

THE INFLUENCE OF INTELLECTUAL WORK ON THE BLOOD-PRESSURE IN MAN.¹

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I.

Physiologists measure the blood-pressure in animals by applying the monometer to an artery; the height to which the column of the monometer is raised by the blood furnishes the measure of the pressure. A measure of the pressure in man can only be made from the exterior, the methods employed by Vierordt,² Marey,³ Kries, v. Basch, Mosso,⁴ Bloch, etc., all consist in suppressing the pulse, or in arresting the circulation in an organ that is easily accessible, *e. g.*, the hand and fingers, and in measuring the minimal pressure necessary for this suppression.

It would evidently be of the greatest value to combine these pressure-results with those which are furnished by the form of the arterial pulse, and by changes of volume in the limbs, in order to determine precisely the influence of intellectual work and of the emotions on the circulation. The question, *e. g.*, whether in any case an active or passive vascular dilation occurs, can only be answered with certitude by the monometer.

We undertook this psychological study in the belief that no one, up to this time, has reached satisfactory results. There are, it is true, some scattered observations in medical journals, on the pressure of the blood during intellectual labor, but the pressure has been generally taken with defective apparatus. The only systematic work on the subject, at least to our knowl-

¹ Translated for the REVIEW from the author's manuscript.

² *Die Lehre von Arterienpuls*. Braunschweig, 1855.

³ *Travaux du laboratoire*, 1876; p. 316.

⁴ *Arch. ital. de Biologie*, 1895; p. 177. This work contains a short historical sketch, a discussion of the researches of Basch, and the description of a new apparatus.

edge, is that of Kiesow; we will indicate later on what criticisms should be made on his work. In short, the problem which we have set before ourselves has no history.

Our first care should be the choice of a good instrument to measure the blood-pressure in man. Clinicists frequently employ the sphygmometer of Bloch, more or less modified by Verdin and Chéron; this instrument resembles Cattell's algometer. It is a pressure-dynamometer which obstructs the pulsation of the radial artery; the experimenter interposes his finger between the artery of the subject and the instrument, and receives on his own finger the pressure of the instrument in such a way that with the finger he presses upon and obstructs the artery of the subject, and at the same time perceives the pulsation of the artery; the method consists in gradually increasing the pressure of the exploring finger until it no longer perceives the beating of the artery which it compresses. We did not make use of this instrument; for after having tried it for some time, we rejected it because it involved a subjective element of estimation. We gave the preference to Mosso's sphygmomanometer which has the advantage of indicating its results by tracings.

It is unnecessary to give a description of the numerous parts which make up the apparatus; this description may be found in the work of Mosso and also in the *Année Psychologique*.¹ We will content ourselves with indicating the principle. Two fingers of each hand are placed in rubber finger-tubes, and through these tubes are exposed to the pressure of water; this pressure is varied by means of a piston and measured by a mercury manometer, which registers at the same time the pulsations of the fingers. If we begin with 0 and increase gradually, we find a regular change in the amplitude of the pulsation; this is very small at first, grows and reaches a maximum, decreases again, and finally disappears; thus the amplitude does not vary directly or inversely with the pressure; there is a most favorable degree of pressure, equal on the average to 80 mm. of mercury, at which the pulse attains its maximum amplitude; a weaker or stronger pressure have

¹ *Année Psychologique*, II., p. 584.

alike the effect of diminishing the pulse. The question is how to measure the blood-pressure with an instrument of this sort.

Marey's opinion was that we must take, as measure of the blood-pressure, the counter-pressure necessary to obstruct and suppress the pulse. Mosso maintained, on the contrary, that it is the most favorable pressure, about 80 mm. of mercury, which is equal to the pressure in the arteries. This disputed point is of little importance. What interests us as psychologists is not the absolute value of the blood-pressure, but the change which it undergoes by reason of mental processes; in relating our experiences we will have to examine the criteria of both Marey and Mosso, and to determine which of the two answers best to the special end which we have in view.

Technique. It is necessary to give some practical details as to the manipulation of Mosso's sphygmomanometer. Two very different methods may be employed together, since they supplement each other. A. The first method consists in registering the pulse with variations of pressure from 0 to 100 or 120 mm. of mercury, either varying the pressure by sudden jumps, *c. g.*, from 0 to 10, from 10 to 20, from 20 to 30, etc., or by slow changes of pressure which are almost insensible. The latter is the method recommended by Mosso.¹ It is very useful when one wishes to compare the blood-pressure to different hours of the day; it is necessary then to make the piston of the apparatus move from the minimal to the maximal pressure, in order to determine the value of the most favorable pressure. The differences of blood-pressure at different hours of the day can in this case be expressed in figures, an expression which is evidently the aim of all scientific research.

Here a parenthesis. In measuring the pressure with Mosso's sphygmomanometer, we must not take account of the absolute amplitude of pulsation, but of the counter-pressure necessary to give the pulsation its maximal amplitude. This is not at all the same thing. Mosso gives an interesting example which will make this distinction clear.² One of his subjects,

¹ We found it practicable to make the piston revolve automatically with a weight-motor.

² *Op. cit.*, p. 180 f.

Dr. Colombo, has his blood pressure taken in the normal state; the most favorable point of counter-pressure is at 80 mm., of mercury. Then the same subject takes a hot bath, and, on coming out of the bath, without dressing, has his pressure taken again. As a result of the bath the amplitude of pulsation was increased enormously, while the blood-pressure was diminished—it was then only 60 mm., of mercury—as was demonstrated by the most favorable degree of counter-pressure. Hence, he would have made a serious error if, on the basis of the enlargement of the pulse, he had inferred an increase of pressure. It is absolutely necessary to determine the most favorable counter-pressure in order to compute the pressure. This is the method with which it is necessary to begin.

But, on the other hand, this method entails great practical difficulties; we observed three: 1., it is slow, it requires a manipulation which lasts at least 1 to 3 minutes; 2., it produces very clear sensations in the fingers of the subject as the pressure is changed, and these sensations might disturb his attention in a manner prejudicial to the experiment; 3., it causes, by the changes of pressure, certain excitations which may produce reflex phenomena, such as vascular constrictions, in the fingers.

The first of these difficulties, the most serious, shows itself when we study the changes of pressure produced by a phenomenon which lasts only a short time; for example, the result of the concentration of the attention, of a mental calculation, or of a deep breath. Suppose we wish to know whether a mental calculation increases the blood-pressure or not, the time needed to take all the pressures from 0 to 120 is at least 1 to 3 minutes. Hence, it is necessary to see that the mental calculation lasts just so long, and that is not always easy. Moreover, the method can only indicate the blood-pressure at the moment when, by trial, we reach the most favorable counter-pressure. We do not know exactly what the pressure at the beginning of the intellectual labor was, nor how it changed during the progress of the experiment. All this shows that this method is insufficient. But such as it is we believe it to be indispensable, 1., to show whether the average pressure has increased or diminished, 2., to indicate in millimeters of mercury the value of the change of pressure.

In Kiesow's article on the effects of psychic excitations, studied by means of Mosso's Sphygmomanometer,¹ the author almost never employed this method; he indicates it only once. He employed it on a Privat-Docent to study the blood-pressure after mental work, and noted a deviation of pressure equal to 8 mm.² But he does not give the tracing, and the experiment indicates only what occurred afterwards, and not what occurred during the mental work.

B. The second method, much the shorter and more convenient, consists in registering the pulsations with a constant pressure of the manometer, and then producing the mental work and other psychic phenomena studied, without changing the pressure of the manometer. Thus by the first method we change the pressure successively, in order to register the maximal amplitude of the pulsation, while by the second we leave the pressure constant, and observe simply the changes of amplitude of the pulsation which the mental operation produces. For example, we begin by registering the pulsation of the fingers under a pressure equal to 50 mm. of mercury; then without touching the piston again, we ask the subject to make a mental calculation and observe whether there are any changes in the pulsation, the pressure remaining always at 50 mm. as before the calculation.

What is the advantage of this method? It will be seen at once: 1. We seize the first modification produced by the mental calculation, and all that occurs at the beginning, the middle, or the end of the process. 2. We do not distract the attention of the subject by changes of pressure in the fingers. 3. We do not produce reflex vaso-motor phenomena by changes of pressure.

But this method cannot inform us whether the pressure has changed or in which direction it has changed. It shows us merely—when it shows us anything at all—that the pulse has changed in amplitude. Now, it was mentioned above that the changes of amplitude in the pulse (the case of Dr. Columbo is an example of this), are not a constant sign of changes of pres

¹ *Arch. ital. de Biologie*, 1895, xxxiii, p. 198.

² *Op. cit.*; p. 207.

sure; hence it may be that when the pulse becomes stronger, the effect is due to a relaxation of the arteries, to a diminution of blood, or in any case to some cause other than an increase of pressure. Hence, before employing the second method we must employ the first, which shows with certainty whether any change of pressure occurs and in which direction it occurs. The first method gives the principle fact and the second the details. The two are complementary.

There remains one very important question: when the second method is employed, what pressure should be chosen as constant? There is a very simple way of determining it, *viz.*, to compare the two tracings of increasing pressures made, the one in the normal state, and the other during the phenomenon which we wish to study, such as mental calculation. The comparison of these two curves allows us to decide for what counter-pressure they differ most. If the maximal difference is, *e. g.*, at the counter-pressure of 120 mm. of mercury, it is that counter-pressure which we must choose for the method of constant pressure, since it is that which is most favorable for the differentiation of the two curves.

We must here make a criticism of Kiesow's work. This distinguished author has not determined the most favorable counter-pressure, and in his experiments with constant counter-pressure, he has always chosen the most favorable counter-pressure, that which gives the maximal amplitude of pulsation. We do not find in his work any justification of his choice. This choice, it must be admitted, is not the most fortunate, as is shown by numerous tracings (1 to 6) inserted in his work. In these tracings it is impossible to see whether the mental calculation has had any influence upon the blood-pressure, since the pulse-amplitude shows no change. It is possible that among the individuals whom he has studied, intellectual labor produced no effect upon the pressure. We cannot tell. But we believe it more probable that the negative result reached by Kiesow is due to the fact that he chooses as the constant pressure the most favorable pressure; for, on the one hand, the maximal difference between the two curves for rest and mental labor does not occur, according to our own experiments, at the most favorable coun-

ter-pressure; and, on the other hand, we observed constantly among the subjects in whom intellectual labor produced an increase of blood-pressure, that this effect is not noticeable when the most favorable pressure is taken as the constant pressure, but is most clearly noticeable when the strongest counter-pressure is used. These considerations lead us to believe that Kiesow has committed a technical error, quite excusable indeed in an author who is not entirely familiar with the graphic method.

II.

Our experiments were made upon three subjects, but principally upon a young student of psychology, 23 years old, and in good health. We will speak simply of the experiments made upon him. Last year we made on him numerous experiments on the effect of mental labor on arterial circulation, and hence he is able to observe himself and concentrate his attention. His pulse, compared with the others whom we examined, is weak, but his pulsation is well formed; when he makes a mental effort there occurs in him almost always a fine and quite radical vascular constriction, with a diminution in the size of the pulse-curve; then the vascular constriction disappears and the tracing returns to its normal level; this return to the normal may take place before the mental effort of calculation is completely finished, particularly if the subject has been given to solve a very complicated problem which requires much time. There is, besides, during the calculation an acceleration of the heart and of respiration. These experiments do not show whether intellectual work increases the blood-pressure. The vascular constriction of the capillaries which we observed tends to relieve the pressure, as does also the acceleration of the heart, but since we do not know what the work of the heart, what its force was, during this time, we cannot say certainly that the pressure has increased.

The Sphygmomanometer relieved all doubt. At the beginning, we employed the first method of experimentation, which consisted in taking the pulse under increasing pressure from 0 to 140 mm. of mercury; this test is made at first while the subject is in a state of rest without excitement or preoccupation

of any sort; then the same experiment is made while the subject is absorbed in a difficult mental calculation; in this way two curves are obtained for comparison; the difference of the two curves can be attributed to the intellectual labor unless some chance circumstance, as an emotion, a shiver, etc., prevents the two experiences from being comparable. This double test was made on our subject at five different times so that we obtained ten curves which may be compared in pairs.¹ The change of pressure from 0 to 140 mm. was made each time very slowly by hand in an almost insensible manner, lasting almost always the same length of time (two minutes and a half); the experimenter regulated the speed of his movement by means of a seconds watch. The pulsations of the mercury column were not written by means of a float on a revolving cylinder (Mosso's method), but were transmitted by means of air pressure to a Marey tambour; a very small escape² attached to the transmission tube prevented the pen from becoming displaced through the influence of the sinking back of the column or mercury (produced by the piston), so that the pen traced at approximately the same level the pulsations of the column of mercury, although the latter was at different heights, varying from 0 to 60 mm. We found this arrangement much more advantageous than that of Mosso, which gives the tracings in steps; by means of ours, one may perceive more easily the gradual changes of amplitude.

The mental calculation was to last for about two or three minutes: we did not give the subject a single calculation, because it would have to be very complex and very difficult to last so long, and the subject, who had no special talent for this sort of exercise, would have become confused and lost the figures; and in the end, we should not have been able to get the strong and concentrated attention which we wished to study. It seemed better to give to the subject a series of easy multiplications; as soon as he had finished one, he gave the answer and was immediately given a second, then a third. In general, during the two or three minutes that the experiment lasted, the subject

¹ A much larger number of experiments have been made since these lines were written.

² On the regulation of graphic tracings by means of an escape, see the *Année Psychologique*, II., p. 776, 1896.

made three multiplications, each of two figures into two figures. As he was very much interested in the experiments, he always made a vigorous effort, as is shown by the correctness of the answers given. He closed his eyes, knit his brows, and leaned his head a little forward.

We measured exactly the amplitude of the pulse for the ten experiments: they were made at the same hour and under strictly comparable conditions.¹

We subjoin the results in Table I.

TABLE I.—AMPLITUDE OF PULSE UNDER DIFFERENT PRESSURES DURING A STATE OF REST AND DURING INTELLECTUAL WORK.

Pressure.	Without Intellectual Work.					With Intellectual Work.					Average Without.	Average With.
	1	2	3	4	5	1	2	3	4	5		
20			0	0.5	1			0.5	0.5	0	0.5	0.5
30			0	1	1.5			0.5	0.5	0	1	0.5
40	1	0.5	0	2	2	0.5	1	1	1	0.5	1	1
50	1	0.5	0.5	2.5	3	0.5	1	1	1.5	0.5	1	1
60	1	1.5	1.5	4	5	1	1.5	1.2	1.5	1	1.5	1.2
70	2	2	2	3	4	1.5	2	3	3	1.5	2	2
80	2.5	2	5	5	5	2	3.5	4	4	2	5	3.5
90	2	2	3.5	4	4	2	1.5	3.5	3	2	3.5	2
100	1	1.3	2	2	0.5	2	0	4	3	2	1.3	2
110	0.5	1	0.5	1.5	0.5	1	0	2	1.5	1.5	0.5	1.5
120	0		0	0.5	0	0.5	0.5	1	0	0.5	0	0.5

Explanation of Table I. The five first vertical columns on the left indicate the amplitude of the pulse during five experiments in the normal state; the amplitude is measured in mm; we begin with an amplitude of 20 mm. of mercury, then 30, then 40, and so on up to 120. The five following vertical columns show the amplitude of the pulse during a series of mental calculations at all pressures from 20 to 120 mm. of mercury. Finally, the two last columns show the average² of the results

¹The pressure varies with the hours of the day. We always made alternately the experiments of rest and intellectual work, in order to keep them in comparable conditions.

²We give, not the arithmetical mean, but the *median value*, as indicated by Scripture (PSYCHOLOGICAL REVIEW, II., 1895, p. 376, and *Année Psychologique*, I, 1894).

obtained from the experiments in the normal state and during intellectual work respectively.

Let us look for a moment at the left side of the Table (I), containing the results of individual experiments. We are struck with the irregularity of certain series of figures. The amplitude of the pulse does not increase regularly up to the most favorable counter-pressure and then regularly decrease. In experiments 4 and 5 in the normal state, *e. g.*, the figures make several quite unexpected jumps. This is due to the fact that the subject is not an automaton; he has had during the experiment vascular constrictions and changes of blood-pressure which have changed the trend of the curve. Similarly in experiment 2, during intellectual labor the subject has had suddenly near the end of the curve at a counter-pressure of 100, a reflex vascular constriction caused by a rather strong emotion (he noticed that he had given a wrong answer to the problem set). These experiments show that we must multiply the experiments and only preserve the average results, in order to eliminate the sources of error.

Let us now compare the averages from the last two columns of Table I. The differences are evident. First, the curve of pressures of the state of rest has a greater amplitude than that of intellectual work; the maximum amplitude of pulsations in the first curve is 5 mm., that of the second is only 3.5 mm. There has evidently occurred in our subject during all the mental calculation, a diminution of the pulse which results from a vascular constriction that is more or less marked. The position of the maximum point in the two curves is about the same, at 80 mm. of mercury, and, if this fact alone were taken into consideration, we might conclude that the blood-pressure was not modified; but we must hasten to add that when the pressure was increased beyond 80 mm. the two curves acted very differently. The pressure curve for the normal state decreased rapidly; at 100, it fell to 1.3 mm., and at 110 it was practically suppressed; on the other hand, the pressure curve for mental work withstands the stronger pressures more vigorously, notably pressures from 100 to 120. In short, here are two cases which coincide in their maximum, but which differ very much in their resistance to strong pressure. We think that this resistance must be taken

into consideration; when one pulse withstands a counter-pressure of 120 and still records, while another pulsation of the same amplitude is checked by this counter-pressure, we must recognize that the former pulsation corresponds to a stronger arterial tension. We are thus led to set aside Mosso's criterion in this particular case, and to accept that of Marey.

The tracings which we have obtained, together with our numerical results show clearly the essential difference between the two pressure-curves.

In determining the complexity of this phenomenon, be it understood, it would be difficult to take account of it with a clinical sphygmometer of Bloch's type, a method which consists in obstructing the radial artery until the finger inserted between the sphygmometer and the radial no longer perceives the beatings of the latter. The experimenter would have to be very skillful in taking exact account of the constriction produced by intellectual work, which decreases the amplitude of the pulsation, and to perceive that in spite of this diminution, which ought to give to the exploring finger a new sensation, the pulsation has greater resistance.¹

III.

From what precedes, we conclude that, with our subject, a pressure of from 100 to 120 completely suppresses the pulsation of a state of repose as also that of a state of intellectual labor. This observation will help to guide us in the second series of researches, where we will employ a constant pressure; it is clear that to make apparent the difference between the circulation in a state of intellectual labor and that of rest, it is this counter-pressure of from 100 to 120 which must be chosen.

In order to remove all doubts we have made a counter-test in the following manner: Seven times in succession our subject made a mental calculation having his fingers subjected to a constant pressure, and each time the pressure chosen was different; the results also were very different. With a constant pressure of 40 mm., there was no modification produced by the

¹Féré, who made some use of the sphygmometer, noticed that when the artery contracted, *e. g.*, under the influence of cold, the apparatus gave only erroneous indications (*Pathologie des émotions*, p. 14,, note).

fact of mental work ; with a pressure of 60, the same negative result ; with a pressure of 70 mm. there was a slight augmentation of pulsation ; at 80 mm., there was again a slight augmentation, not measurable, but visible to the eye ; at 100 to 120 the augmentation is very clear ; it varies from simple to double ; at 140, all pulsation was suppressed. This shows us very well that the constant pressure chosen ought to lie between 100 and 120. These experiments are a confirmation of those made before : they show anew that if we choose the most favorable counter-pressure, we may obtain results which are as completely negative as those of Kiesow are.

Now let us take a counter-pressure of 110. We first register the pulse with this pressure for about a half minute, then tell the subject to commence a mental calculation. While he is absorbed in his work we watch the pressure with care ; for when we give a heavy pressure with the Sphygmomanometer, it tends to diminish ; and in order to keep it equal, it is necessary to give a stroke with the piston from time to time. This slight correction ought to be made very gently, so that the subject does not experience any new sensation in his fingers, and does not perceive anything. Excepting this slight cause of error, for which we ought to watch, this method of experiment is much easier than the preceding ; one does not disturb the person in the experiment, and, moreover, the change of pressure in the hand is seen in the tracing as soon as it is produced. The experiment carries with it a kind of sensible evidence ; as soon as the mental calculation begins, there is an increase in the pulsation.

This experiment was made 11 times upon our subject, always with analogous results. We gave him multiplications of two figures by two figures, and immediately he began the operation in his head. The first three or four pulsations which register themselves are usually of the same character as the preceding, sometimes they are slightly shortened, an effect which is probably due to the vascular constriction which is habitual with this subject at the beginning of intellectual work. Then the pulsation increases, it doubles in size, or becomes twice and often three times as great. This increase in ampli-

tude maintains itself, in general without increase or diminution, and with great regularity during the whole of the mental calculation; when the subject has found the solution and has given it, there is no sudden diminution of pulsation; it may retain its amplitude without change for 15 seconds, sometimes even longer; then the pulsation begins to diminish very gradually; finally it recovers the same amplitude that it had at the beginning of the mental calculation. This return to the original condition is a very significant fact for us, since it shows that the change in amplitude of the pulsation is not due to the apparatus, but to the physiological condition of the subject.¹

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¹ This is part of a more general study which I am making on the physiological expression of thought, including also my experiments with M. Courtier on capillary circulation and respiration. Some of the results will appear in April, 1897, in the third *Année Psychologique*.