. Voluntary motor ability was tested by having the subject tap with the forefinger as rapidly as possible upon a key for 5 seconds, using the recording drum and graphic chronometer. He then continued tapping for 60 seconds to fatigue the muscles. The number of taps during the last 5 seconds was then recorded. In the table is given first the number of taps in the first 5 seconds, then the percentage of loss in the last 5 seconds due to fatigue. The results of the special tests may best be studied from the table. Attention is called, however, especially to the following. The steady increase in the subject's weight during the experiment and the sudden decrease in weight after sleep are noteworthy, and apparently not to be accounted for by accidental circumstances. His average weight during the last 24 hours was 18 ounces greater than the average during the first 24 hours, and at 9 o'clock Saturday night the subject weighed 27 ounces more than at 9 o'clock Wednesday morning. During the 10½ hours' sleep, however, which followed the experiment, the subject lost 38 ounces, being 11 ounces more than he had gained during the experiment. In the tests with the dynamometer the subject lost slightly and gradually in strength of both grip and pull, regaining all after sleep. On Saturday afternoon, however, the subject made what appeared to be a spurt, in view, perhaps, of the approaching end, and gripped and pulled nearly as much as at the beginning. The reaction-time beginning with 122σ increased somewhat regularly, reaching its maximum, 165σ Saturday afternoon, after 81 hours without sleep, and dropped back to the normal immediately after sleep. The discrimination-time appears to decrease, but as it does not increase after sleep the result cannot in this case be attributed to loss of sleep. The acuteness of vision uniformly *increased* throughout the experiment, falling below the normal after sleep. The slight retardation in the increase in the second night corresponds with the period of slight sickness at that time. There is a significant decrease in voluntary motor ability. The decrease in this subject's pulse-beat after fatigue by tapping is abnormal and apparently a result of loss of sleep.

The above experiment upon J. A. G. was regarded as somewhat preliminary. It was, therefore, decided to repeat the experiment upon two other subjects, making such modifications in the special tests and apparatus as seemed to be desirable. The second subject, A. G. S., was a young man of 27 years, instructor in the University, unmarried, quiet and of excellent health. The third subject, G. N. B., was a young man of 24 years, instructor in the University, unmarried, of German parentage, stout and perfectly healthy. At the time of the experiment, A. G. S. was accustomed to 9 hours of sound and regular sleep; G. N. B. to 8 hours. These two subjects entered upon their sleep fast at 7 o'clock, Tuesday morning, March 17, 1896. 90 hours was again the period determined upon. On Friday night, March 20, at 11.15, the last set of experiments being completed, they were allowed to retire, so that their waking period was actually 88¼ hours. In the case of these two subjects there was no illness, no hallucinations of sight, and no serious suffering or discomfort. A. G. S. became very sleepy during the last 24 hours and had to be watched constantly. On Friday, at 9 p. m., after a brisk walk in the cool air, his temperature sank to 35.3° Cent. (95.6° F.), but in 15 minutes rose to 36.3° Cent. (97.3° F.). Of the three subjects he was the only one who apparently could not have prolonged the experiment beyond the period of 90 hours without danger. G. N. B. had less trouble in keeping awake and showed outwardly but slight effects of the abstinence from sleep. Both subjects slept immediately upon retiring at 11.15 p. m., Friday. They both slept uninterruptedly until 10.30 a. m., Saturday. They both awoke then for a few moments and slept again, A. G. S. until 11.15 a. m., G. N. B. until 2.40 p. m. They both felt wholly refreshed upon awaking, required no further extra sleep, and felt no ill effects from the experiment.

The special tests made upon these two subjects are shown with the results in Table II. and Table III., and exhibited, in part, in graphic form in the subjoined curves. They were as before, repeated every 6 hours. To eliminate, as far as possible, the effects of practice, the tests were begun two or three days before the beginning of the sleep fast. The first three sets of results in the tables, being taken the first day before any loss of sleep, should represent the normal reaction of the subject. These, taken together with the results of the tests made after awaking shown in the last column of the tables, make a fairly adequate standard for comparison with the results obtained during the sleep fast. The tests in respect to pulse, temperature, weight, grip, reaction-time, discrimination-time, sharpness of vision, voluntary motor ability, and fatigue, were the same as described above for the first subject. The strength of pull was taken with an ordinary lift dynamometer, the subject, standing upon a small platform with bent knees and straightened back, lifting his utmost by means of two handles connected by ropes with a large spring balance. In the memory test, the nonsense syllables were discarded and 18 figures substituted. 18 small squares of cardboard were provided upon which were printed the 9 figures, each figure thus appearing twice. For each experiment a random order of these figures was made, and then modified, if necessary, to prevent adjacence of same figure and suggestive combinations. The subject, timed with a stop watch, committed to memory the list, the watch being stopped when the subject announced his readiness to recite the list. Each experiment consisted in committing to memory three such lists. The tables show in seconds the average of these three trials in each case. No. 11 was a test in adding numbers. The sheets of figures used by Miss Holmes in studying fatigue in school children and described in the Pedagogical Seminary, Vol. III., No. 2, were used. The subject was required to add each set of 40 figures by twos, setting down the results. He then added the results and then added the original figures in a different order. Any variation recorded in the two results indicated errors. The tables give the time required for the whole process. Test No. 12 was designed to determine the subject's facility in seeing and naming letters. A page from THE PSYCHOLOGICAL REVIEW was used; the subject reading the lines backward merely named the letters as fast as possible. The tables record the number of letters, average of two trials, named in one minute. Test No. 9 was designed to show the acuteness of hearing by discrimination of the intensity of two sounds. The sounds were vibrations of a tuning fork heard in a telephone in the silent room, the intensity being varied by a resistance board, only one telephone being used. The results in the tables have only relative value, indicating the number of divisions upon the resistance board by which the resistance had to be increased to enable the subject to detect the difference in the intensity of the sounds.

We may call special attention to a few of the results. In both subjects we again observe an increase in weight throughout the experiment with decrease after sleep. But with these subjects the decrease is less than the increase. In strength of lift both subjects lose quite regularly and seriously, but regain nearly all after sleep. In the memory tests, the results are very marked, especially with G. N. B. His average time in normal condition for committing the 18 figures was 134 seconds. No remarkable increase in this time was observed until the expiration of 72 hours. At 9 a. m. Friday the subject required 960 seconds to commit the first set of figures and failed entirely to commit the third set, working at it for *20 minutes*. At 9

A. G. S.

TABLE II.

	March 17.			March 18.			
	9 a. m.	3 p.m.	9 p.m.	3 a.m	9 a.m.	3 p.m	9 p.m.
1. Pulse	74	68	75	61	73	73	72
2. Temperature (Centigrade)	37.11	36.39	36.78	37.11	37.00	37.22	36.89
3. Weight (Kilograms)	67.02	67.47	67.47	67.24	66.68	67.24	67.13
4. Grip (Kilograms)	33.56	39.92	30.39	33.11	33.56	29.03	24.04
5. Pull (Kilograms)	155.58	163.30	140.62	117.94	150.60	113.40	127.00
6. Reaction-time. Mean	.121	.134	.138	.134	.141	.138	.143
Mean Variation	0.6	1.5	0.8	0.9	2.2	1.2	7.1
7. Reaction-time with discrimination and choice. Mean	.158	.200	.310	.175	.202	.201	.182
Mean Var.	5.9	4.2	7.4	4.1	3.5	4.5	2.9
8. Acuteness of Vision (C.M.)		103.8	103.8	113.6	122.3	112.8	96.1
9. Discrimination of Sound	8.0	12.5	10.0	11.2	11.6	13.0	12.5
10. Memory (Sec.)	115	110	112	143	129	145	102
11. Addition of Figures		85	119	118	105	103	130
12. Naming of Letters	165	160	155	154	162	155	134
13. Voluntary Motor Ability	38	36	33	37	41	36	30
14. Fatigue. Per cent. of Loss	29.0	13.9	15.1	13.5	29.3	16.6	13.3
15. Pulse after Fatigue	80	69	69	66	79	71	77

	March 19.				March 20.				Mar. 21. After Sleep.
	3 a.m.	9 a.m.	3 p.m.	9 p.m.	3 a.m.	9 a.m.	3 p.m.	9 p.m.	1 p. m.
1. Pulse	71	79	62	67	61	74	68	63	76
2. Temperature (Centigrade)		36.89	36.44	36.56	36.33	37.06	36.67	35.33	37.22
3. Weight (Kilograms)	66.68	67.02	67.36	67.47	67.59	67.02	67.36	67.59	67.24
4. Grip (Kilograms)	24.04	28.12	29.48	26.31	26.76	29.03	30.39	27.22	33.56
5. Pull (Kilograms)	81.65	107.05	89.36	58.45	49.44	49.44	95.26	92.99	131.54
6. Reaction-time. Mean	.154	.147	.150	.141	.146	.143	.148	.193	.160
Mean Variation	1.5	1.7	1.9	2.4	1.5	1.9	2.5	4.0	2.9
7. Reaction-time with discrimination and choice. Mean	.162	.188	.280	.189	.170	.222	.176	.311	.231
Mean Var.	3.6	4.1	8.3	4.7	3.9	5.3	4.3	8.0	6.0
8. Acuteness of Vision (C.M.)	105.1	115.4	116.6	119.2	109.0	119.7	118.0	123.3	119.7
9. Discrimination of Sound	31.0	12.5	22.0	21.0	31.0	23.0	18.7	18.0	16.5
10. Memory (Sec.)	159	120	152	217	202	139	100	570	88
11. Addition of Figures	192	111	108	185	610	113	190	345	109
12. Naming of Letters	113	154	144	127	91	147	135	117	171
13. Voluntary Motor Ability	34	36	36	37	28	39	38	34	42
14. Fatigue. Per cent. of Loss	26.5	19.4	25.0	21.7	0.00	20.5	23.7	26.5	21.4
15. Pulse after Fatigue	65	72	75	64	62	70	64	61	83

G. N. B.

TABLE III.

	March 17.			March 18.				March 19.				March 20.				Mar. 21. After Sleep.
	9 a.m.	3 p.m.	9 p.m.	3 a.m.	9 a.m.	3 p.m.	9 p.m.	3 a.m.	9 a.m.	3 p.m.	9 p.m.	3 a.m.	9 a.m.	3 p.m.	9 p.m.	4 p.m.
1. Pulse	63	64	63	68	68	67	67	69	70	62	64	68	74	65	73	84
2. Temperature (Centigrade)	36.22	36.44	36.33	37.17	36.78	37.22	36.56	36.67	36.33	36.61	36.56	36.89	37.06	35.78	36.56	37.22
3. Weight (Kilograms)	68.49	69.29	69.29	69.17	69.51	69.74	69.85	69.99	69.85	69.99	70.08	70.08	69.40	69.74	69.85	69.29
4. Grip (Kilograms)	42.64	34.47	38.10	33.11	39.36	43.09	37.65	34.01	37.19	37.65	42.64	43.09	44.45	47.63	44.00	41.73
5. Pull (Kilograms)	118.84	129.28	146.15	138.35	125.19	117.94	106.60	111.13	120.20	113.40	113.40	113.40	113.40	111.13	95.26	117.94
6. Reaction-time. Mean	.145	.148	.157	.130	.142	.143	.134	.187	.136	.137	.141	.123	.139	.141	.142	.124
Mean Variation	1.8	1.3	1.4	0.8	1.1	1.7	1.8	2.9	3.7	1.0	1.7	1.8	1.1	2.9	3.2	1.6
7. Reaction-time with discrimination and choice. Mean	.167	.170	.200	.140	.185	.177	.214	.170	.178	.147	.158	.133	.153	.143	.175	.166
Mean Var.	3.6	7.2	5.6	1.4	3.7	1.6	5.5	4.6	6.8	1.8	2.7	3.7	2.3	1.2	2.3	4.0
8. Acuteness of Vision		110.3	115.4	141.0	132.1	134.6	127.4	129.5	134.6	119.2	137.2	126.9	130.9	128.7	135.9	134.6
9. Discrimination of Sound	12.8	20.0	12.5	24.8	14.0	15.0	20.5	17.5	24.5	30.0	23.0	20.0	22.5	21.0	32.0	21.5
10. Memory	170	133	128	206	170	135	273	143	112	353	169	201	820+	645	900+	106
11. Addition of Figures		120	125	141	135	122	140	141	135	120	118	115	118	123	130	109
12. Naming of Letters	177	180	169	165	183	163	158	158	156	165	154	156	157	148	117	188
13. Voluntary Motor Ability	41	37	38	39	41	42	34	39	39	39	40	44	42	42	40	40
14. Fatigue. Per cent. of Loss	19.5	16.2	26.3	28.2	29.3	28.6	14.7	28.2	25.6	33.3	25.0	34.1	26.2	26.2	35.0	22.5
15. Pulse after Fatigue	70	69	60	69	79	63	64	69	79	64	55	64	77	69	70	96

p. m. he could not commit the figures, and having made no progress after 15 minutes he desisted. The attention could not be held upon the work. A kind of mental lapse would constantly undo the work done. With both subjects an energetic 'waking up' by means of brisk walking and fresh air was often necessary during the latter time in order to address themselves to these mental tasks. After sleep, A. G. S. easily committed the figures in 88 seconds, and G. N. B. in 106 seconds, this being in both cases the shortest time in which the work was done. In respect to the number of letters named in one minute, there is with both subjects a steady decrease with the progress of the insomnia, with immediate return to the normal after sleep. In adding numbers similar results appear in a marked form in the case of A. G. S., but with G. N. B. adding time was affected but slightly. Reaction-time increases with A. G. S., as with J. A. G., but the reaction-time of G. N. B. is not lengthened. In respect to reaction with discrimination and choice the results are irregular and unsatisfactory. There is an irregular increase with A. G. S., but an actual shortening of time with the other two subjects.

Attention should be called to the length of sleep following the sleep fast and its relation to the whole amount of sleep lost. A. G. S. found it necessary to make up but 16 % of the lost sleep, as measured by time; J. A. G. 25 %; G. N. B. 35.3 %; As restoration was in each case apparently complete, explanation must be sought in one of two hypotheses or in both. The first is that, owing to the greater 'depth' of sleep after the sleep fast, the anabolism accompanying restoration was more rapid. The second is that the partial restoration which normally accompanies the waking period was, in the case of this long waking, greater than usual; that the subjects, in other words, although apparently awake and, indeed, as wide awake as they could be kept, were nevertheless at times partially asleep. There are reasons to believe that the results depend upon both of these causes. Our subjects well illustrated the fact that sleep is a matter of degree. All that could be done both by objective diligence and subjective effort to keep the subjects wide awake was done. If the subject, contrary to his own intention, closed his eyes, although he immediately opened them in response to his watcher's command, still there was time for a short and, perhaps, refreshing 'nap.' Again, one of our subjects, who was kept jogging about the streets during a sleepy period at 5 a. m., afterwards could remember little about the walk. Another subject, standing with eyes open, reflectively gazing at a piece of apparatus upon which there were some pieces of rope, suddenly reported that he had had a dream about a man being hung. With our first subject we undertook to test the delicacy of the muscle sense by means of lifting weights. These weights were small tin pails loaded with graded weights and lifted by a detachable handle. Lifting these pails was found to be very monotonous and sleepy work. The subject was not permitted to let his attention wander, and yet he reported at least four dreams. For instance, he lifted two pails, carefully judged their relative weight, and as he set the second one down, instead of saying that No. 1 or No. 2 was the heavier, he said 'trimmings,' evidently having fallen asleep as he was lifting or setting down the pails and dreamed that they contained trimmings. It must be understood that these dreams were instantaneous and the subject as wide awake as he could be kept, but these facts reveal a cerebral condition related to sleep. This hypothesis alone, however, would not seem to account fully for the small proportion of sleep made up. And, indeed, a study of our special tests shows that restoration took place chiefly during the profound sleep following the sleep fast, and took place rapidly. That this sleep was actually more profound and that the profound part of it was longer than usual was shown by our experiments in depth of sleep in the case of J. A. G. reported below.

The depth of normal sleep for the consecutive hours of the night has been studied by Michelsen and by Kohlschütter, and the results presented in the so-called sleep curves. The depth of sleep was determined by these observers by the intensity of sound necessary to awaken the sleeper. Their results show the greatest depth of sleep at the end of the first hour. After the first hour the curve drops abruptly and rapidly. Already at the end of the second hour sleep is light and continues slowly

to become lighter until morning. In the case of our first subject, J. A. G., we attempted to ascertain the relative depth of sleep for the consecutive hours of the profound sleep following the sleep fast, for the sake of comparing our results with the normal sleep curve. As a sound stimulus would not be practicable, for the reason that, the experiments all being made in the same period of sleep the sleeper would soon become accustomed to it, we substituted a pain stimulus. An electric garter, to which the subject had become accustomed by wearing it for some nights preceding the sleep fast, was attached to the sleeper's ankle and connected with an induction coil in an adjoining room, and so arranged that the current could be closed for a constant time, viz., .334 sec., by means of a pendulum, and that the strength of the current could be varied by means of a resistance tube. It was agreed that the sleeper should announce his awaking by means of an electric button at his bedside. The current was turned on at intervals of one hour. Unfortunately the least resistance that could be arranged with the resistance tube failed to awaken the sleeper at the first three periods, so that it was necessary to cut out the tube and the pendulum and apply the direct current and measure it roughly by the time the circuit had to be closed. Our results, therefore, lack the exactness necessary for the construction of a curve or table, but still show plainly the relative depth of sleep for the consecutive hours. The deepest sleep was found at the end of the second hour, when the subject could not be aroused sufficiently to ring the bell, but responded by a cry of pain. The next deepest sleep was found at the end of the first hour and the next at the third hour. The current used at these three times was one which it was altogether out of the question for the subject to endure when awake. At the end of the second hour, just after the experiment, we entered the sleeper's room and attempted to awaken him by speaking to him in a loud voice without avail. At the fourth hour the sleep was less deep, and continued to become lighter regularly until awaking, but the decrease in depth was very much less rapid than in the normal sleep curves reported above. At 10 a. m. a very slight current awakened the sleeper, and at 10:30 he awoke spontaneously as stated.

The tendency of our subjects to have short semi-waking dreams suggested to us that in enforced insomnia there would be offered a good opportunity for a study of dreams. This, of course, was incompatible with our purpose, but in the cases of A. G. S. and G. N. B., at the end of the sleep fast and before allowing the subjects to retire, we undertook a few experiments in dreams. We allowed the subjects to sit with head supported behind, and to sleep for periods of 30 seconds, one

TABLE IV.

J. A. G.	2d day before experiment.	1st day before experiment.	1st day of experiment.	2d day of experiment.	3d day of experiment.	4th day of experiment.	4th day of experiment. (Sleep.)	1st day after experiment.	2d day after experiment.
Hours			24	24	24	14	11¾	24	
Total amount urine (ccm.)			1475	1370	1270	805	400	950	
Grams N. per hour			0.901	0.929	0.667	0.723	0.490	0.723	
Grams P_2O_5 per hour			0.1327	0.1438	0.1105	0.1304	0.0564	0.0888	
Relation P_2O_5 to N.			1: 6.8	1: 6.5	1: 6.0	1: 5.5	1: 8.7	1: 8.1	
A. G. S.									
Hours	38		24	24	24	13½	12¾	24	24
Total amount urine (ccm.)	1308		1510	1700	1420	750	525	1000	1240
Grams N. per hour	0.655		0.661	0.628	0.745	0.661	0.414	0.6175	0.761
Grams P_2O_5 per hour	0.0765		0.0708	0.0791	0.1011	0.1000	0.0674	0.0907	0.1023
Relation P_2O_5 to N.	1: 8.6		1: 9.3	1: 7.9	1: 7.4	1: 6.6	1: 6.1	1: 6.8	1: 7.5
G. N. B.									
Hours	24½		24	24	23	13½	16½	24½	24
Total amount urine (ccm.)	920		1240	1205	1730	650	365	705	705
Grams N. per hour	0.4853		0.7094	0.6270	0.6123	0.5195	0.3390	0.5020	0.4765
Grams P_2O_5 per hour	0.0574		0.0802	0.0931	0.0826	0.0815	0.0435	0.0616	0.0613
Relation P_2O_5 to N.	1: 8.5		1: 8.8	1: 6.7	1: 7.4	1: 6.4	1: 7.8	1: 8.1	1: 7.8

minute, three minutes, etc., then awakening them and asking for their dreams. No dreams were obtained in any case. If the period was less than one minute the subject sometimes had a hazy memory of something like a dream which could not be put into words. If the sleep was longer it was apparently profound and dreamless. These rough experiments confirm, of course, the generally accepted opinion that dreams are the product of light sleep, representing indeed the reinstatement of consciousness after the early and profound sleep.

Through the kindness of Dr. E. W. Rockwood, of the University, a chemical analysis of the urine was made throughout the experiments in the case of each of the subjects. The object of the analysis was to determine the influence of continued waking upon the relative amounts of nitrogen and phosphoric acid respectively excreted. The results are fully exhibited in Table IV. as compiled by Dr. Rockwood. Considered in relation to the fact that each subject increased in weight during the insomnia, the results are significant. They show not merely that there was an increase in the excretion of both nitrogen and phosphoric acid during the period of insomnia, but that relatively more phosphoric acid was excreted than nitrogen. A certain amount of support is thus given to the theory of a special connection between mental activity and the katabolism of the phosphorized bodies of the nervous system.