

THE RESPIRATORY RHYTHM IN NORMAL AND PSYCHOTIC SUBJECTS

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In a previous article ⁶ it was found that schizophrenic patients breathed on the average more shallowly and more rapidly than normal subjects. In the present study an attempt is made to examine the respiratory rhythm in normal subjects and then to compare it with that found in individuals suffering from schizophrenia, the manic-depressive psychosis and epilepsy.

The apparatus used to take the records of these patients was that described by Golla and Antonovitch.² This consists essentially of a wooden box with a removable lid and front piece. The subject for experiment sits in the box and only his head projects through the roof. The box is air-tight and communicates with a recording plethysmograph by means of a wide tube. In this way respiratory movements can be recorded. When this instrument is used, the subject need have nothing strapped round his chest or abdomen. He is unaware that his respiration is being examined, and therefore the possibility of conscious interference with rhythm is eliminated.

The respiratory movements as well as being concerned with oxygen and carbon dioxide exchange have, in the phylogenetic development of man, become closely associated with the higher centres of the brain, more especially those connected with speech. It has long been known that changes in thought are accompanied by changes in respiration.

This subject has been studied by various workers since the time of Mosso, and it is worth while recapitulating the conclusions arrived at by succeeding observers.

SUMMARY OF PREVIOUS LITERATURE ON THE RHYTHM OF RESPIRATION

Towards the beginning of this century considerable interest was taken in the character of the respiratory curve. The chief object in view was to ascertain whether certain states of mind were accompanied by characteristic types of respiratory record (see Table I).

Several contributors to Wundt's *Philosophische Studien* and later *Psychologische Studien* discussed this problem. An article by Rehwoldt,⁸ for instance, illustrates the thoroughness of some of these investigators. He applied six bands round the subject's thorax and abdomen. Attempts were made to ascertain if there were characteristic curves in such conditions as

hilariousness, æsthetic pleasure, bliss, or enthusiasm ; also in anger, depression rage, pain and tension. The results of these investigations were for the most part negative. He concluded that affects could be divided into three classes :— (1) Restful affects. (2) Affects with excitement. (3) Tension. Diminution in the height of the curve occurred in (1) and (3), increase in (2). The rate of respiration was greater in (2) than in the other two conditions.

TABLE I. SHOWING SUPPOSED EFFECTS OF MENTAL STATES ON RESPIRATION

Author	Pleasant sensation	Unpleasant sensation	Sudden emotional reaction	Voluntary attention	Reverie
Mosso	—	—	—	slow	fast, deep and irregular
Rehwoldt	—	—	fast and deep	—	—
Lehmann	deep and regular	deep irregular	— —	— —	— —
Mentz	slow	fast	—	—	—
Zoneff and Meumann	shallow and fast	deep and slow	— —	fast and shallow (but great individual differences)	— —
Angell and Thomson	little affected	little affected	irregular	regular generally : irregular when tendency to vocalise	—

Lehmann³ was especially interested in the effect of pleasant and unpleasant impressions. He believed that the former increased the depth of respiration, and that strong unpleasant impressions were accompanied by several deep respiratory movements. Mentz⁴ concluded that pleasant feelings caused a slowing of respiration while unpleasant quickened it. Zoneff and Meumann¹⁰ made an exhaustive study in normal individuals, employing various stimuli—optic, acoustic, gustatory, cutaneous and psychic (arithmetical problems and space conceptions); and studied at the same time the effects of voluntary attention and pleasant and unpleasant impressions on the respiration. They found that there were great individual differences but that voluntary attention usually caused increase in rate but decrease in depth, sometimes amounting to inhibition of respiration. They believed that pleasant sensations caused shallowing and acceleration, but unpleasant sensations deepening and slowing. Reference to Table I will show how conflicting the results arrived at by these investigators were.

In England, Angell and Thomson (1899)¹ made a contribution to the subject. They refer to the work of the physiologist Mosso who had previously given much of his attention to this subject. He studied chiefly the effects of emotion and found that it was 'impossible to make any satisfactory classification of breathing types as connected with mental activity or emotion.' Angell and Thomson themselves came to very reasonable conclusions. They found that respiration tended to be regular where the organism was undisturbed by changes in the environment, that is, so long as the subject's equilibrium was maintained. In voluntary attention the rhythm was generally regular. They mentioned incidentally that where there was a 'tendency to pronounce words'—as when the subject was asked to remember nonsense syllables—the breathing became irregular.

An important contribution to the subject was made by F. Peterson and C. G. Jung⁷ in 1908. They studied the pneumographic curve in conjunction with the so-called psychogalvanometer. Among other things they studied the characteristics of the normal curve, and the effect on it of emotional stimuli and also of attention. They also studied the same phenomena in schizophrenics. Their material, however, was small compared with that about to be described in this investigation. In the article referred to they made some observations which are of interest in relation to the present study.

'It is altogether probable that there are more inexplicable influences at work in relation to the pneumographic curve than we are at present able to comprehend. There are many respiratory fluctuations which have nothing to do with the emotions, but are the result of physical or intellectual processes, together with the enforced quiet of the body at rest, the test person, with the disposition to speak, etc.'

'Again, when the emotions are very labile, and show the most marked excursions in the galvanometer curve, the respiratory curve is often regular and even. On the other hand in instances both normal and pathological, where the galvanometer curve is marked by little fluctuation, or even by none, as in some cases of catatonia, there will often be most decided variations in the pneumographic curve. There does not seem to be the intimate and deep relationship between the respiratory function and unconscious emotions that exists between the sweat glandular system (which influences the psychogalvanometer) and the emotions. . . . Respiration is an instrument of consciousness. You can control it voluntarily while you cannot control the galvanometer curve. The respiratory innervation is closely associated with speech innervation, anatomically and functionally, and the physical connection in the brain is, perhaps, one of the closest and earliest' (*loc. cit.*, pp. 173-175).

One of the most important advances in the above paper was the observation that there are irregularities in the respiratory curve which have not to do primarily with emotion; also that there is a close connexion between the

intellectual functions, especially the function of speech, and the respiratory function.

These facts were further elucidated by Golla and Antonovitch ² in 1931. These observers examined 67 normal subjects with reference to the regularity of respiratory rhythm. Neglecting the emotional factor, which they believed to be easily recognizable when it occurred, they directed their attention to an examination of the mental content of these individuals. They were at once struck by a correlation between visual imagery and regular breathing on the one hand, and auditory imagery and irregular breathing (with a tendency to vocalize) on the other. Of the 67, 34 were classed as regular breathers. All except one had considered themselves to use predominantly visual imagery. The remaining one had said he used predominantly auditory imagery. Thirty-two subjects showed an irregular rhythm, and of these 28 had been assessed by their answers as using predominantly auditory imagery, the remaining four being classed as visualists. One had been doubtful.

In discussing the significance of the two types of respiratory rhythm, these writers point out that in their experiments irregular rhythm frequently became regular when a problem was set, the solution of which required purely visual imagery. They considered that irregular respiration was caused by the use of a kind of internal speech. They added, however, that it would be wrong to assume that such irregularity of rhythm is in any sense a point-to-point representation of the actual respiratory disturbance that would take place if the auditory images were to be translated into spoken words. If this were so, such images could only occur, as in speech, during the expiratory phase, whereas anyone belonging to the auditory type is conscious that the images arise uninterruptedly both during expiration and inspiration. The irregularity is of a less definite character, diaphragm and thoracic, as well as laryngeal, muscles helping to cause it.

SCOPE OF THE PRESENT ENQUIRY

The object of the present inquiry has been to find out with the improved apparatus if there is any particular mental process which in normal subjects gives rise to a special type of respiratory tracing. The results of the investigations just quoted, for instance, would seem to indicate that auditory imagery with a tendency to vocalization gives rise to an irregular type of respiration.

Secondly, is there any feature which is more frequently found, or solely found, in the respiratory tracing of a psychotic as compared to a normal individual?

Thirdly, are the respiratory reactions of psychotic subjects to various stimuli different from those of normal subjects?

In what follows an account is given of the results obtained, and also a discussion of how far the questions stated above are answered.

RESPIRATORY RHYTHM IN NORMAL SUBJECTS

In the present series 65 normal subjects were tested. These were nearly all members of the staffs of the Maudsley and Colney Hatch Mental Hospitals, who kindly consented to co-operate in this work. The first

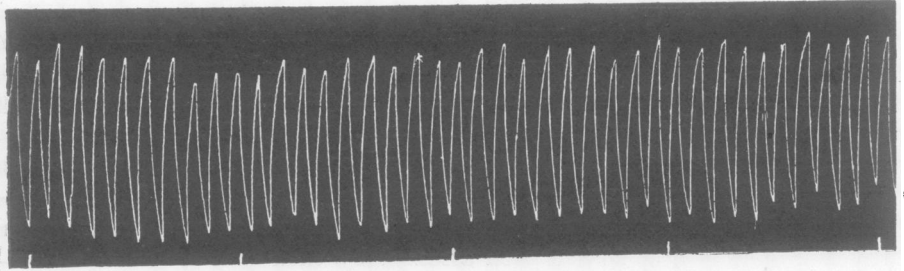


FIG. 1.—Example of regular breathing. Time signal 30 seconds. (In all these figures upstroke represents inspiration.)

problem to be examined in each of these experiments was whether the individuals showed either predominantly regular or irregular rhythm (figs. 1 and 2).

Of the 65 normal subjects, 45 males and 20 females, 32 (22 men and 10

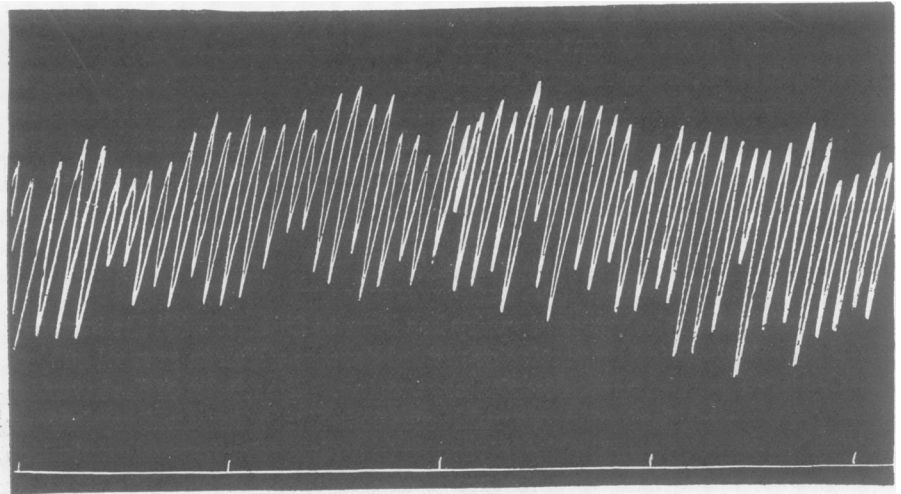


FIG. 2.—Irregular breathing. Time signal 30 seconds.

women) were regular breathers, while 33 (23 men and 10 women) were irregular (Table II). These figures corresponded roughly to the figures of Golla and Antonovitch quoted above, who found that of 67 normal cases, 54·5 per cent. were regular and 45·5 per cent. irregular.

TABLE II. RELATION OF REGULAR OR IRREGULAR RHYTHM TO TYPE OF IMAGERY (VISUAL OR AUDITORY)

	Regular	Irregular	Visual	Auditory	Regular and visual	Percentage of regular breathers who are visualists	Irregular and auditory	Percentage of irregular breathers who are auditorys
Men	22	23	23	22	16	72.8	16	69.6
Women	10	10	10	10	8	80	8	80
Both	32	33	33	32	24	75	24	72.8

An attempt was made to eliminate from the outset any physical causes of irregularity. Any tongue or lip movements in the nature of a tic caused irregularity. It was possible, however, for the observer to stand at the side of the subject and watch for any movement of the lips or tongue. If any such were seen, the record was discarded. Another factor which influenced the rhythm was catarrh of the respiratory passages. All the subjects were free from this at the time of examination. Any marked restlessness on the part of the individual was apt to cause a characteristic kind of irregularity, although small movements failed to interfere with the predominant rhythm. As might be expected, the respiratory curves were also affected by any emotion of even moderate degree. The whole subject of the effect of emotion on respiration is a wide one, as has been indicated, and it is not proposed to discuss it here. The nature of the change caused by emotion, whether to deeper or shallower breathing, depends on a variety of causes, which have been studied by the workers quoted above. In what follows, it is only pointed out that the irregularity caused by emotion is of a different type from that under discussion. Where the respiration was influenced by emotion, it would suddenly change and then return to normal after a number of breaths. For a record where the phenomenon was frequent, the term 'labile' seemed applicable. The true irregularity of rhythm which is the present subject for study is something different. The irregularity is rather from one respiration to the next, not from series to series (fig. 2). The change of respiration to deeper or shallower for a while following emotion might characterize either an otherwise regular or irregular record. It was impossible to tell beforehand which individual would be regular and which irregular, merely by noticing the degree of 'nervousness.' Some cases of anxiety neurosis were very regular, and also not labile, while some apparently apathetic subjects were irregular.

Neglecting therefore the question of emotion, the writer proceeded to test the degree of auditory imagery with its tendency to vocalize, in these subjects. He asked a number of individuals to think out a problem while sitting in the apparatus. They did not know during the test that their respiration was being examined. The inquisitive were merely told that the apparatus had in some way to do with metabolism. The first problem was

of such a kind that the subject would most easily solve it by using not auditory but visual imagery. He was asked first to look at a sheet of paper which showed each of the capital letters of the alphabet. He was then asked to picture each letter as he would see it in a mirror. He was told that at the end of the experiment he would be asked which of the letters looked the same in the mirror as when looked at direct. This ensured that the subject would concentrate as thoroughly as possible.

In fact, A H I M T U V W X Y appear the same in a mirror as when looked at direct. If an individual, for instance, included N S and Z he was considered to have a bad capacity for visual imagery. This was called the visual test.

Secondly, the subject was asked to perform a task for which most people

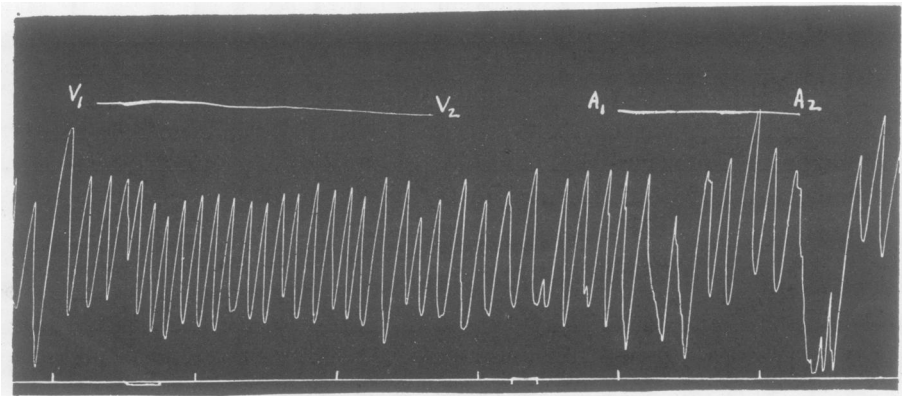


FIG. 3.—This subject shows regular breathing during 'visual test' ($V_1 - V_2$) and irregular breathing during 'auditory test' ($A_1 - A_2$). Time signal 30 seconds.

would use auditory imagery. It had been found from previous questions that most people used predominantly this type of imagery in adding up a column of figures. This test was set, and may be referred to as the 'auditory test.'

In all, 44 normal individuals were examined. Eighteen, or 41.0 per cent., were regular in one test and irregular in the other. Of these 18, all except one exhibited the regular rhythm in the test for which visual imagery was indicated, but irregular rhythm in the test for which auditory imagery was commonly used. The results in one of these cases are shown in fig. 3. In only one doubtful case was the rhythm regular in the adding test and irregular in the visual test. Of the 44, 13, or 29.5 per cent., were regular in both tests and the same number were irregular in both tests. Subjective tests (which will be described later) indicated that 12 of those 13 regular breathers employed predominantly visual imagery, while 10 of those 13 irregular breathers had a preference for auditory imagery.

From the fact, then, that 17 out of 18 individuals showed regular rhythm during the test where visual imagery was indicated, but irregular rhythm where auditory imagery was more suitable, it may be deduced that respiration tends to become regular where an individual is employing visual imagery, and irregular when using auditory imagery.

The fact that 13 individuals breathed regularly both during a test for which visual imagery was indicated and also during a test where visual imagery might or might not be used, suggested that they preferred employing visual imagery to auditory imagery wherever possible. The fact that 13 subjects used irregular rhythm throughout seemed to indicate that they were persons who had difficulty in using visual imagery exclusively at any one time, even where the problem seemed to require the visual type of thinking. As already stated, it was confirmed by subjective tests that 12 of the 13 subjects who breathed regularly throughout both tests employed predominantly visual imagery, while 10 of the 13 whose rhythm was irregular throughout used predominantly auditory imagery.

It has also been stated that tests were carried out on these normals to find out which type of imagery they used. These tests were partly subjective and partly objective.

The subject was first of all asked to think of a clock face with the hands pointing to twenty minutes past eleven. He was then asked to imagine that the big hand was the small hand, and the small hand the big hand, and further asked what the time would then be. The interval which elapsed between putting the question and receiving the answer was noted. The subject was then asked how he did the problem and how easily he could picture the clock face.

He was then shown a sheet of cardboard with the capital letters of the alphabet clearly printed on it. He had to picture each of the letters as he would see it upside down, and told that he would be questioned at the end of the test as to which letters looked the same upside down as the right way up. In fact, H I N O S X and Z look the same upside down as the right way up. If an individual, for instance, included N S and Z he was considered to have a good visual capacity.

Lastly he was asked to look at these dice patterns : $\begin{matrix} \cdot & \cdot & \cdot \\ \cdot & & \cdot \\ \cdot & \cdot & \cdot \end{matrix}$; $\begin{matrix} \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \end{matrix}$; $\begin{matrix} \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \end{matrix}$, and to write them down from memory. The strongest visualists were those who wrote them straight down without saying the numbers to themselves. The strong auditorys were those who translated the patterns into the sounds of the numbers and then translated them back again. From these data it was recorded whether the subject used predominantly auditory or predominantly visual imagery. After he had been classed as auditory or visual, the respiratory record was taken and examined to see whether the respiration was regular or irregular in type (Table II). Of the 32 regular breathers, 24, or 75 per cent., were visualists, while of the 33 irregular breathers 24, or 72·8 per cent., were auditorys. It would appear then from these figures that regular and

irregular breathing is accompanied in a significant number of cases by visual and auditory imagery respectively.

These findings are in keeping with the work recorded above by previous writers. Peterson and Jung had concluded that regularity was dependent more on intellectual than on emotional factors. The above results would bear out the supposition that where there is no tendency to think in terms of one's own voice the rhythm is peculiarly regular. Where, however, the individual is inclined to vocalize, the rhythm becomes irregular. This irregularity would seem to be dependent on movements of muscles of the chest to a greater extent than of those of the larynx, being noticeable on the record during inspiration, as well as expiration. Those who do not tend to think in terms of their own voice, or use a kind of inner speech, appear from the above results to use predominantly visual imagery.

Further work remains to be done to elucidate the relation of type of rhythm to type of imagery. For instance, the respiration of a series of congenitally blind individuals might be tested in order to ascertain whether they breathe irregularly, and a series of congenitally deaf individuals in order to see whether their respiration is regular. (The latter test would not be so conclusive, since nowadays such patients are taught to vocalize from an early age.)

RESPIRATORY RHYTHM DURING NORMAL SLEEP.—Eight records of three different subjects who fell asleep in a plethysmographic apparatus made on the same principle as that used in the present series were compared with the above records. I am indebted to Dr. Antonovitch for these records, hitherto unpublished. In each case the subject became more irregular in the dozing state which preceded sleep. During sleep the subject became regular. In the case of one who was fairly regular when awake, the rhythm became regular in sleep.

RESPIRATION IN PSYCHOTICS

Records of 179 psychotic patients were examined. Of these, 133 were schizophrenic, 32 were melancholic, and 14 were epileptic. As has been already reported, the schizophrenics differed on the average from normal subjects in that their breathing was shallower and more rapid.

The rhythm of respiration in schizophrenic patients was studied to find out whether it differed in respect of regularity or irregularity from that of normal subjects. The same technique was employed as previously in the case of normal subjects. In all, 136 schizophrenics were examined, 100 males and 36 females. Of these, 94 were classed as regular and 42 as irregular. This represents 69.1 per cent. of regular breathers as compared to 49.2 per cent. of regular breathers in the normal group. Examination of the schizophrenic group showed that the irregular breathers were mostly to be found among those who had been ill for less than five years (Table III and fig. 4). It will be seen from the table that out of those who had been in hospital for

less than one year 11 were regular and 18 irregular. Fig. 4 shows how the percentage of regular breathers goes up according to the length of time that the patient has been in hospital.

TABLE III. RELATION OF REGULAR OR IRREGULAR RHYTHM TO DURATION OF MENTAL DISEASE

Length of time in hospital	Under 1 year		2-5 years		6-10 years		11-20 years		Over 20 years		Total
	Reg.	Irreg.	Reg.	Irreg.	Reg.	Irreg.	Reg.	Irreg.	Reg.	Irreg.	
SCHIZOPHRENIA											
Males	7	16	12	6	13	3	22	4	15	2	100
Females	4	2	2	3	3	1	1	1	15	4	36
Total	11	18	14	9	16	4	23	5	30	6	136
MELANCHOLICS											
Males	7	5	0	1	0	0	0	0	0	0	13
Females	7	4	0	5	0	0	0	3	0	0	19
	14	9	0	6	0	0	0	3	0	0	32
EPILEPSY											
Males	0	1	2	1	0	1	0	0	8	1	14

Further analysis of the figures, however, showed that the difference between the percentage of regular breathers among the schizophrenics who had been in hospital less than one year, and those who had been in from two to five years, was not significantly different. Neither of these groups was significantly different from the normal. All the schizophrenic groups, however, who had been in hospital more than five years showed a significantly greater percentage of regular breathers than the other three groups, namely, (1) the normal group ; (2) the group of patients admitted less than one year ; and (3) the group of patients admitted two to five years previously.

When we examine the records of 32 melancholic patients we find that 14 are regular and 18 irregular. (As only three of these had been in hospital more than five years it was not possible to correlate regularity with the duration of the illness, as has been done in the case of the schizophrenics.)

Of the epileptics who had been in more than 20 years, eight were regular and one irregular. These were all considerably demented. Of those who had been in less than five years, two were regular and two irregular.

It may be observed, then, from these cases that where there is considerable dementia whether in schizophrenics or epileptics, the respiration is usually regular. The most regular were those who were not able to do work of any kind. No marked difference could be seen between the record of the typically regular normal and that of the typically regular schizophrenic. The extremely regular type of rhythm, however, such as is found in sleep, was commoner among schizophrenics than normals. There was no obvious difference between the typically irregular normal and the irregular schizophrenic. Some schizophrenics, however, gave rather unusual respiratory

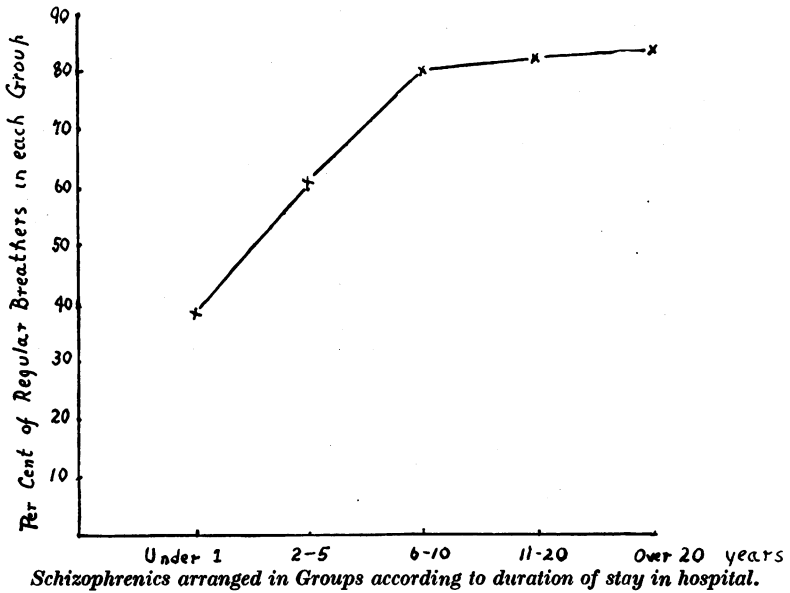


FIG. 4

In those groups that have been in over six years the number of regular breathers is over 80 per cent. in each case.

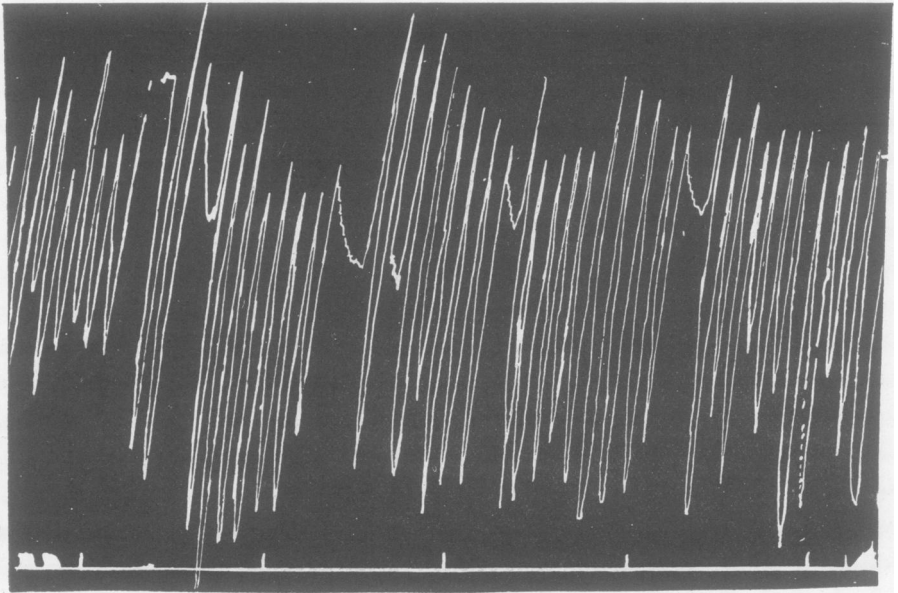


FIG. 5.—Periodic breath-holding in a schizophrenic.

records, such as periodic holding of the breath (fig. 5). Another showed a curious tremor of the respiratory muscles during each respiration (fig. 6).

There were still other unusual records which were in keeping with the rhythmical and bizarre character of other schizophrenic symptoms.

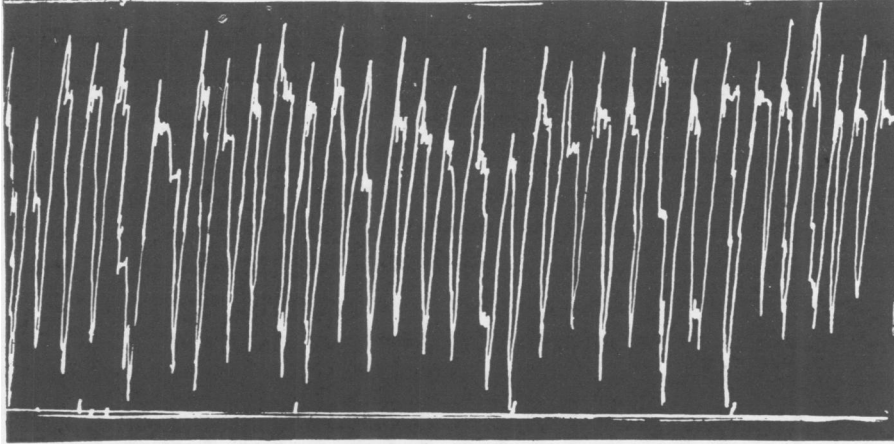


FIG. 6.—Rhythmical tic-like respiratory movements in a schizophrenic.

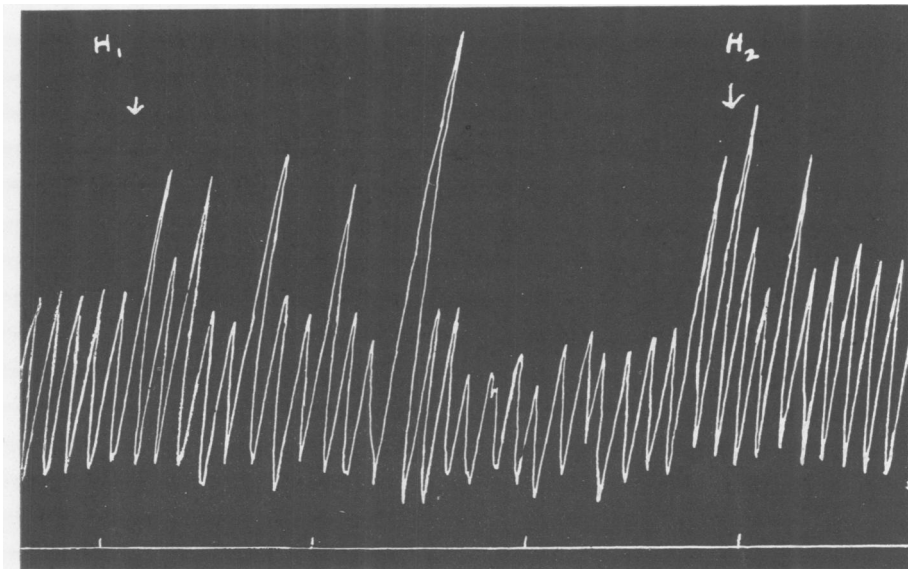


FIG. 7.—Schizophrenic, a regular breather, shows irregular respiration between H_1 — H_2 , during which time he was hallucinating. No movement of lips or larynx was noticeable.

RECORDS SHOWING HALLUCINATIONS.—It not infrequently occurred in one of these experiments that while a patient was breathing regularly he suddenly started to breathe irregularly (fig. 7). When questioned, he would say

that he had heard a voice speaking to him, even although his lips had not been observed to move. On more than one occasion this occurred where the patient had denied hallucinations, but later admitted them, when asked about his thoughts at the moment when his breathing changed. On other occasions sudden irregularity of breathing was found to be accompanied by olfactory hallucinations.

THE I : E RATIO.—Some writers have claimed to find a difference in the character of the respiratory curve obtained from schizophrenics as compared to that obtained from normals. In these experiments inspiration is represented on a moving drum by an upstroke and expiration by a downstroke. One can compare the duration of inspiration with that of expiration (fig. 8). The duration of inspiration divided by the duration of expiration has been called 'inspiration-expiration ratio.' The expiration period lasts from the

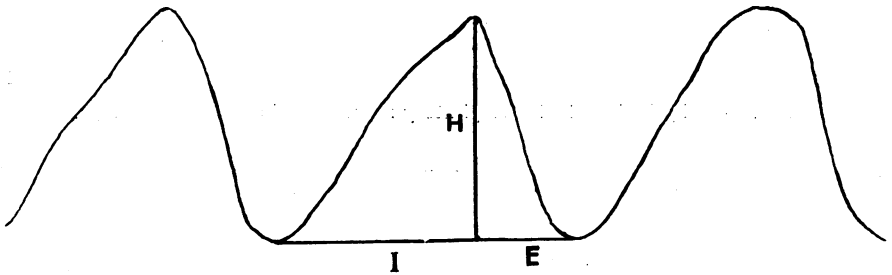


FIG. 8.—The figure is taken from a stethograph tracing, inspiration being represented by an upstroke and expiration by a downstroke. I = duration of inspiration, and E = that of expiration. Some writers have stated that the I/E ratio is different in schizophrenics from normals.

end of inspiration to the beginning of the next inspiration and so includes the respiratory pause. Now if the rate of respiration be decreased the decrease in rate occurs chiefly at the expense of the respiratory pause. Since, then, the respiratory pause is included in the expiratory phase, E will be relatively longer. For instance, Mignot and Le Grand⁵ studied a few cases in which there was especially slow respiration. They found that the I : E ratio from being 10 : 14 in normals was as much as 10 : 20 or even 10 : 80. Since, however, in most cases of schizophrenia the rate of respiration is increased, the I : E ratio is less than 10 : 14.

OTHER CHARACTERISTICS OF THE RESPIRATORY CURVE IN SCHIZOPHRENICS.—A great deal of the work done on this subject gave negative results. It has been said by Sandri⁹ that in schizophrenics if inspiration is represented by an upstroke, the first half is steeper than the second half. In normals it is said that this feature is much less marked. In expiration also, the first half of the downstroke in schizophrenics is said to be steeper than the second half. In the present series, however, no difference of such a kind

could be seen in the plethysmographic tracings, nor in the thoracic or abdominal tracings where these were also carried out.

REACTIONS TO STIMULI BY NORMALS AND SCHIZOPHRENICS

Both normals and schizophrenics were subjected to certain disturbing factors in order to ascertain whether the latter's change of respiratory depth and frequency was significantly different from that of the former. The first of these consisted of a mental exercise. Not only normals but also those schizophrenics who could give correct answers were asked to add up a column of figures while sitting in the apparatus.

TABLE IV. COMPARISON OF UNDISTURBED RESPIRATION WITH THAT OCCURRING DURING MENTAL TEST (ADDITION) AND DURING PINCH, IN NORMALS AND SCHIZOPHRENICS

	Normals			Schizophrenics		
Addition Difference	h_1 47.5	f_1 17.9	v_1 824	h_1 38.7	f_1 20.3	v_1 786
	h_2 49.6 Not sig.	f_2 22.1 Sig.	v_2 1037 Sig.	h_2 43.3 Not sig.	f_2 21.6 Not sig.	v_2 946 Borderline
Pinch Difference	h_1 45.7	f_1 17.4	v_1 762	h_1 35.7	f_1 19.7	v_1 693
	h_2 37.2 Sig.	f_2 18.3 Not sig.	v_2 654 Not sig.	h_2 29.6 Sig.	f_2 18.4 Not sig.	v_2 521 Not sig.

h_1, h_2 = height of respiratory curve in mm., during undisturbed state and during the respective tests. f_1, f_2 = frequency of respirations per minute. v_1, v_2 = volume, product of h and f . 'Sig.' indicates that the difference between undisturbed and disturbed values is significant. In the 'addition' test there were 43 normals and 34 schizophrenics. In the 'pinch' test there were 20 normals and 20 schizophrenics.

Forty-three normals and 34 schizophrenics were subjected to this test (Table IV). With the normals the height during addition was not found to be significantly different. This, however, may have been due to the fact that too few cases were examined. The frequency and also the total ventilation, however, were significantly greater during addition. In the schizophrenic group the height and frequency were not significantly changed during the mental exercise compared to the undisturbed state. The change of total ventilation was found to be on the border line of significance.

Twenty normals and 20 schizophrenics were also subjected to a painful pinch. Following the pinch there was a significant decrease in the height of the curve both in normals and in schizophrenics. The changes in frequency and volume, however, were not significant in either class.

Statistical analysis showed that the only values of normals in both these tests which could be compared with those of schizophrenics were (1) volume of respiration in the addition test, (2) frequency of respiration during the addition test, and (3) height of respiration during the pinch (Table V).

TABLE V. EFFECT OF STIMULI ON SCHIZOPHRENICS COMPARED TO NORMALS. THE DIFFERENCES WERE RECKONED AS PERCENTAGES OF THE UN-DISTURBED VALUE.

		Mean percentage of change	Standard error
<i>Volume of respiration during addition</i>	Volume for normals ,, schizophrenics	+ 29.4 + 17.7	± 6.6 ± 5.8
<i>Frequency of respiration during addition</i>	Frequency for normals ,, schizophrenics	+ 30.0 + 5.3	± 7.2 ± 3.2
<i>Height of respiration during pinch</i>	Height for normals ,, schizophrenics	- 19.2 - 19.0	± 4.0 ± 5.9

Only in frequency of respiration is the difference in normals significantly greater than in schizophrenics.

It will be seen from the table that the only significant difference is in the frequency of respiration during addition. This is significantly greater in the normals than in the schizophrenics.

From the above figures, then, no very decisive conclusions can be drawn, owing to the relative amount of scatter, and the relative paucity of material. One can only say that the figures have not proved the existence of a greater or less reaction to pain in schizophrenics. They allow, however, of a tentative conclusion that there is a greater increase of the frequency of respiration during mental exercise in normals than in those schizophrenics capable of correct addition.

Both normal and schizophrenic individuals were also subjected to the sudden hoot of a motor horn and also to the light of a magnesium flare. The reactions, however, varied so much from individual to individual that no conclusion could be drawn.

DISCUSSION

As has been already stated, the whole subject of the relation of normal and pathological mental processes to the respiratory curve is a very large one.

In what follows an attempt is made to answer the three questions which were suggested in describing the scope of the present inquiry.

1. *Is there any particular mental process which gives a special type of respiratory record?*—In the present study there was seen to be a relation between the type of mental imagery, auditory or visual, and type of respiration, irregular or regular respectively. As already mentioned, early investigators obtained no very clear results when they attempted to find characteristic respiratory curves for various emotions. Peterson and Jung, however, stated that the respiratory variations were associated with intellectual rather than emotional changes. Golla and Antonovitch went further and concluded that irregularity was associated with auditory imagery and regular with visual imagery.

In the present study the main argument to prove that regularity of rhythm tends to go with visual imagery was provided by the fact that where the subject was asked to work out a problem requiring visual imagery, the respiration was nearly always very regular except in those cases where the individual appeared from subjective tests to find difficulty in using visual imagery at all. Again, subjects nearly always breathed with an irregular rhythm while doing a test which experience had shown usually to require auditory imagery, with a tendency to vocalization, except where the individual found difficulty in employing any sort of auditory imagery.

An attempt was made to examine 65 normals by subjective and objective tests to see whether they used predominantly visual or auditory imagery. It was then found that regularity of rhythm corresponded to visual imagery in 75.0 per cent. of cases, and irregular rhythm to auditory imagery in 72.8 per cent. of cases. It is possible that these percentages might have been even higher if more elaborate tests had been carried out.

A considerable amount of evidence, therefore, has been brought forward to indicate that regular breathing is accompanied as a rule by visual imagery and irregular by auditory imagery, the subject tending to use a kind of inner speech in the latter case.

2. *Is there any feature which is more frequently, or solely, found in the respiratory curve of a psychotic compared to a normal individual?*—It has been found that the respiration of schizophrenics is more shallow and more rapid on the average than normal subjects. Further, those schizophrenics who had been in hospital more than five years showed a significantly greater percentage of regular breathers than either normals or recently admitted schizophrenics. About 83 per cent. of those who had been in hospital over 20 years were regular compared to 49 per cent. of normals.

Further work is therefore suggested on the subject of the mental imagery of schizophrenics, to find out whether these use predominantly visual imagery, and if so, whether it differs from that employed by most normal persons. The question whether the regularity of rhythm accompanies a mere cessation of mental processes or a series of visual images remains undecided.

Schizophrenic patients were found on occasion to give peculiar kinds of records which would not be found in normal subjects. Some, for instance, showed a regularly recurring phenomenon such as holding the breath. Another feature which was characteristic of schizophrenia was extreme regularity of rhythm broken by a temporary extreme irregularity, followed again by a very regular rhythm. Yet during the irregular period the patient's lips or cheeks were not observed to move. These patients were found to be hallucinating.

3. *Are the respiratory reactions of psychotic subjects to various stimuli different from those of normal subjects?*—It was difficult to devise tests which would give sufficiently uniform results in normals to enable them to be compared to those obtained from schizophrenics. When those schizophrenics

who were capable of giving correct totals in adding up a column of figures were compared to normals, the increase of respiratory rate was significantly less than the increase of rate during adding in normals. No conclusions could be drawn with regard to pain, sound or light reactions.

SUMMARY

1. The respiratory function has been studied in its relation to the higher cerebral centres. A description has been given of previous work on the subject. Some earlier workers had studied the effects of various emotions, pleasant and unpleasant stimuli, etc., on the respiratory rhythm. On the whole the results were disappointing.

2. F. Peterson and C. G. Jung indicated that changes of respiration were more closely related to conscious thought and vocalization than to emotional changes. Golla and Antonovitch found that about 50 per cent. of normal individuals breathed with regular rhythm and about 50 per cent. with irregular rhythm. They stated that the regular breathers more commonly employed visual imagery as an instrument of thought, while the irregular employed predominantly auditory imagery, the tendency to vocalization being responsible for the irregularity.

3. In the present inquiry, an attempt is made to answer three questions in relation to respiratory rhythm. (a) Is there any particular mental process which in normal subjects gives rise to a special type of respiratory tracing? (b) Is there any feature which is more frequently found, or any feature which is only found, in the respiratory record of a psychotic individual as compared to a normal? (c) Are the respiratory reactions of psychotic subjects to various stimuli different from those of normal subjects?

4. The respiratory records of 65 normal subjects, and of 178 psychotics were examined. Of the normals, 32 breathed with a regular rhythm and 33 with an irregular rhythm. The various causes of irregularity of respiratory rhythm are investigated, and evidence is brought forward to show that auditory imagery with its tendency to vocalization is responsible for this irregularity, when other causes have been excluded.

5. The following facts support this conclusion. Forty-four normal individuals were first set a problem, the solution of which would ordinarily demand visual imagery, and then one which would require auditory imagery. Eighteen were regular in one task but irregular in the other. Of these 18, all except one showed regular rhythm in the test for which visual imagery was indicated but irregular rhythm in the test for which auditory imagery was commonly used. Thirteen individuals were regular in both tests, and 13 irregular in both tests. Subjective examination of these individuals indicated that 12 of the 13 regular breathers employed predominantly visual imagery, while 10 of the 13 irregular breathers had a preference for auditory imagery.

6. Of the 136 schizophrenics, 94 were regular and 42 irregular. When

these were arranged in groups according to the length of time spent in hospital, of those who had been in hospital less than one year 38 per cent. were regular; of those from two to five years, 61 per cent. were regular; from six to ten years, 80 per cent.; 11 to 20 years, 82 per cent., and over 20 years, 83 per cent. Thus among the groups who had been in hospital more than five years, the proportion of regular breathers was significantly higher. Of the 32 melancholic patients, only three of whom had been in hospital more than five years, 14 were regular and 18 irregular.

Of the epileptics who had been in hospital more than 20 years, eight were regular and one irregular. These were all considerably demented. Of those who had been in less than five years, two were regular and two irregular.

7. There was no characteristic difference between the regular rhythm of normal subjects and that of schizophrenics. In the latter group, however, an extreme degree of regularity was more frequent. They also showed on the whole a shallower and more rapid rhythm. Some showed records of a peculiar character not found in normals. Those with hallucinations showed characteristic records, the extreme regularity being broken by extreme irregularity during the hallucinations, even when there was no movement of lips.

8. Reactions of the respiratory mechanism to stimuli were studied in normals and schizophrenics. Not enough cases were examined to give definite results owing to the scatter among normal subjects. There was a significant difference, however, between the reaction of those schizophrenics who were able to perform an intellectual exercise, and normals. The schizophrenics did not react with so great an increase of respiratory rate.

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