

**THE RELATIVE INFLUENCE OF MENTAL AND MUSCULAR WORK ON THE PULSE-RATE AND BLOOD-PRESSURE.** BY R. D. GILLESPIE, *McCunn Scholar in Physiology.*

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STUDIES of the changes in pulse-rate resulting from various kinds of stimuli are numerous. As Tigerstedt has remarked: "It is an old and well-known fact, that the pulse-rate changes in one or other direction under the influence of all kinds of stimuli." But not much is known of the influence of mental work on the rate of the heart, and in the results obtained there is a lack of unanimity. Yet the question is of some importance; for it has been suggested by Benedict<sup>(1)</sup> that "pulse-rate indicates, in a general way, internal muscular work and muscular tonus" and is consequently within limits, an index of metabolism. For this and other reasons it is desirable that definite data should exist as to the effect of mental work on the rate of the heart, and also on the blood-pressure. The data so far obtained are as follows:

*Pulse-rate.* Vaschide<sup>(2)</sup> observed a diminution in his pulse-rate during a period of nine days in which he worked for an examination, as compared with a period when he did a similar amount of light work (attending classes, etc.) but little or no mental work.

Benedict and Carpenter<sup>(1)</sup> found a rise in pulse-rate in students working at an examination paper. Dodge<sup>(3)</sup> criticised their methods, on the ground of unsatisfactory controls, but confirmed their results. Dodge's own methods are open to criticism. He investigated the pulse-rate changes in only three subjects, and this at a time when they were under a certain amount of emotional stress. In investigations of this sort it is essential to eliminate so far as possible all emotional factors. Dodge, however, recognised the importance of obtaining a basal rate before commencing an experiment, and attributed the lack of unanimity in other observer's results to neglect of this.

According to Binet and Henri<sup>(4)</sup>, mental calculation lasting for periods varying from a few seconds up to 3 or 4 minutes has almost constantly the effect of accelerating the pulse by 5 to 20 beats per minute. They attribute the acceleration to nervous influences. Mosso<sup>(5)</sup>

found, in observations on persons with cranial openings, that mental work was accompanied by an increase in brain-volume and an increase in amplitude of the cerebral pulse-wave. A plethysmographic tracing taken simultaneously from the forearm showed, however, no change. Hence the alteration in the cerebral pulse is, according to Mosso, not due to increased heart-action. Gley<sup>(6)</sup> confirmed this, and attributed the result to vasomotor influences on the carotid. Morselli<sup>(7)</sup> stated that the increase in brain-volume did not occur immediately and considered that it was caused by psychic activity. Binet and Courtier<sup>(8)</sup> experimented with prolonged intellectual work, and noted that the pulse was small and diastole high. Ioteyko<sup>(9)</sup> concluded that a strong short intellectual effort produced vaso-constriction and acceleration of pulse, followed by a slight falling off.

*Blood-pressure.* Kiesow<sup>(10)</sup> obtained negative results, while Binet and Vaschide<sup>(11)</sup> observed an increase of blood-pressure in the hands. Lahy<sup>(12)</sup>, measuring the blood-pressure just after the cessation of mental work, found that it was greater than the blood-pressure existing before the experiment began; and on comparing the results obtained by measuring the blood-pressure of soldiers after a march, with that of typists after a fast typing exercise, concluded the blood-pressure rose higher in mental than in physical work. This rather astonishing result depends on two fallacious assumptions: (a) that measurements taken after work are a reliable index of the changes in blood-pressure during work, and (b) that the muscular movements of typing produce no change in blood-pressure. L. Hill<sup>(13)</sup> observed an increase in blood-pressure as the result of what he cautiously calls "mental excitement"—the result of his ordinary day's work of lecturing, etc.—as compared with his blood-pressure on a holiday. Pillsbury and Griffiths<sup>(14)</sup> found a decrease in blood-pressure after mental work; but their observations were made only after work, the differences recorded were very small, and they were not always careful to ensure that a resting-level had been attained before work was begun.

*Methods.* The mental work in our experiments consisted as a rule in the addition of vertical columns of 4 single-digit figures. The figures were arranged in the way suggested by McQueen<sup>(15)</sup>, only the numbers from 5 to 9 being used, so that the 4-figure additions were of fairly uniform difficulty. The band of white paper on which the figures were inscribed (in blue, in large script about 5 cm. high and easily legible at the required distance of nearly 2 metres) travelled over three drums, one of which was actuated by an electric motor. The speed of presentation of the figures could be varied to suit each individual. The figures moved from right to

left, the subject adding vertically and proceeding from left to right. A screen was arranged so that no more than six columns of figures were exposed at the same time. This allowed for variations in the rate of addition, and facilitated the subject's attention by eliminating the rest of the figures from his vision. The experimenter noted the results of addition as they were called out by the subject, at the same time marking the passage of 10 sec. intervals: the rate of addition could thus be estimated. Twenty-three subjects were available and over 80 experiments in three series were carried out.

The blood-pressure readings were taken by means of a carefully-calibrated Tycos instrument attached to the arm placed at the level of the subject's heart. A Tycos was used because from it readings can be taken rapidly with a minimum of disturbance to the subject. The pulse-rate was counted at the wrist. In all cases, care was taken that the blood-pressure and pulse-rate had reached resting-level before an experiment. The duration of an experiment varied from 5 to 30 minutes. Three distinct series of experiments were carried out—the first series with a group of ten male students, the second with five (male) laboratory workers, and the third with a group of eight women students. The second series was especially directed to the elimination of emotional and other factors which might invalidate the results of the entire research.

*Series I.* In the first series of ten male students, a comparison of the blood-pressure and pulse-rate changes occurring in mental work was made with those occurring in the same subjects in muscular work, and in simultaneous mental and muscular work. The muscular work consisted in exercise with one arm on the convertible ergometer of Cathcart, Wishart and McCall(16). The subject was instructed to work at the rate that seemed to him the most comfortable, against a resistance of 1 kgm. The work done was usually of the order of about 11,000 kgm. per hour. The revolutions of the ergometer wheel (and thus the rate of working) were recorded continuously during the experiment. By means of an electrical device, the two "Veeders" used for this purpose recorded alternately over 10 second intervals: records of any variation that might occur in the working rate could in this way be obtained. Each experiment in this series consisted of three parts, viz. (a) mental work alone, (b) muscular work alone, and (c) combined muscular and mental work, and each tripartite experiment was repeated at least three times. Each part of an experiment lasted on the first occasion for 15 minutes: on the two subsequent occasions the duration of each part was 5 minutes. The experiments were performed as a rule on separate days, with about a week's

interval between each experiment. The subjects in this group were instructed to perform the mental work as rapidly as possible.

The individual results of the first set of experiments of this series are given in Table I. The averages of the second and third sets, which were similar to those in Table I, are given in Table II and with these for comparison the averages of the first set.

Subject	Muscular work alone				Mental work alone				Muscular and mental work combined			
	Percent- age increase		Percent- age increase		Percent- age increase		Percent- age increase		Percent- age increase		Percent- age increase	
	Max. B.P.	in B.P.	Max. P.R.	in P.R.	Max. B.P.	in B.P.	Max. P.R.	in P.R.	Max. B.P.	in B.P.	Max. P.R.	in P.R.
A.	154	45.3	144	50	122	22	126	23.5	148	23.3	156	92.7
S.	168	50	160	196.3*	140	22.8	80	29	159	42	128	103.2
McK.	144	26.3	100	56.2	146	10.6	80	33.3	—	—	—	—
C.	140	20.7	112	33.3	136	17.2	104	8.3	138	30.2	108	22.7
B.	144	33.3	120	43	126	31.2	90	37.4	144	30.9	102	55.6
M.	157	8.2	116	65.7	164	32.2	114	18.8	150	25	136	41.8
S. R.	130	25.5	112	47.3	136	9.7	102	21.4	154	22.2	140	45.6
M.	156	36.8	120	43	124	8.7	88	22.2	176	46.6	150	97.4
R.	148	15.6	106	20.5	136	65	100	8.7	148	23.3	108	27.7
P.	138	30.3	114	31	144	37.5	104	28.6	158	41.1	136	68
Av. percentage increases		29.2		58.6*		25.8		22.8		33.9		61.6

\* If the exceptional reading of S. be omitted, average percentage rise is then 43 %.

TABLE II. Average percentage increases in pulse-rate and blood-pressure.

	Pulse-rate			Blood-pressure		
	Muscular work alone	Mental work alone	Mental and muscular combined	Muscular work alone	Mental work alone	Mental and muscular combined
1st set	43	23	62	29	26	34
2nd "	43	22	39	26	22	27
3rd "	41	19	46	24	14	31

It will be observed that the values for the percentage increases in blood-pressure diminish in the two latter sets of experiments, and this fall is rather greater in the case of mental work alone.

The pulse-rate also rose during mental work alone, in all the experiments of this group, but it showed a less close correspondence with the rise in pulse-rate occurring during moderate muscular work than did the corresponding changes in blood-pressure. It will be observed that the rise in pulse-rate is not so marked in the later experiments.

Where mental and muscle work are combined, the rise in pulse-rate and blood-pressure tends, in a majority of cases, to be higher than when either mental or muscular work is performed alone (*vide* Tables I and II).

The diminished extent of the rise in pulse-rate and blood-pressure in the later experiments suggested that the increases recorded might be

due partly or even wholly to emotional factors. The second series of experiments was therefore initiated in a group of five laboratory workers, who might be expected to experience, and as a matter of fact did experience, little emotional disturbance of any kind in tests of this sort.

*Series II.* In the second series of experiments with five laboratory workers, mental work only was undertaken. The duration of the experiments was from 5 to 15 minutes. The position of the subject was varied, in some cases the subject sat on a stool, in others at ease in an armchair, and in others, he lay recumbent on a bed. The object of the last two positions was to secure as complete muscular relaxation as possible. The instructions to the subject varied: in some instances, it was to add as rapidly as possible, in others to add at a comfortable rate. Since the blood-pressure and pulse-rate might conceivably be influenced apart from definite mental effort, by *e.g.* articulatory movements ("subvocal" during additions, vocal while calling out the results) or by the ocular movements of fixation of the figures on the moving paper, control experiments were performed in which the subject was instructed simply to read aloud certain of the figures as they appeared, or merely to call out numbers while keeping his eyes closed.

Twenty-one experiments, consisting, as a rule, in adding for 5 minutes in the manner already described, were done by them, together with ten controls. In all 21 experiments a rise occurred in blood-pressure, and in 19 out of 21 a rise occurred also in pulse-rate (Table III A). Of the two experiments in which the pulse-rate failed to rise, in one the pulse had certainly not fallen to its resting level before the start, and in the other this was also probably the case. In only two of the experiments was there a subjective record of anything like excitement. In the control experiments (Table III B), which were performed with the object already stated, *viz.* to eliminate the effect of muscular tension, and of movements of articulation and ocular fixation, a rise in blood-pressure occurred in six out of ten experiments, but it was much less on the average than the changes produced by mental work (see Table III c). Similarly with the pulse-rate, which showed a rise in only four cases out of ten, and then of much less magnitude than in the mental work experiments. It appears, then, that adding performed while in a state of as complete muscular relaxation as it was possible to obtain, *i.e.* in the recumbent position in a bed, did not fail to produce a rise in pulse-rate and blood-pressure. On the other hand, when no addition was done, the subject simply reading aloud figures from the moving paper, little or no rise occurred.

*Series III.* A third group of subjects, consisting of eight women

TABLE III A. Mental work alone. (Laboratory workers.)

Subject	Blood-pressure			Pulse-rate			Conditions	Subjective records
	Before start	Max.	Per-centage increase	Before start	Max.	Per-centage increase		
E. P. C.	112	130	15	72	80	11	Slow addition (sitting)	No excitement
"	118	126	7	72	84	17	Rapid " "	"
"	110	118	7	72	84	17	Slow " "	"
"	108	118	9	72	84	17	" " "	"
"	100	114	14	60	68	13	" " "	"
"	110	114	4	54	63	17	" " (recumbent)	"
"	104	110	6	69	76	10	" " (sitting)	"
G. M. W.	96	100	4	66	66	0	" " (recumbent)	"
"	96	100	4	64	70	9	Rapid " "	"
"	94	100	6	66	80	21	" " (sitting)	Some excitement
"	92	98	7	64	76	19	" " "	"Felt tense"
"	98	102	4	72	80	11	" " "	No excitement
"	96	114	19	70	80	14	" " "	"Very difficult"
"	96	106	10	80	76	5	Adding the first 2 figures, subtracting the third and multiplying by the last	No excitement
"	98	102	4	64	75	17	Rapid additions	"Got out of breath"
"	94	98	4	66	74	12	Rapid additions. Reclining in chair	No breathlessness
"	94	98	4	66	74	12	Very complicated test, adding, subtracting and multiplying. Reclining in chair	No breathlessness
S. D.	94	106	13	66	76	15	Slow additions	No excitement
"	96	120	25	64	76	19	" "	"
H. G.	106	126	19	78	84	8	" "	"
"	110	124	13	80	88	10	" "	"
R. T. G.	106	110	4	84	92	9.5	" "	Completely relaxed No muscle tension

TABLE III B. Control experiments.

E. P. C.	102	112	10	60	58	3	Muttering any figures that occurred to him at approximately the same rate as in adding exp. (Recumbent)
"	108	106	2	56	56	0	Vocalising only
"	104	100	3	52	50	4	" (eyes shut)
"	108	108	0	50	52	4	Vocalising+ fixation of figures with eyes
"	100	106	6	64	70	9	Eyes shut. Limbs flaccid*
"	102	106	4	64	72	12	Vocalising+ fixation† of figures with eyes
G. M. W.	92	94	2	72	72	0	Articulation only
"	104	102	2	74	76	3	"
H. G.	116	118	2	88	84	5	"
R. T. G.	106	108	2	80	84	5	"

\* Deliberately imagining that he was losing speed. "Static contraction of chest."

† Irritation from having to wait for next figure.

TABLE III C. Summary of results [tabulated in Table III A].

Subject	Blood-pressure						Pulse-rate			
	No. of expts.	No. of + controls	No. of expts. in which B.P. rises	Av. rise in B.P.	No. of controls in which B.P. rises	Av. rise in controls	No. of expts. in which P.R. rises	Av. rise in P.R.	No. of controls in which P.R. rises	Av. rise in P.R.
E. P. C.	7	+6	7	10.3 %	3	2.5 %	7	16 %	3	2.6 %
G. M. W.	10	+2	10	7	1	2	9	13	1	1.5
S. D.	2	0	2	19	—	—	2	17	—	—
H. G.	2	+1	2	16	1	2	2	9	0	0
R. T. G.	1	+1	1	4	1	2	1	9.5	1	5

students, was utilised for a series of mental work tests, as before. They added as a rule at a comfortable self-selected rate (Table IV). In them

TABLE IV. Women students. Mental work alone.

Subject	Blood-pressure			Pulse-rate			Conditions	Subjective records
	Before start	Max.	Percent-age rise	Before start	Max.	Percent-age rise		
W.	120	140	17	80	96	20	Slow addition	Excited
"	120	128	7	80	96	20	Rapid "	"
"	114	124	9	68	80	1.8	Slow "	Not at all excited
"	118	126	7	62	78	26	Multiplication and subtraction	" "
R.	114	130	14	84	114	36	Slow addition	No excitement
"	106	138	30	74	108	46	" "	" "
"	110	114	4	76	78	3	Control—reading figures without adding	" "
S.	112	125	14	84	126	50	Slow addition	—
Gr.	128	152	19	108	138	29	"	—
McG.	122	128	5	92	120	30	"	—
G. W.	120	132	10	108	140	29	"	—
M.	122	144	10	120	150	25	"	—
C.	118	124	5	112	116	4	"	Considerable excitement
			—			—		
			13			26		

Av. percentage rise (exclusive of "excited" records and of control)

also an obvious increase in pulse-rate and blood-pressure occurred, but curiously enough the percentage increase in pulse-rate over the resting level was much greater than the corresponding increase in blood-pressure; whereas in the group of men students the percentage rise in pulse-rate and blood-pressure was closely similar.

	Rise in pulse-rate	Rise in blood-pressure
Women	26 %	13 %
Men	22.8 %	25.8 %
	19.7 %	19.4 %
	19 %	14 %

An emotional factor is suggested as the cause of the difference.

*Course of the blood-pressure and pulse-rate changes during mental activity.* The maximum blood-pressure was attained early in all cases, and thereafter tended to fall till the end of the work period. In the first series, in which, in the earlier set of experiments at least, the emotional factor could not be altogether excluded, the primary rise in blood-pressure was rapid (a maximum being attained in 30 seconds to 5 minutes in 15 minutes work-period) and the falling-off as work proceeded was often considerable.

It did not appear from our experiments that the rise in blood-pressure was proportional to the difficulty of mental work: but more observations are required in this direction.

The pulse-rate also rose rapidly at the beginning of mental work,

TABLE V. Blood-pressure and pulse-rate during mental work.  
First series of experiments.

Subject	Max. rise of B.P.	Time to reach max. in mins.	B.P. at end of 14 mins.	Max. rise of P.R.	Time to reach max. in mins.	P.R. at end of 15 mins.
A.	22	5	112	22	8½	120
S.	26	1½	136	18	1	72
D. M.	30	1½	112	22	1¾	72
M.	40	1	152	18	2	112
McK.	14	3	138	20	6	70
D. M.	8	1	110	16	1½	86
J. R.	12	½	126	18	3	92
P.	40	2½	128	20	3	96
R.	8	2	132	8	1½	96
C.	16	1½	118	8	1	96

attaining a maximum in from 1 to 3 minutes, and fell towards the end of the work-period.

#### CONCLUSIONS.

- (1) Mental work produces an increase in pulse-rate and blood-pressure.
- (2) The increase is independent of emotional factors.
- (3) The increase is not accounted for by movements of the articulatory muscles, or by known muscle-tensions.
- (4) In combined mental and muscular work, the increases in pulse-rate and blood-pressure are greater as a rule than in mental or muscular work performed singly.
- (5) In the case of the women students, the pulse-rate increased proportionately twice as much as the blood-pressure: whereas in the male students, the proportionate increases in blood-pressure and pulse-rate were fairly similar.

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