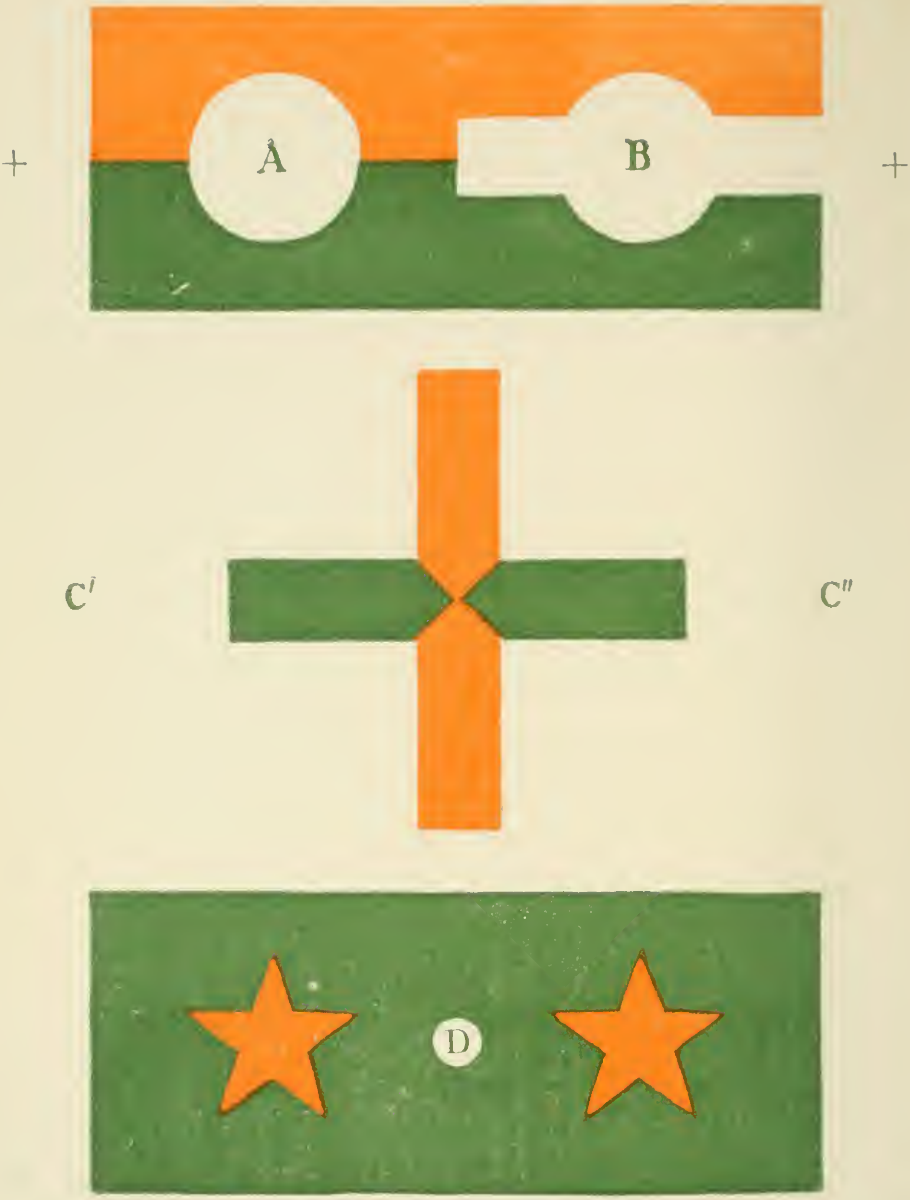
Thinking Feeling - Doing



A, B, C, Blind-spot Figures (see page 149, note).
D, Fluctuation Figure (see page 151).

Thinking Feeling, Doing

An Introduction to Mental Science

By

E. W. Scripture, Ph.D., M.D.

Assistant Neurologist, Columbia University

Second Edition, Revised

Illustrated

G. P. Putnam's Sons
New York and London
The Knickerbocker Press
1907

The Knickerbocker Press, New York

PREFACE TO THE SECOND EDITION

THE first edition underwent many vicissitudes. It had a phenomenal sale—over 20,000 copies the publishers said. More than half the book appeared with a few changes of phraseology, but entirely uncredited, as a small book on psychology by a school principal. A translation into Mandarin Chinese was prepared by Prof. Headland, of Peking University, but the buildings of the university were burned during the Boxer outbreak in 1900, and both manuscript and plates were lost.

The first edition was exhausted and a second was called for in 1900. In spite of a promise to furnish the revision promptly I have been hindered from doing it by scientific work and other duties. I feel that I owe an earnest apology to persons who have been seeking copies of the book and to the publishers who have waited with patience and courtesy.

It is quite impossible to give credit to all to whom it is due. The references to the investigators who have built up the new psychology may be found in more technical works, such as those of Wundt; full literature is given in Titchener's laboratory manuals and in Baldwin's *Dictionary of Philosophy*. Where the material of this volume has not been drawn from other investigators, it is the work of myself and my pupils in the Yale Psychological Laboratory. Figure 13 is from an investigation by McAllister; 24, 30, 57, 79, 80, 177, 180, from Gilbert; 31–33 from Marey; 42 from Miyake; 45 from Bliss; 50–55 from Hensen; 59–62 from Féré; 78, 81, 166–171 from Wundt; 105 from Kirschmann; 138–141, 148–156 from Martius-Matzdorff; 157–164 from an art catalogue; 165 from Witmer; and 176 from Wolfe. The figures for the optical illusions have been so frequently repeated that it seems impossible to assign credit.

Vanderbilt Clinic, Columbia University,
October, 1907.

PREFACE TO THE FIRST EDITION

A FELLOW psychologist said to me one day, "Are you not afraid that all this accurate and fine work in the laboratory will scare away the public?" . . . We all belong to the great public except in regard to the particular handiwork, trade, or science that each knows something about. And yet we are all interested in hearing about a new science. There is nothing too good for the public—the finer the work, the more novel the invention, or the more important the discovery, the greater the duty of telling it to the public in language that can be understood. . . . This is the first book on the new, or experimental, psychology written in the English language.

Yale University, Jan., 1895.

CONTENTS

ILLUSTRATIONS

THINKING, FEELING, DOING

THINKING, FEELING, DOING

CHAPTER I

WATCHING AND TESTING; OR OBSERVATION AND EXPERIMENT

THE fundamental method of acquiring knowledge is observation, or watching. We watch our thoughts and feelings to know what goes on in our own minds; we watch the actions of others to draw conclusions concerning their thoughts and feelings.

A great difficulty lies in the fact that the act of observing may change the person or thing to be observed. Every public man wears a mask, because he is watched. If we wish to know just what kind of a man he is, we must watch him in unsuspected moments. A great deal of ridicule has been cast on the enthusiasts who pry into the most intimate details of a statesman's or poet's private life. In one respect these men are quite in the right. They say to themselves, "The public is interested in knowing just what the man really is when he has his mask off."

If there is anything wrong about this, it is not the method; just this method is to be used in acquiring all knowledge. In fact, I shall want you to watch the processes thinking, feeling, and doing, in exactly the same fashion. Lie in wait, concealed; catch your "process" going on in a perfectly natural way. Moreover, strange as it may seem, this is the only way, the fundamental rule being that the act of watching must not change the person or thing watched.

It is not sufficient to know this rule; we must be constantly on guard against several very dangerous sources of error. The first is the error of prejudice. Grandmother M. has used Dr. Swindle's liver pills all her life long. She always believed they would do her good; she remembers the dozen times she happened to feel better after taking them and forgets the hundreds of times she did not. Therefore she has facts—incontestable facts—to prove the goodness of the pills. Possibly her picture appears in the newspaper with an enthusiastic testimonial. It is useless to attempt to convince her that her method of observation has been vitiated by the error of prejudice.

Of course, this error is very plain in other people, but most of us believe that we always judge fairly. But to think scientifically we must realise that each one of us is so biased by prejudice that in many ways we cannot possibly observe correctly.

To show that everybody is prejudiced, let me ask you such questions as: Have you not some pet fad on which you are sure you are right and all the rest of the town are wrong? Are you not quite sure that there is only one side to the tariff question? Are you not astounded at the fact that some people find a good side to a man you know—yes, *know*—to be utterly bad? Don't be ashamed to confess. The great scientist Faraday did. "It is my firm opinion that no man can examine himself in the most common things having any reference to him personally or to any person, thought, or matter related to him without soon being made aware of the temptation to disbelieve contrary facts and the difficulty of opposing it. I could give you many illustrations personal to myself about atmospheric magnetism, lines of force, attraction, repulsion, etc."

Seven alienists of good standing swore that according to the facts before them a certain murderer was sane; they were employed by the prosecution at $100 a day. The defence employed seven equally good alienists at $150 a day; these swore that according to the same facts the man was insane. Everyone of these men was honest in his opinion—at least as far as his consciousness went; there was at work a cause which unconsciously led him to give his opinion in a certain way: he was paid to do so. How shall such errors of prejudice be avoided? In Germany the court sends for any expert it pleases; his pay is $2 a day with no compensation for the damage done to his profession or business; if he is not willing to serve, the policeman brings him to court by force. He has no motive for making his observation favour either side and he is punished for any laxity or misrepresentation. Among scientific men preconceived opinions, the fear of taking back anything that has been published and the desire to achieve novel results produce the "will to observe" that makes us see so many things that do not exist. How shall we combat the error? Several ways are possible. We may use moral suasion. We may partly remove the motives by agreeing to recognise that the withdrawal of an erroneous statement is a most honourable thing. We may also learn to recognise that the reverence for the "old" is the most misleading of all guides. Not much is to be hoped from such methods; the best method is to force the investigator to arrange experiments and recording instruments so that the facts can speak for themselves. We can thus "police" a man's statements by obliging him to furnish experimental proof for them. This is what the new psychology tries to accomplish.

Another very dangerous error is that of unconscious additions.

Play the game of twenty questions. The company choose some object and some one who does not know what has been chosen has to guess it from the answers "Yes" or "No" to his questions. Stop him when he is half through and ask him to tell you what he concluded from the different answers. You will find that he adds far more than is justified by the answer to each question. For example, something chosen is neither animal nor mineral; it is, therefore, so the questioner thinks, "a" vegetable. But suppose you had chosen "buckwheat cakes"?

This error is one of the most troublesome ones in reading printer's proof; letters and words that have been omitted by the compositor are unconsciously supplied by the reader. An author, on account of his interest, is more liable to this error than any one else; he is generally a very unreliable proof-reader.

A familiar case of this error is found in the story of the ten white crows—which I will leave the reader to hunt up in his old school books.

This source of error, as Wundt has pointed out, renders almost absolutely worthless an enormous amount of painstaking work in animal psychology. The facts are observed and collected with untiring diligence, but the critical study of the results is generally entirely lacking.

Take, for example, a case reported by Romanes in his volume on animal intelligence.

An English clergyman writes concerning the "funereal habits" of ants: "I have noticed in one of my formicaria a subterreanean cemetery, where I have seen some ants burying their dead by placing earth above them. One ant was evidently much affected, and tried to exhume the bodies; but the united exertions of the yellow sextons were more than sufficient to neutralise the effort of the disconsolate mourner."

Wundt asks, How much is fact, and how much imagination? It is a fact that the ants carry out of the nest, deposit near by, and cover up dead bodies, just as they do anything else that is in their way. They can then pass to and fro over them without hindrance. In the observed case they were evidently interrupted in this occupation by another ant, and resisted its interference. The cemetery, the sextons, the feelings of the disconsolate mourner, which impelled her to exhume the body of the departed—all this is the fiction of the sympathetic imagination of the observer.

Another friend of ants gives this account: "At one formicary half a dozen or more young queens were out at the same time. They would climb up a large pebble near the gate, face the wind, and assume a rampant posture. Several having ascended the stone at one time, there ensued a little playful passage-at-arms as to position. They nipped each other gently with the mandibles, and chased one another from favourite spots. They, however, never nipped the workers. These latter evidently kept a watch upon the sportive princesses, occasionally saluted them with their antennæ in the usual way, or touched them at the abdomen, but apparently allowed them full liberty of action."

The correctness of this observation, says Wundt, need not be questioned. Why should not a number of young queens have been crowded together upon a pebble, and some workers have been with them, and occasionally touched them with their antennæ, as ants do everywhere? But that they "sported" and played, that the others "kept watch upon them" like chaperones, and now and again did homage to them by "saluting"—all this is due to the imagination of the observer. He would hardly have told the story in this way had not the suggestive name "queen" been introduced for the mature female insects. If the adults are "queens" the young ones must, of course, be "princesses" to the other ants as well as in the imagination of the observer. And since no princess ever went out without an attendant or a chaperone, the rest of the tale follows as a matter of course. If, instead of the name "queen," the mature female ant had been called by the still better term "mother," we would have had an entirely different story from the same facts. I leave it to my readers to tell it.

It is this activity of the imagination that turns men of perfectly honest intentions into "nature fakers" in their stories of animals.

How easy it is to misinterpret an observation if the very greatest care is not taken in recording it, and if it is impossible to vary the circumstances by experiment and thus to obtain accurate knowledge of the details, is well shown by the following facts.

Pierre Huber, one of the most reliable students of the habits of ants, stated that he had assured himself that an ant, if taken from the nest and returned after an interval of four months, was recognised by its former companions; for they received it in a friendly manner, while members of a different nest, even though they belonged to the same species, were driven away. The correctness of the observation cannot be doubted; it has also been confirmed by Lubbock. Lubbock, however, made the matter a subject of experiment. He took ant larvæ from the nest and did not put them back till they were fully developed. They, too, were received in a friendly manner, although there could be no question of resemblance between the larva and the grown ant. There must, therefore, be some characteristic peculiar to all members of a particular nest, possibly a specific odour, which determines the "friendliness" of the ants.

I shall warn you against only one error more, that of untrustworthiness of the senses, as it is called. Sir Walter Raleigh was one day sitting at a window when he observed a man come into the courtyard and go up to another standing by the door. After a few words the latter drew his sword, they fell to fighting, and the first comer was finally wounded and carried out. A person who had been standing close beside the door afterwards flatly contradicted the observation of Sir Walter, saying that the man at the door had not been the first to draw his sword and that it was not the first comer who was wounded and carried out. Sir Walter's senses had deceived him. Note the flat contradictions of eye-witnesses in the next trial you read about.

Let us now take a few lessons in observing.

1. Below on this page you will find a figure. Write what you see. I am not going to tell you another thing about it; not even what the exercise is for. Show the figure to other people with the same directions. Compare your result with theirs. Just as you progress in understanding what the exercise is for, just so far will you have profited by it.

2. On the second page from this you will find a number of letters printed in a square. Turn over the page for just an instant and then close the book. What letters can you remember? You can readily prepare a set of cards with various combinations of letters and can train your friends in observing. Or you can use cut letters, such as go under the name of letter-tablets. Make irregular combinations on the

Fig. 1.—An Exercise in Observation.

table behind a screen of some kind, *e. g.*, a book; snatch the book away for an instant, and have the onlookers write down the ones they saw. Then form words instead of letters. You will notice that people can catch almost as many words as they can catch disconnected letters. Or you can write on a slate and turn it over for an instant. Or you can use dominoes.

3. Place a number of objects on a table in the next room. Let each person go in and walk once around the table during the time you count twenty. Coming out he is to write down a list of what he saw.

At first you can catch almost nothing in the last two exercises. It is very important to continue the practice; you cannot go too far. You will be encouraged by knowing that the magician Robert-Houdin began in the same way. He and his son would pass rapidly by a shop-window and cast an attentive glance at it. A few steps farther they noted down on paper the objects they had seen. The son could soon write down forty objects. This training was kept up till an astounding ability was acquired. On the occasion of one performance the son gave the titles of more than a dozen books in another room with the order of arrangement on their shelves. He had seen them in a single glance as he passed rapidly through the library.

There are many women who have unintentionally educated themselves to a high degree of ability in quick observation. It can be safely asserted of many a one of them that, seeing another woman pass by in a carriage at full speed, she will have had time to analyse her toilet from her bonnet to her shoes, and be able to describe not only the fashion and quality of the stuffs, but also say if the lace be real or only machine made. It is said that, when passing on the street, eight women out of ten will turn around to see what the other one wears. I have often wondered at the two who did not turn around—but the reason is clear: they did not need to.

Innumerable exercises in quick and accurate observation can be used in direct assistance to the regular work of the schoolroom. The spelling of words can be learned by quick glances; the outlines and parts of a country can be taught in greater and greater detail by successive quick exercises; a problem in mental arithmetic is to be grasped with only a momentary presentation of it; an object is to be drawn after an instantaneous glimpse; etc., etc. Indeed, there is not a single school exercise that cannot be so taught as to train this ability. In fact, the children are naturally quicker than we suppose them to be; it is often the case that lessons of interest to the child are presented in such a way as to actually teach him to be slow instead of quick.

M	B	X	O
Q	R	A	G
F	C	W	P
T	E	D	L

FIG. 2.—An Exercise in Quick Observation.

In ordinary observation we wait for things to happen in one way or another; possibly they never happen in just the circumstances most favourable for studying them. In an experiment we arrange the circumstances so that the thing will happen as we wish. How good is the memory of a certain child? We might wait a long time before he happened to perform some memory exercise that would exactly answer the question. Instead of this we experiment on him by giving him lines of figures, sets of syllables, words, etc., till we know in just what condition his memory is.

Vary only one circumstance at a time. If you wish to find how strong a child's memory is at different times of the day, you should not make the morning test with words and the next with figures. There might be a difference due to the change from words to figures, and you would suppose this difference to be due to the time of day.

Experiments can be conveniently divided into three grades. 1. *Tests.* The test is the simplest form and is an answer to the question: Is something so or not so? The usual test on hypnotised persons is pricking them with a pin to see whether they feel or do not. By flashing a light we determine whether a person is absolutely blind or not. 2. *Qualitative experiments.* By these we aim to answer the question: What? In experiments on the emotions we ask what bodily processes change with them. To determine what colour a person can see, we make experiments for colour-blindness. 3. *Quantitative experiments.* How much? is the question we ask in this case. How small a difference can you detect? How many syllables can you remember? How quickly can you think.

The objection is sometimes made that experiments in thinking, feeling, etc., are physical and not mental. This confuses the means with the thing, the tools with the work done. The apparatus is physical, but your accuracy of judgment, your suggestibility, your power of will, are mental.

CHAPTER II

TIME AND ACTION

FOR the purpose of measuring small intervals of time one of the most convenient methods is the graphic method. Being one of the most beautiful and accurate methods of experiment, it is extensively employed in physics, astronomy, physiology, and psychology.

The first thing to be done is to set up a tuning-fork —not a little one, such as musicians carry in the pocket, but one a foot long, vibrating one hundred times a second. By means of a battery and a magnet this fork is kept going of itself as long as we please. The prongs of the fork move up and down one hundred times a second. Every time the lower prong moves downward, a point on the end dips into a cup of mercury, whereby an electric circuit is closed. This electric circuit passes through a little instrument called a

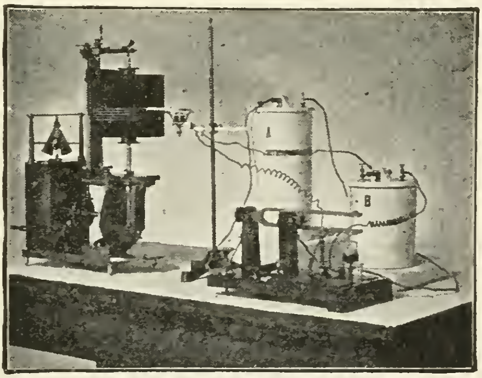


FIG. 3.—Apparatus for Recording Time.

time-marker, which makes a light pointer move back and forth also one hundred times a second. The point of the time-marker rests on a surface of smoked paper around a metal drum. The smoked paper is prepared by stretching ordinary glazed paper around the drum and holding a smoky gas or benzine flame under it. A soft black surface is thus obtained, in which the point of the marker draws a wavy line as the drum is turned (Fig. 4).

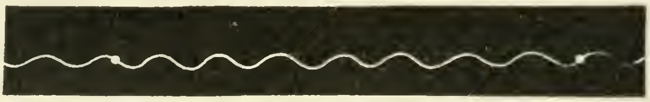


Fig. 4.—A Specimen Record.

Now, if the point of the marker moves back and forth just one hundred times a second, each complete wave must mean 0.01^s of time. Consequently if a dot is placed on the line whenever I move my finger, as is illustrated in Fig. 4, I can tell just how much time elapsed between any two movements by counting the waves and the fraction of a wave. Thus the two dots are distant by seven whole waves and five-tenths of a wave extra; the time is, therefore, 0.075^s. The wavy line is called the "time-line."

In making careful records in the laboratory it is needful to count in thousandths of a second, but there is so much uncertainty about the last figure that in the final statement of results is not only unnecessary to state the thousandths, but it is also misleading on account of the false degree of accuracy implied. We will therefore use hundredths of a second to count by.

In order to save the multitude of 0's and decimal points let us introduce the sign Σ to indicate hundredths of a second. We will call the sign "sigma." Thus instead of 0.08^s we write 8Σ.

To put dots on the time-line when a finger is moved, it is placed on the button of a special telegraph key, so arranged that the slightest movement of the finger breaks an electric circuit. Fig. 5 shows the finger ready to make a record when it moves downward; the electric circuit passes through the rear contact of the key. This electric circuit runs through a large coil of wire which makes a spark whenever the circuit is broken. Two wires run from this spark-coil, one to the drum and the other to a metal point resting on the smoked paper. Whenever a spark is made, it jumps through the paper scattering the smoke and making a white dot. In Fig. 3 the metallic point is the time-marker itself. Every time we move the finger a dot is made on the time-line. Fig. 4 shows the time between two downward movements of the finger. To preserve the record, *i. e.*, to keep the smoke from rubbing off, the paper is cut from the drum, run through a varnish, and dried.

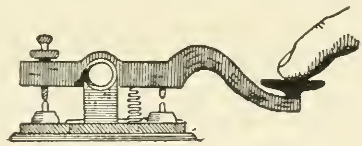


Fig. 5.—Electric Key.

Such movements of the finger are called "taps." The study of tapping enables us to draw deductions concerning the will and how it varies. For each tap there are two acts of will, one to move the finger down and the other to lift it. There is no resemblance or relation between tapping and what are known as "tremors"; we can will to tap, but we cannot will to tremor; the one is voluntary action, the other involuntary. "Trembling" is a term applied sometimes to voluntary movements of the same nature as tapping, sometimes to tremors.

In one form of experiment the person is told to tap as rapidly as he can. Series of sparks fly off the end of the point of the time-marker in Fig. 3. On counting up the records we obtain the number of hundredths of a second for each tap. A good average rate is 15Σ per tap, or nearly seven taps to the second. Faster records have been made, 8Σ having been recorded for tapping with the middle finger.

The rapidity of tapping decreases with fatigue. Fig. 6 represents the results of a continuous series of taps, the lower the line the faster the tap; the straight, horizontal line corresponds to a tap-time of 15Σ and the short checks on this line mark off the seconds. At first the tapping is rather irregular, but it is on the whole very rapid, one tap-time being only 11Σ. The

FIG. 6.—Influence of Fatigue on Tapping-time.

tapping soon becomes steadier and remains rapid for about seventeen seconds. After that it is somewhat slower and more irregular, owing probably to fatigue.

The mental condition has a most powerful influence on the rapidity of tapping. Excitement makes the tapping more rapid. The influence of distraction of attention is shown in Fig. 7. This figure has the same meaning as Fig. 6. Adding 214 and 23 produced a marked slowness in tapping ; so did the mental labour of multiplying 14 by 5. It requires some effort for an ordinary man to perform these calculations, and the mental work of association seemed to leave less energy for the work of will. The figure seems to show that momentary distractions not involving any work, such as

Fig. 7.—Influence of Mental Activity on Tapping-time.

whistling, clicking the tongue, or lighting a match, do not change the rapidity. They do, however, improve the *regularity;* the curve is smoother. It is a noteworthy fact in all our mental life that the less attention we pay to an act the more regular it is.

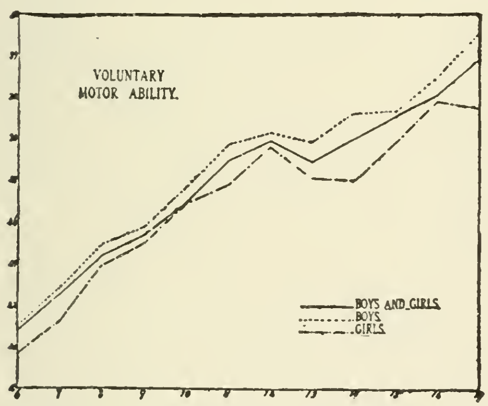


Fig. 8.—Rapidity of Tapping as Dependent on Age.

The rapidity of tapping varies with the time of day. The averages of six weeks of work gave the following results : at 8 A. M. the time required for making 300 taps was 37.8^s ; at 10 A. M.; 35.5^s ; at 12 M., 34.6^s ; at 2 P. M., 35.5^s ; at 4 P. M., 33.5^s , at 6 P. M., 35.1^s .

It is noticeable that these results corresponded to the habits of the previous two years of the person experimented upon; these years were spent in public school work with a daily program beginning at 8 A.M. and closing at 4 P.M., with an hour and a half intermission at noon.

The rapidity of action increases steadily with age. Measurements of tapping-time on one hundred New Haven school children of each age from six to seventeen are shown in Fig. 8. The figures at the left give the number of taps in five seconds; those at the bottom the ages. The little children are very slow; the boys at each age tap much faster than the girls.

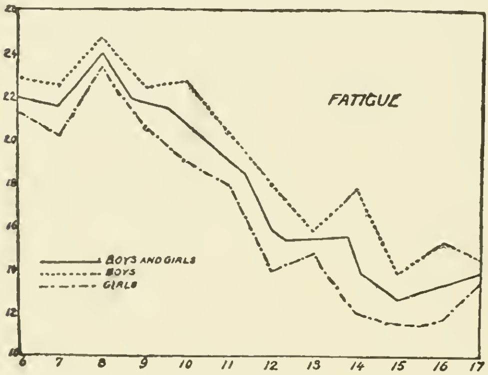


FIG. 9.—Fatigue in Tapping as Dependent on Age.

In these experiments the children continued tapping after the five seconds. After tapping thirty-five seconds longer a record was again taken. The difference between the two sets of record tells how much the child lost owing to fatigue. The results are shown in Fig. 9. The figures on the left give the percentage of loss; those at the bottom the ages. Thus, at six years of age the boys lost $\frac{23}{100}$, or 23 per cent. of the original number of taps.

The amount of fatigue was greatest at eight years, and decreased with advancing age. It is very remarkable that without exception of a single age the girls were less fatigued than the boys. A comparison of the two Figures suggests a conclusion as to the impetuosity of the boyish character.

By connecting both the front and back contacts of the telegraph key in Fig. 5 a spark is obtained at the beginning of each up and down movement; this analyses the tap into its two components. A slight change in the contacts and a strong spark coil make it possible to get a record at the end of each movement also. There are then four sparks for each tap, one for the beginning of the down movement, one for its end, one for the beginning of the up movement and one for its

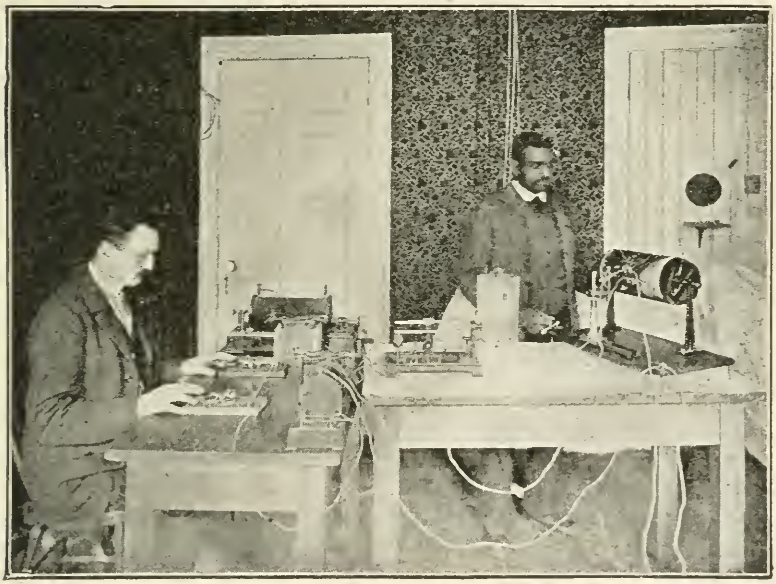


FIG. 10.—Measuring the Simultaneity in Actions of a Piano-player.

end. The tap is thus analysed into two movements and two intervals of rest. For the middle finger the time of each movement varies around 4Σ and the period of rest around 0.3Σ.

We are justified in supposing that in regard to a single finger we cannot will to do two inconsistent things at the same time. Therefore the two movements represent two successive acts of will, each of which required not over 4Σ to arise and execute its movement. This includes what we feel in our mind as the act of will itself, the time occupied in the brain, the time of transmission along the spinal cord and the nerves to the muscles of the arm, the time to arouse the muscle to contraction and the time for the entire contraction. At present it seems hardly wise to attempt to isolate any of these factors, although it would be highly interesting to get the figures for the mental action alone.

Let us now inquire if, when we will to move the two corresponding fingers of the two hands at the same moment, they really do move as intended or if one is behind the other. To do this we must have two keys, two spark-coils, and two metal points, one each side of the time-line. The plan of this arrangement is shown in Fig. 10. When the fingers move, two sparks fly through the paper and two white dots are made. Do they occur at the same moment? A specimen record by a famous organist is shown in Fig. 11.

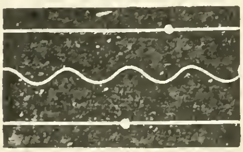


FIG. 11.—Result of the Experiment in Fig. 10. The right hand (upper dot) is 0.005 of a second behind the left (lower dot).

Thus the will to move both hands at the same time results in moving the two at different times. A careful investigation shows that sometimes the right precedes, sometimes the left, in irregular order. The difference frequently amounts to 1Σ and in a condition of fatigue may reach 5Σ. Such differences are found between all pairs of movements that can be made by any parts of the body. Attention to one movement brings it ahead of the other. The differences are not due to muscular or peripheral-nerve changes, but to differences in the original will-impulses.

For many purposes it is necessary to obtain the tap time without the labour and apparatus involved in the method described. We can do this by employing a tap-counter. One form of this is shown in Fig. 12; it has to be very carefully made to avoid the error of failing to count some of the taps and that of counting two when it should count one. The finger can tap directly on the arm *H* or on a key connected with the electromagnet *G* which pulls *H* at each tap. Each movement of *H* around its axle *F* causes *D* to plunge into a notch of the toothed wheel *A* whereby

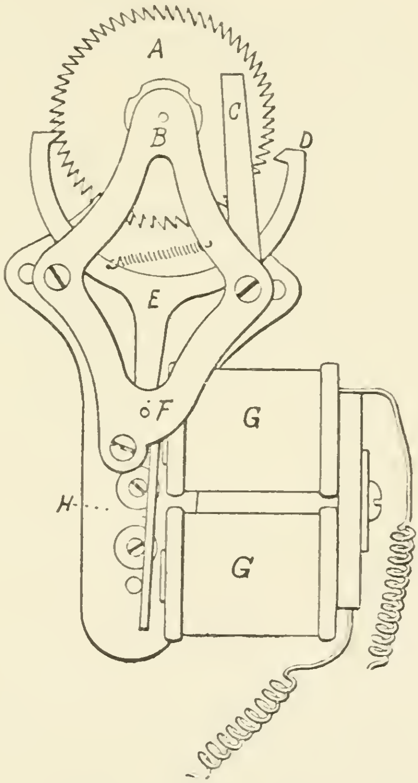


Fig. 12.—Tap Counter.

A turns forward one notch. A pointer (not shown in the figure) on the axle *B* passes over a dial and shows how many taps have been made.

The person to be experimented on is told to tap as rapidly as possible, or slowly, or rhythmically as the case may be, for fifteen seconds; this divided by the number of taps indicated gives the average tap-time. To measure the fatigue a record is made before the work is performed, and again afterward; the percentage of loss is taken as the fatigue-index. The arrangement makes it easy to tell when children become fatigued, whether a lesson is too long or too difficult, etc.

In some experiments with this apparatus both index fingers and great toes were tested as to their greatest rapidity in tapping; then the right great toe was practised daily for ten to twenty days. Thereafter all four digits were tested as before; there was a gain in rapidity not only in the toe that had been practised but also in each of the other digits. Practice in one activity had thus improved other activities. The phenomenon may be called "cross-education"; we shall refer to this remarkable fact again.

Some of the fundamental phenomena of mind can be demonstrated by simply tapping with the finger on a table. Tell a person to tap as rapidly as he can and to keep it up under all circumstances. You will notice that during the first few seconds he gains in rapidity—the gain of "warming up," which means that his nervous adjustments become better and his attention becomes better concentrated. You next notice that he taps less and less rapidly but that soon he taps fast again; this repeats itself over and over, the fast portion becoming shorter and the slow portion longer. Here we have an illustration not only of the fact of mental fatigue, but also of the fact that fatigue proceeds by waves of loss and recovery. Finally the person will stop as if paralysed. But you tell him he *must* go on tapping; he will do so but will again stop, again recover, etc. This is also an illustration of the course of fatigue.

Again, a person taps as rapidly as he can; suddenly tell him to tap still faster; he will do so, thus illus-

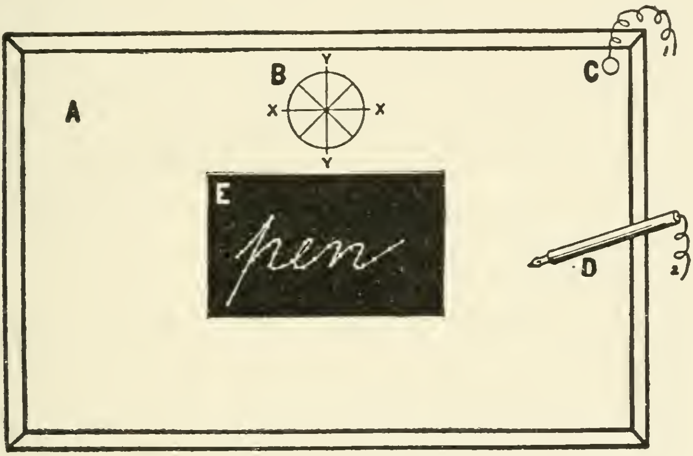


FIG. 13.—Experimental Writing-board.

trating the principle that we have a reserve of energy which can be called forth by the proper stimulus. The slowing of tapping during mental work, the increase of regularity during distracted attention, etc., can all be demonstrated in the same way.

It is often desirable to study how time is distributed in performing an act. As an illustration, let us consider a method of registering the movements used in writing. The board in Fig. 13 is covered with a sheet of metal *A*. A piece of paper *E* covered with soot (smoked while on a drum and then removed) is placed on it. It is connected with a wire *C* from the spark coil. The other wire from the coil leads to the pen *D* in a metal holder covered with rubber. A vibrating electric fork (Fig. 3) is placed in the primary circuit of the spark coil; consequently a spark flies from *D* through the smoked paper at each vibration of the fork. A person is asked to write letters, words and sentences on the smoked paper with the pen; the sparks from the pen make white dots on the line at each hundredth of a second. When the pen moves rapidly, the sparks are farther apart. In the illustration we see them grouped (slower movement) whenever the pen makes a change in direction. We also notice that they are farther apart when no effort is made to connect letters. The conclusions are self-evident.

The diagram *B* at the top of the board is for judging the slant of the lines. It was found that horizontal movements to the right and left were most rapid, that the slant downward and to the left was next best, and upward to the right nearly as good. Vertical and backhand writing were slower; the persons tested had first learned to write with a slant; it still remains unsettled how persons who have learned vertical writing at school would act.

CHAPTER III

REACTION-TIME

WHEN you signal to the car conductor to stop, he reacts by pulling the bell-strap, the driver reacts to the sound of the bell by pulling the reins and the horses react by coming to a rest. By reaction, then, we will understand action in response to a signal. The time between the moment of the signal and the moment of the act is known as the reaction-time.

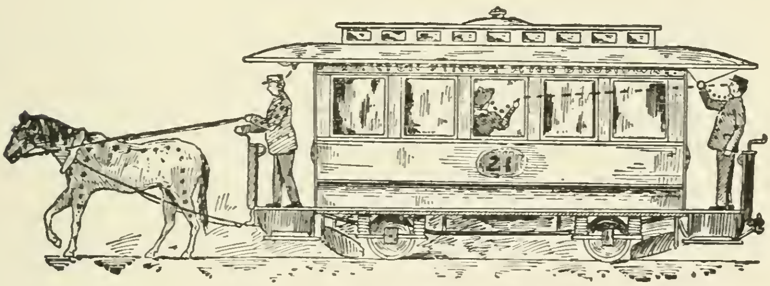


FIG. 14.—A Series of Reactions.

Is there any such time? Quick as thought—that must be pretty quick. Let a number of persons stand in Indian file as if about to march; each one places his right hand on the head (or shoulder) of the person in front. Bend the file around till a complete circle is formed with every right hand on the head of the one in front. One of this file we will call the experimenter; in his left hand he holds a watch—preferably a stop-watch. All the rest close their eyes. The instruction is given: whenever you feel a sudden pressure from the hand on your head, you must immediately press the head of the person in front. When the seconds-hand of the watch is at the beginning of a minute, the experimenter presses the head of the one in front, he presses that of the next in front, and so on. The pressure thus passes all around the group and finally comes back to the experimenter. At the moment he feels the pressure he notes how many seconds have passed. Suppose there were ten persons in the circle and the watch has gone three seconds;

Fig. 15.—Chain-reaction.

then three seconds is the time required for ten acts in response to a signal. The average time for one reaction is obtained by dividing the number of seconds by the number of persons; thus, in this case the reaction-time would be $\frac{3}{10}$ of a second, or 0.3^s.

It takes time, then, to react. A hundred years ago people did not know this. And thereby hangs a tale.

Astronomers have to record the moment of the passage of a star across lines in a telescope. In 1795 the British astronomer royal found that his assistant, working with another telescope at the same time, was making his records too late by half a second. Later on, this difference amounted to 0.8^s. This difference was large enough to seriously disturb the calculations, so the poor fellow lost his place for the sake of eight-tenths of a second.

Many years later two famous astronomers were observing the stars together and recording their passages across the telescope. Strange to say, one was steadily behind the other. Now it would not do to make accusations against a noted astronomer; this set people to thinking. One of the astronomers went to a third astronomer and again there was a disagreement. Finally, after more experience, astronomers in general reached the conclusion that everybody disagreed with everybody else. Moreover men who disagreed in one way at one time would be likely to disagree differently at another time; so that a man did not even agree with himself. As this was evidently not the fault of the star, the conclusion was finally reached that each person had a peculiar error of his own. This was called by the queer name, "personal equation." The British astronomer, who did not suspect that he himself might be incorrect was perhaps no nearer right than his assistant. At any rate, the actual time of the star differed from the recorded time. These observations led to a search for the reaction-time.

If we could get the star to make the first dot on the time-line (Fig. 4), and the astronomer to make the second one, we could measure his reaction-time. This was attempted by using artificial stars with electric connections. Finally an entire technique of reaction-time experiments was developed.

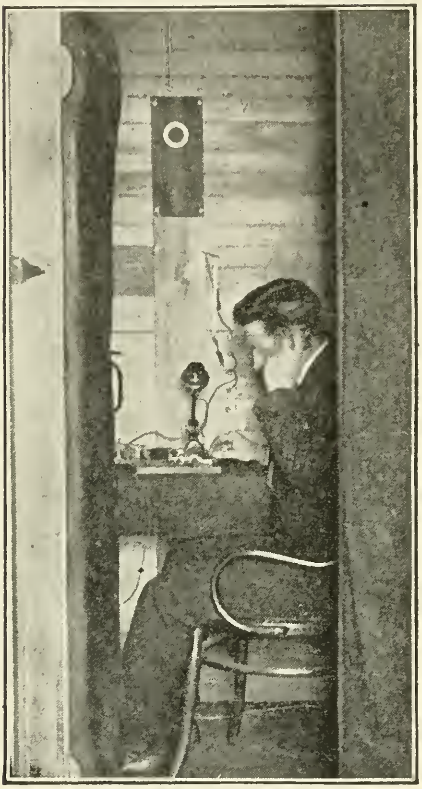


Fig. 16.—In the Reaction-room.

To make careful experiments on reaction the person is placed in a reaction-room where he will not be disturbed. The best reaction-room is an "isolated room," whose thick walls and double doors keep out all sound and light. When a person locks himself in, he has no communication with the outside world except by telephone.

The person in the reaction-room—sits comfortably with the telephone at his ear and with an electric reaction-key (Fig. 17) in his hand (the ordinary telegraph key may be used). The forefinger is placed in the hole of the smaller, or movable, slide, and the thumb is placed in the hole or against the hook of the lower, or adjustable, slide. Flexible wires lead to the post at the top and to the movable slide. The hand is placed in any convenient position, and the thumb and finger are held apart. The wires lead to a spark coil in a distant recording room.

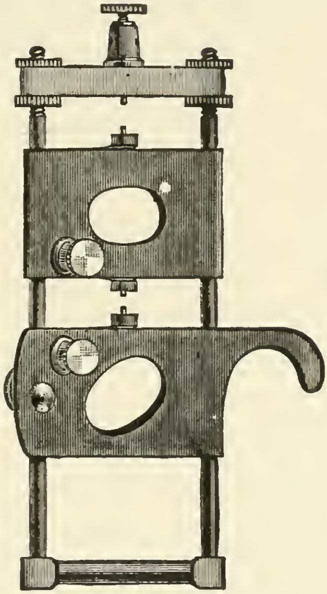


FIG. 17.—Reaction-key.

A double key is arranged in the recording-room so that when it is pressed a sound is sent through the telephone in the reaction-room and at exactly the same instant a spark is made on the time-line on the drum. The moment the sound is heard by the person experimented upon, he moves the finger in the reaction-key; thus a second spark is made on the time-line. A record similar to that of Fig. 4 is obtained; the number of waves, however, will depend on the particular person, the particular sound, etc.

To illustrate how psychological results are obtained from reaction-times, let us suppose ten experiments to give the results in the first column of the example on page 30. Adding the results and dividing by their number, we get the average reaction-time, 0.142^s. We now find the difference between this average and each of the original results; these differences are then averaged to find the "average variation." In this case it is 0.0076^s or, let us say, 0.008^s.

0.162^s	0.020
0.145	3
0.157	15
0.136	6
0.131	11
0.140	2
0.135	7
0.139	3
0.139	3
0.136	6
0.1420	0.0076

The average reaction-time includes the time taken by the sound waves to affect the ear, the time for conducting the nerve impulses to the brain, the time occupied by a series of brain processes, the time for conducting the nerve impulses to the hand, and the time for setting the muscles to work. From physiological experiments it is known that very little time is required for the first and last two; the main part is taken by the brain processes. Somewhere in connection with the brain processes there occur the mental acts of perceiving the sound and willing to move the hand; the reaction-time thus includes the time of perception and volition. The following illustrations of differences in reaction-time are due to changes in perception and volition.

We notice first that the reaction-time is longer and less constant for the first few experiments; this agrees with the observations on tapping (p. 16). Let us repeat these experiments a number of times and take more than ten each time. Then let us average all the first ones separately, all the second ones likewise, etc.

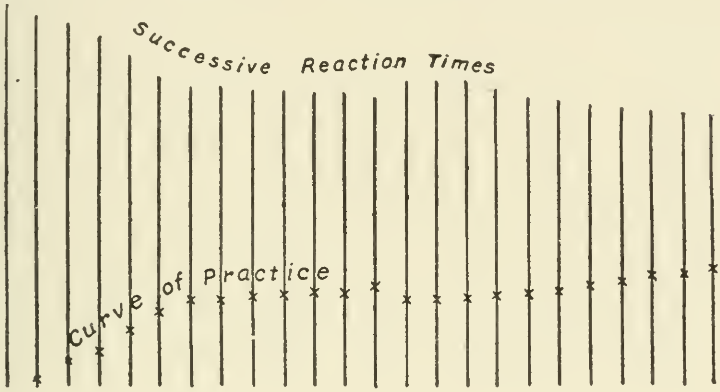


FIG. 18.—Curve of Practice.

Fig. 18 shows lines erected proportional to the successive average times. The decrease from the first average time we may term the "gain by practice"; a line

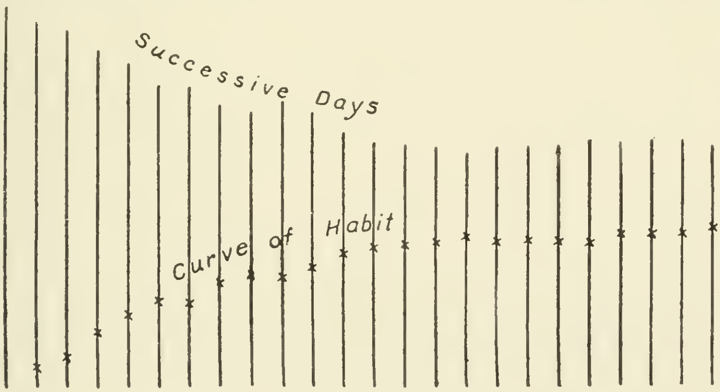


FIG. 19.—Curve of Habit.

showing the amount of this gain will be the "curve of practice."

Let us now average all the results for each day; Fig. 19 shows the result. The decrease in time for each succeeding day may be called the "gain by habit;" a line expressing this will be the "curve of habit."

We now make two sets of experiments under exactly the same conditions, but in one set we warn the subject about two seconds beforehand when to expect the sound whereas in the other we tell him to watch all the time. The results show a somewhat longer reaction in the second set and a far larger average variation; for example, 0.159^s and 0.047^s as contrasted with 0.142^s and 0.008^s. We find this to be always the case, and we established the principle that a state of relaxation with a call to attention just before something is to be done enables us to act somewhat more quickly and far more regularly than an attempted state of continuous attention. In the former state we attain maxima of energy by relaxing between times; in the latter we keep at a dull level. It is on a small scale the same principle of intermittent activity and recuperation that is involved in sleep. Distraction of attention likewise produces a longer average time and a far larger average variation.

Persons may be divided into groups according to their reaction-times. Four types of persons are familiar to the physician. The self-controlled man of abundant vitality reacts quickly and regularly; the phlegmatic or relaxed man responds regularly but slowly; the excitable man of strong vitality gives quick but variable responses; the neurasthenic weakling is excessively irregular and his average reaction-times are slower than normal.

Conditions of disease also show themselves in the reaction-times. In the first stages of intoxication by alcohol the reactions may be quicker and more regular but they soon become slower and very irregular; in an attack of alcoholism where the person's nerves are on edge so that he cannot sleep and feels himself on the verge of delirium tremens, his average reaction-time is very short and his regularity is remarkably good.

The reaction-time depends somewhat on the kind of sensation. For noises it is a trifle shorter than for tones. For example, a person who reacts to a noise in 11Σ will take perhaps 15Σ for a tone. Even the whistle of a locomotive is not so conducive to a quick jump by the passengers on the platform as a sudden escape of steam.

A particular case of reaction to sound is found in starting a race. In short-distance, or sprint, racing the time required for the reaction is a very important factor. The starter's pistol is fired and the racers are off, but the man with a very short reaction-time will have gained a respectable fraction of a second over the other. To measure this reaction-time an electric contact is put on the end of the starter's

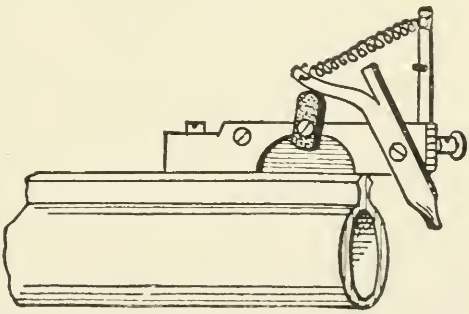


Fig. 20.—The Pistol-key.

pistol. The arrangement is shown in Fig. 20. The firing of the pistol causes the wing to fly back and break an electric circuit, thus making a record. A runner's key of the kind shown in Fig. 21 is attached to the runner by a thread. The start of the runner jerks and breaks the thread; this moves the lever and makes another record. It is noticeable that long-distance runners are

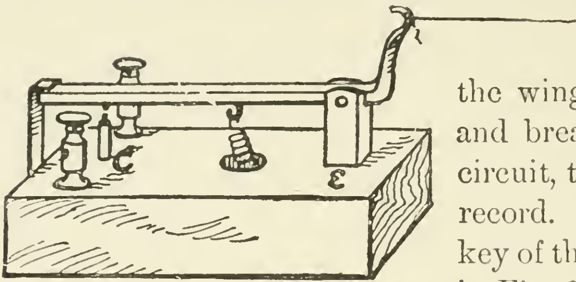


FIG. 21.—The Runner's Key.

FIG. 22.—Measuring a Runner's Reaction-time.

very much slower than sprint-runners who practise quick starting; this shows that the reaction-time can be reduced by practice. The reaction-time seems to be longer where the whole body has to be started than where only a finger is moved; the mass to be moved thus seems to have an influence on the time. In some races the pistol has gone off and the photograph has been made of the runners before they have reacted.

The reaction-time to touch can be found by using the instrument shown in Fig. 23. The flexible conductors carry the current through the screws of this touch-key and then through the reaction-key. The person experimented upon closes his eyes. Some one takes the touch-key and touches him, whereupon he reacts by moving his finger. Both keys make records on the drum.

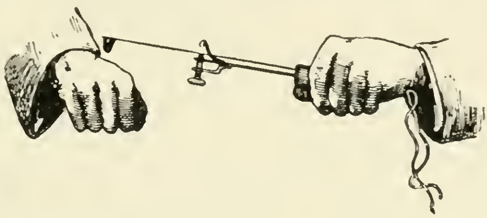


FIG. 23.—The Touch-key.

A weak touch is answered by a slower reaction than a moderately strong one. As the touch becomes stronger the reaction-time decreases, but when it becomes very strong the time is again lengthened.

To experiment on the reaction-time for temperature-sensations a metal ball is screwed on the touch-key in place of the rubber tip. The ball is heated or cooled as desired. The reaction-time for cold is somewhat shorter than that for hot, and both are longer than for touch. For example, the figures for one experimenter were: touch, 11Σ; cold, 12Σ; hot, 13 Σ.

The reaction-time to light may be found by using an electric flash. The intensity of the light has a very great influence. A very weak light might give 33Σ, while the strong one would give 20Σ for the same person.

This interval renders it possible for the photographer to get perfectly natural flash-light pictures. The flash goes off, the picture is taken, and all is again dark in a couple of hundredths of a second. But such a

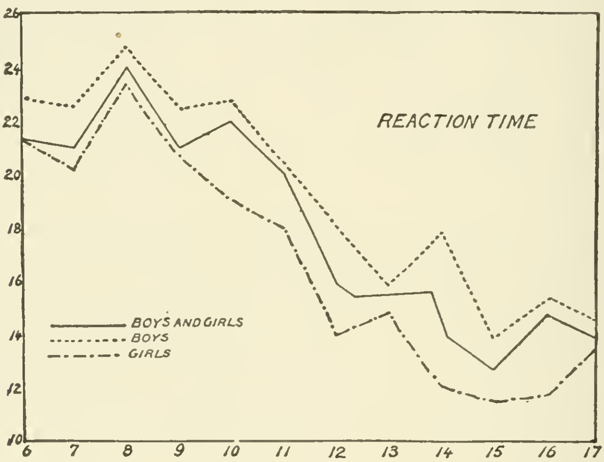


Fig. 24.—Reaction-time Decreases with Age.

small time is quicker than the reaction-time and so the whole is done before the person can move.

Children become steadily quicker as they grow older. The results of the New Haven measurements are shown in Fig. 24. The figures at the left indicate the number of hundredths of a second required for reaction to sight; those at the bottom the ages. Boys are much quicker than girls at each age—that is, in simple reaction; how they compare in quickness of thought will be told in the following chapter.

CHAPTER IV

THINKING-TIME

ONE of the fundamental processes of thought is recognition. To determine the time of recognition the subject reacts on one occasion just as quickly as he can, without waiting to notice what he is reacting to. In popular phrase, he hits back without waiting to know what struck him. Recognition cannot be said to be present. On the next occasion he fully recognises what he hears, sees, or feels before he reacts. The difference in time between these two cases gives the recognition-time. Properly speaking, the former reaction would be the truly simple reaction, but this distinction is often overlooked and both kinds are then lumped together. Experiments on one subject gave the following recognition-times: for colour 3Σ; for a letter, 5Σ; for a short word, 5Σ.

By using a rapid drop-shutter with adjustable opening we can find the briefest exposure requisite for us to recognise an object. The time of exposure can also be termed the "recognition-time." The following results are of interest.

A single figure, such as a triangle or a square, is recognised as quickly as a simple colour. We can grasp enough of a triangle to recognise it without attending to details; a three-cornered figure is as simple as a colour when nothing but its corneredness is noticed. A single letter takes the same time as a short word. The total impression of a well-known object is so familar to us that we need no more divide it into its parts in order to distinguish it than we do in the case of a simple colour. In reading we do not divide the word into its letters, we grasp the word as a whole by a single thought.

The various letters of the alphabet require different times for recognition. There are differences for letters of different sets of type; they vary from 0.6Σ (0.006^s) to 5Σ (0.05^s). The following sets of letters are arranged in the order of time required.

Good.	Fair.	Poor.
m w d q v y j p	k f b l i g h r x t	o v a n e s c z
m w p q v y k b	**d j r l o n i g h u**	**a t f s x z c e**
d p q m y k n w	o g v x h b j l i a	t u z r s c f e

A German requires 1Σ to 2Σ more time to recognise a letter of his antiquated alphabet, for example, 𝔴, than to recognise a letter in the Latin type, **w**. But in reading words no more time is required to recognise the word in either case. The twists and tails of the old letters caused a loss of time in recognising a single letter, but in grasping the words only the main features received attention anyway.

Another of the fundamental processes of thought is discrimination: Is it white or black, loud or weak, hot or cold? Can we measure the time required for discrimination?

Suppose that the subject of the experiment is to discriminate between two different tones. In addition to the arrangement described on page 29 we require two tuning-forks of different pitch. The sound is sent by telephone as before. The person is told not to react till he has recognised which tone he hears. Sometimes one tone is sent, sometimes the other. If we determine the person's reaction-time for a single tone, where he knows that only one tone is used, and also the reaction-time with discrimination between two tones, we are justified in subtracting the former from the latter, and calling the result the "discrimination time" for two tones. In a similar manner the discrimination-time for three, four, or more tones can be measured.

The discrimination-time for sight can be illustrated by Geissler tubes filled with different gases so that when an electric current is sent through them they show different colours. An induction-coil (or spark-coil) is fitted up so that the current can be seen through any tube at pleasure. To get the simple reaction-time one tube alone, *e. g.*, a red tube, is used, the time between the flash and the reaction being measured as before. Then two, three, etc., are used, just as described for tones. Ordinary times for discrimination can be represented by the following specimens; for two objects, 8Σ; for three, 14Σ; for four or five, 15Σ.

The next element of thought-life to be considered is choice. The Geissler tubes can be very conveniently used for experiments on choice-time. The subject places his five fingers on a five-knobbed telegraph key. When he sees the red light he is to press his thumb; when he sees the yellow he is to press his forefinger, and so on. There are thus five objects for discrimination and five movements among which to choose. Of course the time is much lengthened. If we know the discrimination-time and reaction-time for five colours, we can subtract these from the total time with choice, thus getting the choice-time for five. It is evident that the choice-time for two, three, four, six, or more objects can be similarly found. One subject gave a choice-time of 8Σ for two fingers, with steady increase up to 40Σ for ten fingers.

After some practice with the same fingers for the same colours, the act of choice gradually falls out and the movement becomes associated to the colour. The action becomes more and more "automatic."

The time of discrimination and choice combined can be obtained from a group of persons without any other apparatus than a watch. The persons of the group stand in a ring, as shown in Fig. 15, each with his hand on his neighbour's head. In the first place, the simple reaction-time is measured by giving the head a slight push and sending the push all around the circle, as described on page 25. "Next time," says the experimenter, "each of you will receive a slight push on the head either forward or backward. You are to send the push along in the same way."

The experiment is made three or four times, sometimes with a forward push, sometimes with a backward one. Each person, not knowing what he is to receive, will be obliged to discriminate and then choose the appropriate movement of the hand. By subtracting the simple reaction-time from this last result, the time for discrimination and choice for two things is obtained. Then the experiment is repeated with three movements: right, left, or forward. Then with four: right, left, forward, or backward. The time will be found to grow longer as the number increases.

The time of association of ideas, which is what is usually meant by "association-time," is best measured by calling out words or showing pictures to some one who is to tell what he associates to each. For example, I call out "house" and you say "street."

A peculiar mouth-piece (Fig. 25) is placed before the transmitter in the recording-room and a somewhat similar one in the reaction-room. The experimenter shouts some word, *e. g.*, "glass." This causes the thin plate in the mouth-key to rattle and make a spark record on the drum. At the same moment the subject hears the word in the telephone at his ear. He shouts back what he first thinks of, *e. g.*, "water." This makes a similar record. The total time between the

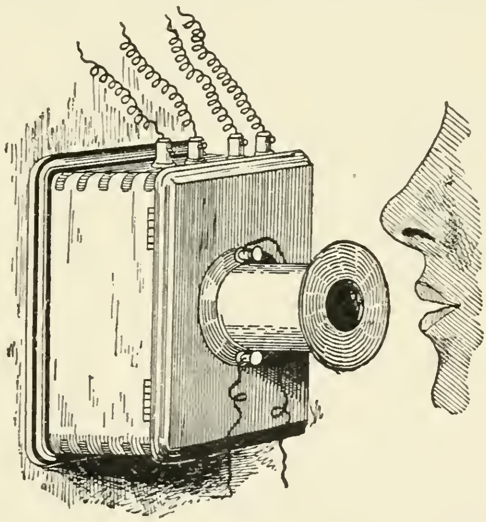


FIG. 25.—The Voice-key.

two records less the discrimination-time and choice-time will give the association-time.

The associations may be of various kinds. In "free" association, the subject thinks of whatever he pleases. The time for free association can be put in the neighbourhood of 50Σ to 100Σ according to circumstances.

In a "forced" association the subject is allowed to associate only objects bearing certain relations to the object presented. Thus, whenever he hears the name of a country he must name one of its cities. In such a case he has a moderate range of association. In a strictly forced association there is no freedom. Thus, whenever the name of a person is mentioned, his native land must be associated. As specimen results we can give the following association-times: translation from one's own language to one a trifle less familiar, 60Σ to 90Σ; giving the succeeding month of the year, 70Σ to 80Σ; simple addition of two figures, 60Σ to 75Σ; simple multiplication of two figures, 80Σ to 100Σ.

A particular form of association is found in logical judgments. In fact, many of the forced associations are really abbreviated logical judgments. Suppose it to be required to associate the whole when a part is given, *e. g.*, given "root," associated "tree"; this is simply a practical abbreviation of "a root is part of a tree." More difficult cases can be devised. It holds good as a general rule that in actual thinking the forms of logical thought become forced associations.

The visit of several expert swordsmen to Yale furnished the opportunity for some experiments on their rapidity in some of the fundamental movements of fencing.

The first experiment included a determination of the simple reaction-time and of the time of muscular movement. The fencer stood ready to lunge, with the point of the foil resting to one side against a metal disk (Fig. 26). A flexible conducting cord, fastened to the handle

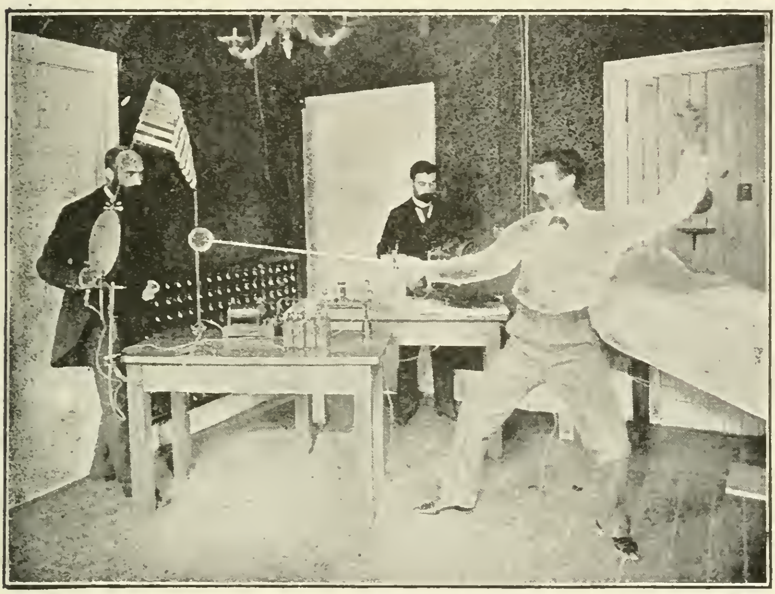


Fig. 26.—Measuring Mental and Muscular Time in Fencing.

of the foil, hung in a loop from the back of the neck. A large metal disk was placed directly in front of the fencer at a distance of 75^{cm}. Just above this disk was a flag held on a foil by an operator standing behind it. A movement of the flag was the signal upon which the lunge was executed.

The spark method of recording was so arranged that the primary circuit passed through the electric switch, a spark-coil, the flexible conducting-cords, the foils, and either one of the two disks. Every make and break of this circuit made a spark record on the drum. As long as the foils rested against the disks the current was closed. The movement of the flag-foil broke the circuit for an instant, making a record of the moment of signal. The first movement of the fencer's foil broke the circuit again at the small disk, making a record of the moment of reaction. The striking of the foil against the large disk made a third record. The time between the first and second records gave the simple reaction-time; that between the second and third gave the time of movement through the given distance. About ten experiments were made on each person.

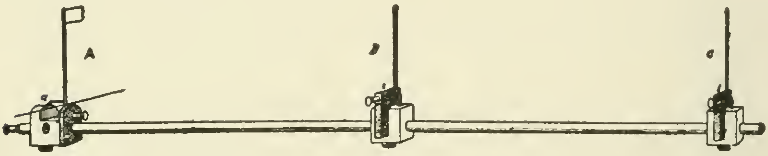


Fig. 27.—Apparatus for Measuring Rapidity of Thought and Action.

In the second experiment the flag-foil was moved in various directions. The point of the foil rested against the small disk. The movement of the flag in any way was the signal for a corresponding movement of the foil. Acts of discrimination and choice were thus introduced in the reaction-time. The movement of the foils gave records as before. The time required can be considered as reaction-time with discrimination and choice.

The persons experimented upon included a fencing master J. (a professional athlete), three physicians H., E., and O., and a business man, S. (all expert amateur fencers), and two college professors, L. and W. For the muscular movement the records in hundredths of a second were: for J., 27; O., E., S., and W., 29 to 32; for L. and W., 52 to 57. The superior quickness of trained fencers is apparent. For the simple reaction-time the results were for E., W., and H., 17–19; for L., J., and S., 23; and for O., 26. The trained fencers thus showed no superiority over the untrained persons, L. and W. For the reaction with discrimination and choice the results were for H., L., and W., 22–25; for J. and E., 29–30; for S. and O., 36. The two college professors and one physician were thus quicker than the rest.

In order to study the quickness of movements of the arm we use the apparatus shown in Fig. 27. A horizontal brass bar carries on it three adjustable blocks, A, B, and C. The block A has a flag which may be sud-

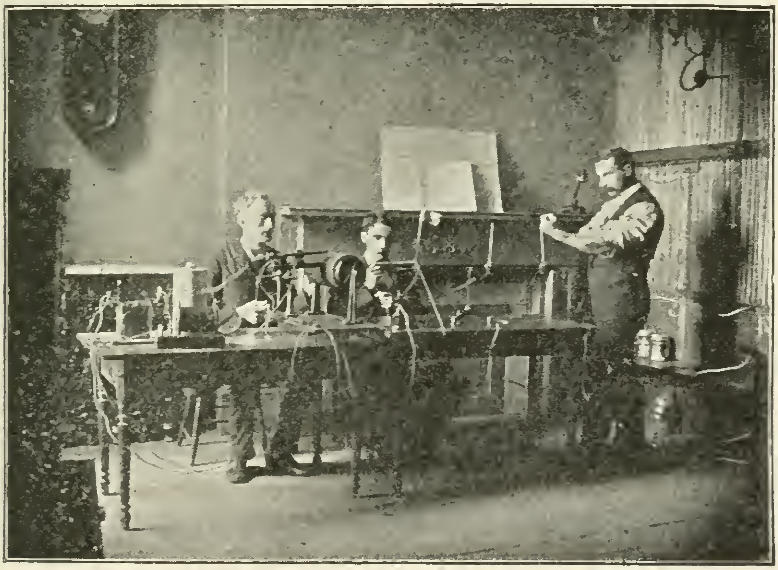


FIG. 28.—Measuring how Rapidly a Pugilist Thinks and Acts.

denly jerked to one side by a thread. The other blocks have light bamboo sticks projecting upward. The whole arrangement as used on a pugilist is shown in Fig. 28. The boxer takes his position and places his fist just behind the stick at C. At the moment the flag moves he is to strike straight out. The apparatus is connected with the spark-coil and the recording drum.

The flag is jerked; this makes a spark on the time-line. The boxer strikes, knocking down both sticks. Each stick makes a spark also. We thus have three sparks on the time-line. The time between the first and the second gives the simple reaction of the boxer; that

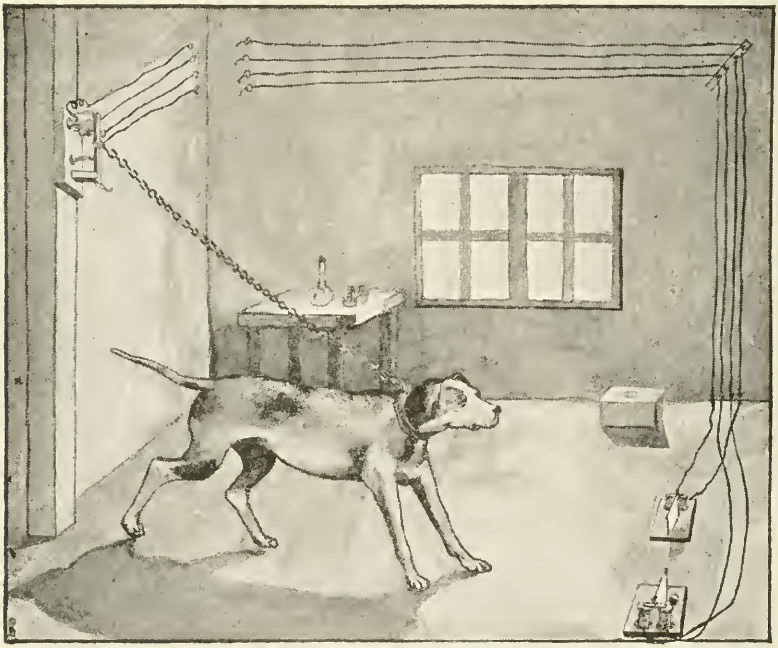


FIG. 29.—Measuring how Fast a Dog Thinks.

between the second and the third gives the time required for the fist to travel the distance between the two sticks.

The boxer is next told that the flag will be jerked to the right or left in irregular order and he is to punch only when it goes to the left. He is thus obliged to discriminate and choose. Sparks are obtained as before, but the time between the first two dots is longer because two extra mental acts are included.

It is possible to extend these experiments to animals. The arrangement for measuring the discrimination-time of a dog is shown in Fig. 29. The dog is fastened to an electric key on the wall. Two magnetic shutters stand on the floor. To get the dog's simple reaction-time a piece of meat is placed behind one of the shutters. The dog is to see this done; this secures maximum attention and lets him know what to jump for. The fall of the shutter makes a spark on the time-line (Fig. 4) and shows the meat; the dog attempts to jump and pulls the key, making another spark. The simple reaction-time is thus measured. Pieces of meat are then put behind both shutters, the dog's attention is attracted to a spot between them, one shutter falls and he jumps toward it after having discriminated and chosen.

In the New Haven experiments the school children were required to distinguish between two colours, reacting to blue and not to red. This involved the mental processes of discrimination and choice, in addition to simple reaction. The results are shown in Fig. 30. The figures at the bottom indicate the ages, those at the left give the number of hundredths of a second required for reaction with discrimination and choice.

The time required decreases with age. On the whole, the boys and girls are equally quick, the differences generally being too small to be worth noticing. It might be suggested that, since boys are quicker in simple reaction, they must take a longer time for mere discrimination and choice in order to give equal totals. The figures seem to indicate that for the more involved mental processes the girls are quicker. It has been suggested that the difference may arise from the fact that games of boys generally involve simple activities that must be rapidly performed, while those of girls are quieter and more intellectual.

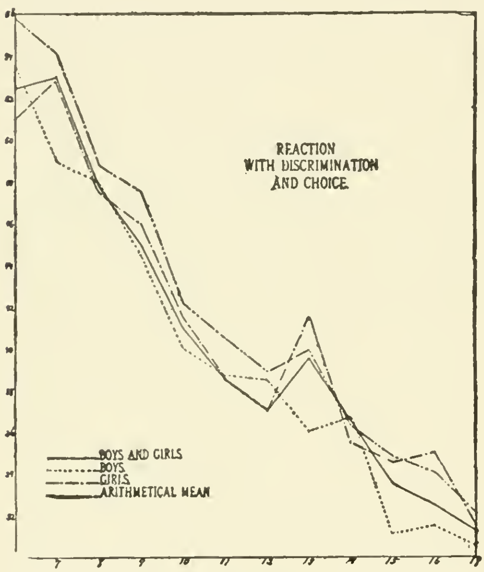


FIG. 30.—Time of Thought at Various Ages in School Children.

Every thought we think, every act we perform, takes time. Time is money. Rapid thought and quick action sometimes makes all the difference between success and failure. A man who can think and act in one half the time that another man can, will accumulate mental or material capital twice as fast. If we could think twice as fast as we do, we would live twice as long, although we would live only the same number of years. Country people think more slowly than city people; the uneducated are slower than the educated. To-day the mental processes of the mass of the people go at a much more rapid rate than they did a few centuries ago. The mind has been educated by our whole civilisation to act more rapidly. The difference between the sluggish Englishman of mediæval times and the quick Yankee of to-day is delightfully told in Mark Twain's *A Yankee at the Court of King Arthur*. If it were possible to take a man of two centuries ago and bring him into the laboratory, the results obtained from experiments upon him would be entirely different from those obtained from one of the students of to-day. The reactions of the student would be more rapid, especially the complicated ones.

A great factor in the education of children is to reduce their reaction-times. When the country boy first comes into the schoolroom everything he does takes him a very much longer time than when he has been there for a while, especially any complicated act. Arithmetic, for example, is simply a matter of the association of a set of ideas. Let the teacher give just so much time to do an example. When that time is over, the pencil must be put down, the slate dropped. The child is thus trained to think and act quickly.

The manner in which rapidity of thought is increased by practice in learning a language has been made the subject of experiment. Ten boys were taken from each class of a high school and were asked to read rapidly the first hundred words of a Latin book. The number of seconds that they required is shown in the following list :

Class	10,	average	age 9,	average	time	262^s
“	9,	“	“ 11,	“	“	135
“	8,	“	“ 12,	“	“	100
“	7,	“	“ 13,	“	“	89
“	6,	“	“ 14,	“	“	79
“	5,	“	“ 15,	“	“	57
“	4,	“	“ 16,	“	“	54
“	3,	“	“ 18,	“	“	49
“	2,	“	“ 19,	“	“	48
“	1,	“	“ 22,	“	“	43

The lowest class knew nothing about Latin, the rest had begun it in Class 9.

When the same children were tested with their native language the results were successively 72, 55, 43, 37, 39, 28, 27, 26, 25, 23^s. There was a similar gain.

Was the gain due to general gain in mental rapidity? One hundred papers of five familiar colours were shown and each child was required to name them. The average times were 83, 66, 79, 66, 63, 56, 63, 63, 54^s. There had been a general gain in quickness but not nearly so great a gain as for the words. A study of the blunders made by the children showed that in the next to the lowest class there was a very slight tendency to grasp the Latin letters as words; they blundered occasionally by reading a similar word for the correct one. In the succeeding and higher classes this mistaking of words became steadily more frequent; they had been trained to grasp larger groups as single things and in this manner to save time in discrimination.

How far we can push the education of rapidity in all the elements that make up thinking-time, reaction-time, and action-time can be seen in the records for rapidity in telegraphing and typewriting.

By careful estimate it has been found that in general press matter the average number of letters per word is five, and that the average number of vibrations of the key in the formation of the telegraphic characters is five to each letter. Thus on the average there are twenty-five vibrations of the key in the formation of each word. Now, were it possible for an operator to transmit sixty words per minute, he would make one word, or five letters, per second, being twenty-five vibrations of the key per second.

When we consider that the telegraphic alphabet is made up of dots and dashes and spaces of various lengths, and that these almost incredibly rapid vibrations must be so clear and clean cut as to be easily read by the ear, we can form an approximate idea of the wonder of such an achievement. The most rapid manipulator in the country has reached a speed of fifty-four words per minute, which is about $23\frac{3}{4}$ vibrations of the key per second.

In using the typewriter a rate of about 120 words per minute has been attained in recording an address during its delivery. In writing a familiar sentence repeatedly a speed of 208 words per minute has been reached ; in such a test much of the association becomes somewhat automatic.

CHAPTER V

RHYTHMIC ACTION

BY rhythmic action we understand an act repeated at intervals which the doer believes to be regular. Walking is a simple rhythm. The beating of a drum is intended to be in a more or less complicated rhythm.

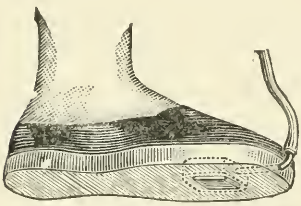


FIG. 31.—The Pneumatic Shoe.

In a research on walking the person experimented on puts on a pair of shoes with hollow rubber soles (Fig. 31). Each sole communicates by a long tube with a small capsule that writes on a small smoked drum (Fig. 32) carried in the hand. When the foot is on the ground, the air is pressed through the tube to the recording capsule; this causes it to make a mark on the drum.

The character of the results is indicated in Fig. 33. The length of time during which the foot rests on the ground is indicated by the length of the mark on the drum. In walking, one foot leaves the ground just as the other touches it; in going up-stairs, both feet touch for a while at the same time; in running, both feet are off the ground for short intervals.

For a study of rhythm as it appears in walking I have devised a little reaction-key for the foot, to be used with the spark method. This key is shown in Fig. 34. It is attached to the heel of the shoe; flexible conducting cords lead from it to the spark-coil. The spark-coil is arranged to record on the drum by making a dot on the smoked paper (p. 15).

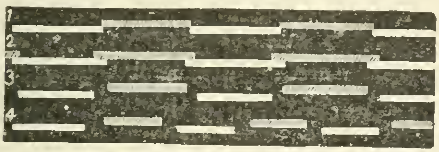


FIG. 33.—Graphic Records: 1, Walking; 2, Going Up-stairs; 3, Running; 4, Faster Running.

FIG. 32.—Walking with Pneumatic Shoes and Recording Drum.

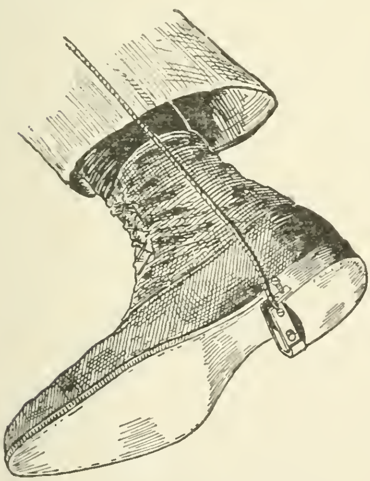


FIG. 34.—The Electric Shoe.

In one form of rhythmic action which I may term "regulated rhythmic action," a person attempts to keep time with a regular sound of some kind, for example, a regular click. An experiment can be arranged in the following way: To produce the click we use the graphic chronometer. This is essentially a stop-watch which makes a fine pointer beat either in seconds or in fifths of a second. This pointer writes on the smoked drum. At the same time it breaks an electric current and makes a click by means of a telegraph sounder.

The foot key is fastened to the heel of one shoe. The record on the drum will be like that shown in Fig. 35. It shows a line drawn by the chronometer

Fig. 35.—Regular Retarded Rhythm.

point, on which, at regular intervals representing seconds, there are side lines corresponding to the clicks. The dots are made by sparks at the moment the heel touches the floor.

In the record, shown in Fig. 35, the foot struck the floor with fair regularity about two-tenths of a second behind time. Another person of nervous temperament, or the same person anxious to do better but flurried by the effort, might give a record like that of Fig. 36. On an average the step is still behind time but the beat is very irregular. Still another characteristic record is shown in Fig. 37. The step is very regular but slightly ahead of the click. The record may even show on an average neither retardation nor acceleration, but may yet be irregular, as indicated in Fig. 38. The ideal of precise rhythmic action is that indicated in Fig. 39 where there is a minimum of irregularity and no retardation or acceleration.

The distance between each two of the checks in the preceding figures means an interval of one second.

With a fine measure, or even by the eye alone, we can divide the interval into ten parts, each of which

FIG. 36.—Irregular Retarded Rhythm.

FIG. 37.—Regular Accelerated Rhythm.

FIG. 38.—Irregular Accurate Rhythm.

FIG. 39.—Regular Accurate Rhythm.

will mean one-tenth of a second. Now, note down how many tenths of a second the dot is distant from the check; if it is ahead of the check, put + in front of it; if behind, —. The record in Fig. 36, for example, will give

— 3, — 4, — 2, + 1, — 1, — 3, — 1, + 1, + 2, 0.

Take the average, that is, add them all up and divide by ten. This gives — 1.0 tenth of a second as the average amount by which the foot was behind time. In physics this is called the constant error; in psychology—especially in educational psychology—I propose to call it the "index of inaccuracy."

Now let us find the "index of irregularity," or, as it has already (p. 30) been called, the average variation.

Find the difference between the number in the index of inaccuracy, in this case 1, and each of the numbers, 3, 4, 2, 1, etc., of the original records. You will get a second set of ten figures, 2, 3, 1, 0, 0, 2, 0, 0, 1, 1. As you will notice, no attention has been paid to + and —. Average these last results; answer, $\frac{10}{10}$, or 1.0, of a tenth of a second, which is the index of irregularity. By chance the two indexes have the same figures.

A very irregular person might have the same index of accuracy as a very regular one; they might both be one-tenth behind time; but their indexes of irregularity would be different. On the other hand, two regular persons will have small indexes of irregularity, whereas their constant errors might be quite different.

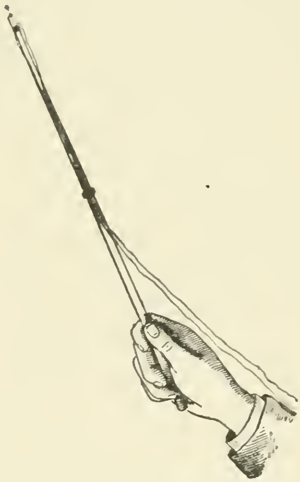


Fig. 40.—The Electric Baton.

In "free rhythmic action" the person makes the movement of his own accord and is not controlled by any outside impulse. Such is the case in walking, in marching without anything to mark time, in beating time, etc. There is no index of inaccuracy because the person sets his own time; the index of irregularity is the important factor.

To measure the irregularity in a case of an orchestra leader, for example, an electric contact on the end of a baton can be arranged so that a spark record is made in the usual way (Figs. 40, 41). Suppose we have a record of eleven beats measured to hundredths of a second with the following results: 41, 42, 37, 41, 39, 40, 40, 40, 41, 38, 41. The average time of a beat is just 40. How *regular* is

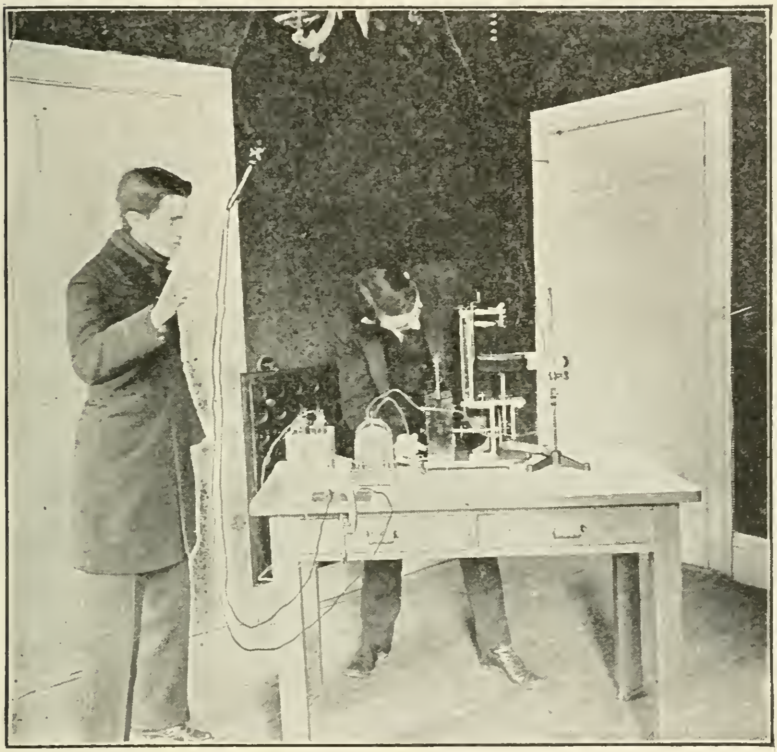


Fig. 41.—Taking an Orchestra Leader's Record with the Electric Baton.

the beating? This is determined by finding the difference between each separate beat and the average, and taking the average of these differences, as before; the average variation here is 1.1Σ.

Now let us take another orchestra leader whose record gives 40, 41, 42, 40, 39, 37, 35, 40, 41, 41, 38; which is the better man? The average is 40 as before, but the index of irregularity is 1.8 as compared with 1.1.

Suppose we have a third leader from whom we get the ten records: 40, 39, 40, 40, 39, 38, 39, 39, 39, 39. The average is 39.2, and the index of irregularity is less than 0.5.

It is evident that the second leader beats so irregularly that an orchestra cannot possibly keep time, that the first leader is somewhat better, and that the third is far superior to the others. The actual average time of a beat makes no difference within such small limits, as music played at the rate of one beat in 0.40 of a second is not sensibly different from that played at one beat in 0.39 of a second. An essential qualification, however, for the success of an orchestra leader is his regularity in estimating intervals of time.

Another example similar to the one just mentioned is that of a piano player, who must learn to strike the notes at regular intervals. The quarter-notes should all be about the same length; equal measures should be completed in equal times. For most beginners the irregularity in the time given to successive measures varies to such an extent that it is painful to hear them attempt a tune. By practice with the metronome successful players are able to reduce their irregularity till it does not disturb the playing. It is not known just how far this may be carried, as no one has ever taken the trouble to make measurements. It might be suggested, however, that, even when the irregularity is so small that no one notices it, yet it may be great enough to injure the effect. A successful musician of any kind should know not only that his instrument is in tune but also that he himself is in time.

What is rhythmic action? The process in the mind of the one who is acting is in the first place an estimate of equal intervals of time; after a few strokes at equal intervals he knows just when to expect the next one. In other words, it is a case of time-memory corrected by an actual stroke each time. Knowing when to expect the next stroke, an act of will is executed so that the movement occurs in some definite relation to the stroke, generally at the same moment or just after it. This process might be called a reaction to an expectation.

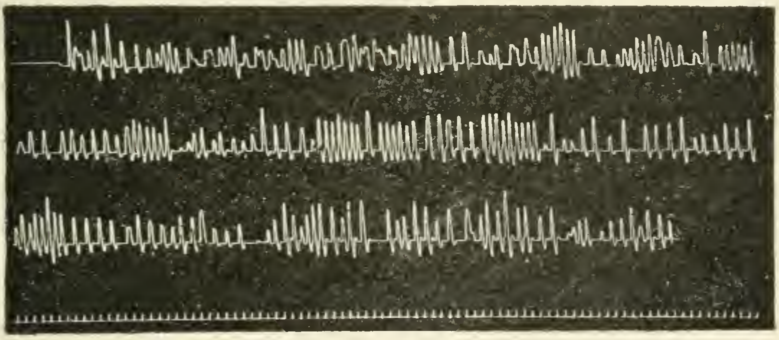


FIG. 42.—Record of Arhythmic Action.

For some unexplained reason the human race finds pleasure in rhythmic action as seen specially in marching and the dance. That this desire for rhythmic action has its source deep in the economy of the organism can be seen in attempts to act without rhythm. Fig. 42 shows a record of movements of the finger intended carefully to be at irregular intervals (the record was obtained by the method of air transmission to be described in Chap. VI). We see at once that the movements repeatedly come in regular groups, sometimes with one interval, sometimes with another. At the start the irregularity is somewhat successful, but with fatigue the tendency to rhythmic action becomes marked. Arhythmical action is both difficult and displeasing; our pleasure in rhythm may well be termed an "organic delight."

CHAPTER VI

STEADINESS

STEADINESS of action may be steadiness of position or steadiness of movement. In position the impulses to the various muscles are so arranged that the member or the body remains still. In movement the impulses are varied in power in such a way that a change occurs.

In studying action, voluntary or involuntary, we

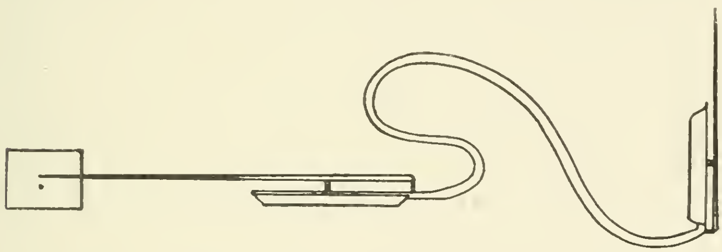


Fig. 43.—Arrangement of Capsules for Recording Steadiness.

need to have some method of recording every part of the act. This is found in the principle of air transmission.

In investigations of the steadiness of position we generally make use of a pair of capsules (Fig. 43). Each consists of a little metal cup covered with thin rubber. From one cup a tube leads to the other. A very light lever is placed above each cup; the lever is connected with the rubber top. If one of the levers is moved downward, the rubber will be pressed in and the air will be slightly pressed out through the tube. The pressure will pass along the tube to the other capsule, where it will bulge the rubber top and will make the other lever move upward. When the lever is released, the spring will draw it back, the air will be drawn in, and the other lever will move downward.

To make a record, a fine metal point is attached to the second lever and this is made to write on a metal cylinder covered with paper and smoked in a gas flame, as previously described (p. 14). The most frequently

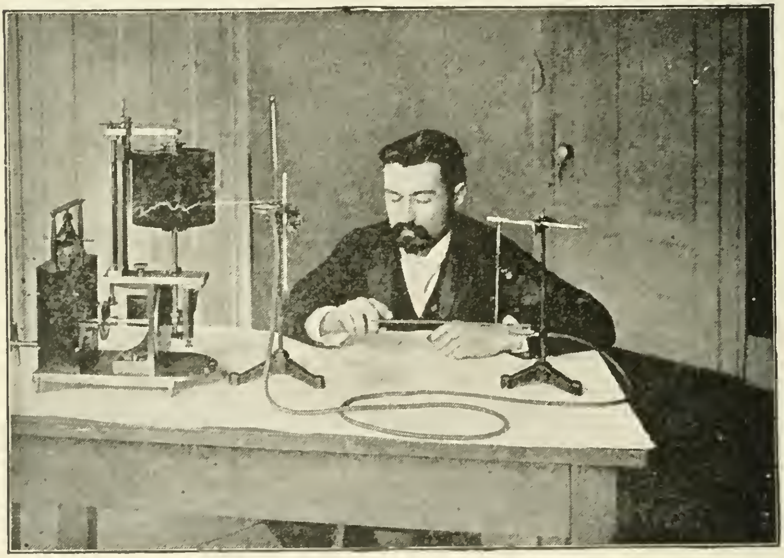


Fig. 41.—Taking a Record of Steadiness.

used cylinder for slow movements is a clock-work drum of the kind shown in Fig. 44.

Fig. 44 shows a person with his eyes closed, trying to hold his arm steady. Every shake of the arm is transmitted to the recording point and is scratched in the smoke on the drum. A specimen record is given in Fig. 45. During the time between the two vertical strokes the attention was disturbed by some one walking around the room; steadiness was improved by distraction of attention (compare with page 17). In Fig. 43 a card with a dot is placed behind the lever on

Fig. 45.—A Record of Steadiness.

which the finger is to rest; the person, with eyes open, tries to keep the end of the lever opposite the dot.

Let us study steadiness in a special case, say in holding a gun. The sportsman takes his position,

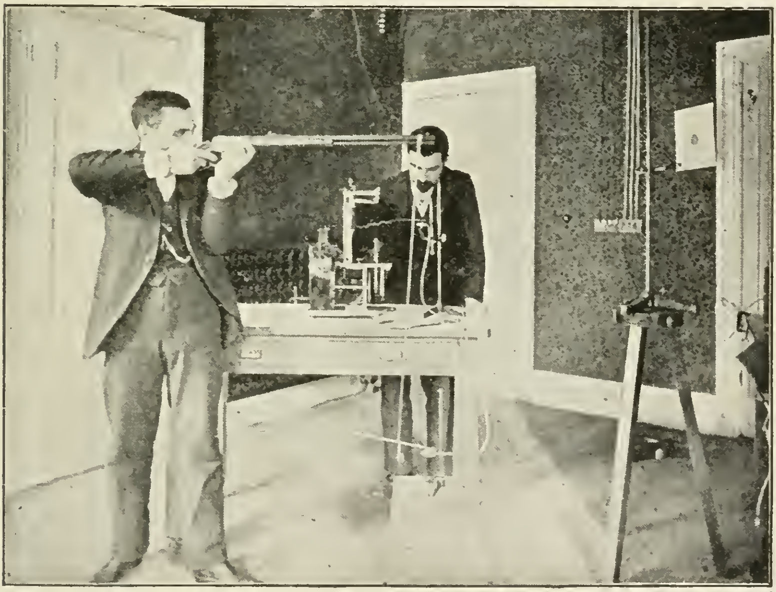


Fig. 46.—Recording a Sportsman's Unsteadiness.

standing, with gun aimed at the target. A thread hangs down from the gun with a small sinker at the end to keep it stretched. The thread is given one turn around the lever of a receiving capsule, as seen in the figure. The weight of the gun makes the trembling slower but more marked. Fatigue shows itself quickly in large movements. By an extra effort of the will the trembling can be lessened for a time (compare p. 23).

Can steadiness be increased by practice? This problem has been answered in respect to the hand. The arrangement for measuring steadiness is made very simple, involving no capsules or drums. It consists of a flat block of hard rubber supported vertically by a rod. On the face of the block is a strip of brass in which there are five hard rubber circles, 1^{mm}, 2^{mm}, 3^{mm}, 4^{mm}, and 5^{mm} in diameter. The edges of the circles are flush with the brass. The object is to touch the rubber circle with the metal point at the end of a stick by a single steady movement. Sufficient unsteadiness of the hand will cause the point to touch the metal. With the same circle the steadiness of the hand can be considered to be directly proportional to the percentage of successful trials. To indicate when the metal point strikes the plate instead of the circle, an electric current can be sent from one pole of a battery through an electric bell to a binding-post connected with the metal plate, and from the

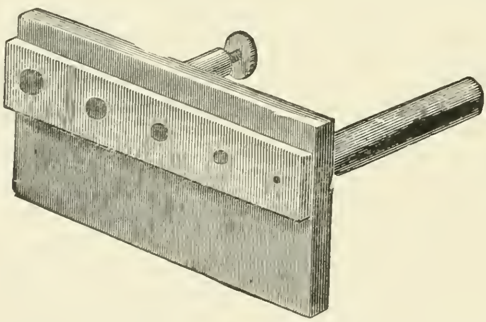


Fig. 47.—Steadiness-gauge.

other pole through a flexible conductor to the metal point. Any contact of the point with the plate will cause the bell to ring.

In making the experiment the plate is set up in front of the person experimented upon. The pointer is grasped in the middle like a lead pencil; the forearm is rested on a cushion at the edge of the table and the trial is made by a single steady movement under guidance of the eye (Fig. 48).

A series of experiments on the subject of steadiness gave the following results: The first set consisted of twenty experiments with the left hand; the result was fifty per cent. of successful trials. Immediately thereafter twenty experiments were made with the right

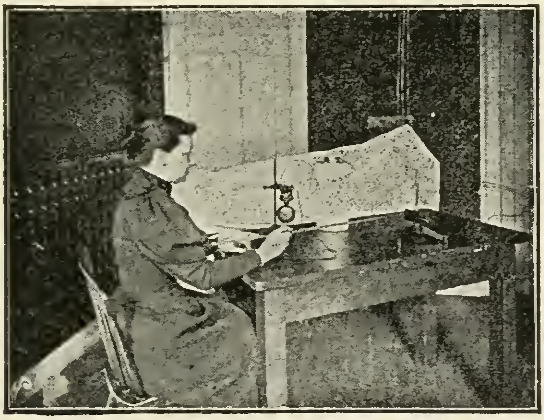


Fig. 48.—Measuring Steadiness and Attention.

hand, with the result of sixty per cent. of successful trials. On the following day and on each successive day, two hundred experiments were taken with the right hand, the same conditions in regard to time, bodily condition, and position in making the experiments being maintained as far as possible. The percentages of successful trials ran as follows: 61, 64, 65, 75, 74, 75, 82, 79, 78, 88. The increase in accuracy is represented in the curve in Fig. 49.

On the tenth day the left hand was tested with twenty experiments as before, with seventy-five per cent. of successful trials, thus showing an increase of twenty per cent. without practice in the time during which the right hand had gained as shown by the figures above. This is an illustration of the curious process I have ventured to call "cross-education" (see also p. 22 and Chap. VII).

The pitch of a tone sung from the throat depends on the tightness with which the vocal cords are stretched by the muscles of the larynx. If a singer can keep

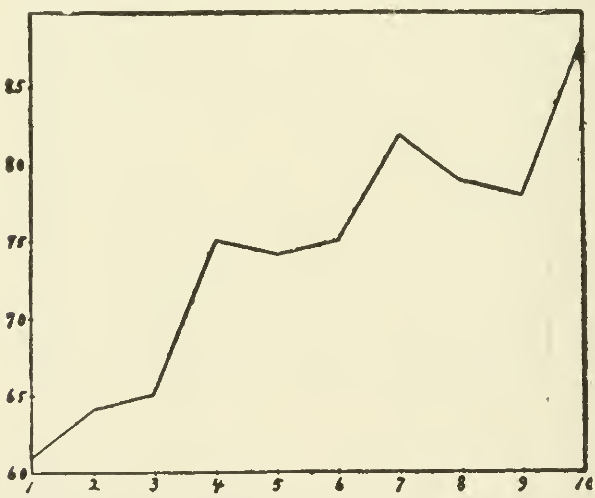


Fig. 49.—Result of Educating Attention to the Arm.

these muscles steady in position, the tone remains the same; if he allows them to change ever so little the tone changes.

A method for studying the accuracy of singing a tone is found in the gas-capsule and mirror-tuning-

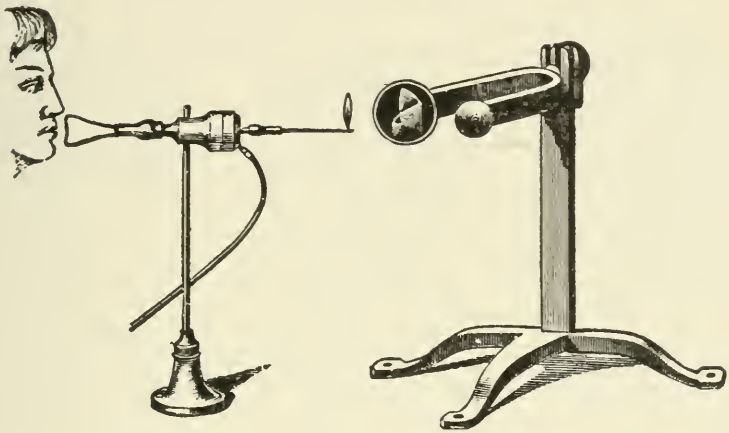


Fig. 50.—Testing Steadiness in Singing. The Unison.

fork. The gas-capsule consists of a little box (Fig. 50) divided into two parts by a thin rubber membrane. A gas pipe leads to one part and a small burner is attached. The person sings into the other part. Every vibration of the voice shakes the membrane and makes the little flame bob up and down too rapidly to be seen. The flame is placed in front of a tuning-fork having a little mirror on one end. The fork is set going and the person sings the same tone. A flame with a single point appears in the mirror.

Any inaccuracy or change in pitch in the singing makes the picture rotate in the mirror. If it rotates in the way the flame points, the person sings too low: if backwards, then too high. If the singer is only a trifle wrong, the rotation is slow; a poor singer makes the picture fly around at all sorts of speeds.

The apparatus can do more than this. When the unison is sung, a flame with a single point is seen (Fig. 50.) When the octave is sung, a double-pointed flame appears (Fig. 51). For the duodecime we get

FIG. 51.—Singing the Octave.

FIG. 52.—Singing the Duodecime.

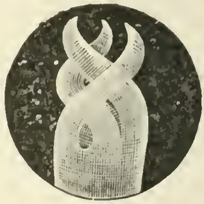


FIG. 53.—Singing the Fifth.

three points Fig. 52); for the double octave, four points. These points seem to be upright, but for musical intervals, such as the fifth, the pointed flames are twisted to gether. For the fifth we see three

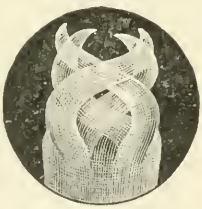


FIG. 54.—Singing the Fourth.

FIG. 55.—Singing the Third.

points twisted as in Fig. 53; for the fourth we get Fig. 54; for the third Fig. 55.

When these intervals are properly sung the flames appear sharp and steady; any inaccuracy causes rotation. The apparatus thus tells directly how steadily the singer maintains his pitch.

CHAPTER VII

POWER AND WILL

WHEN on his return home Ulysses desired to punish the insolence of the beggar, Irus, by inflicting a severe blow, yet feared lest the well-known power of his arm would betray him if he put forth his whole strength, he deliberated on the amount of force to be employed:

> "Whether to strike him lifeless to the earth
> At once, or fell him with a measured blow,"

and decided to deal one which would only fracture the jaw. This was evidently a very fine regulation of the amount of exertion.

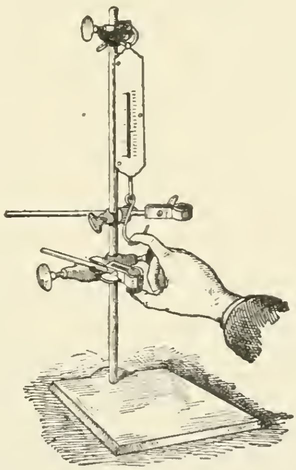


Fig. 56.—Spring-dynamometer.

We first take up the problem of the accuracy with which force is exerted, and use the grip between thumb and finger for illustration. The force can be measured by the dynamometer shown in Fig. 56. The upright rod holds a spring scale of appropriate strength; the finger is placed in the hook of the scale. A projecting arm holds a cork against which the thumb is placed. When the grip is exerted, the hook is pulled toward the cork. A second projecting arm is so fixed by a collar that when it projects in front, the hook of the scale strikes and hinders further movement. The movement is arranged to stop at, say, one pound, or 500 grams. The person is seated with the eyes closed. The stop is swung on and the pressure is exerted till the hook strikes; this is a pressure of 500 grams. The finger is released, the stop is turned back, and the experiment is repeated. As the person finds no hindrance, he stops when he thinks he is exerting the same force as before. The actual position of the pointer is read off and the error is noted. Suppose he stops at 470^g; he then makes an error of -30^g. The experiment is repeated a number of times under the same conditions. The results can be used like those for reaction-time to get a picture of the person's mental characteristics.

Suppose, for example, a person's average force to be 473^g, when he tries to reproduce a force of 500^g. His constant error is -27^g. This is his "error of reproduction."

The error of reproduction varies with the size of the force exerted, but not proportionately. If the error is 20^g on a force of 200^g, it will be 30^g on 400^g, 40^g on 800^g, and 46^g on 1600^g. As the force grows larger, the actual amount of the error increases; the proportion of the error, however, is not increased or even the same, but is decreased; 20^g is a much larger part of 200^g than 46^g of 1600^g.

A method of making similar experiments with the arm is to lift cylindrical weights between thumb and finger. The weights are sorted into two groups, those that appear the same as the standard used and those that appear different. The amount of difference that

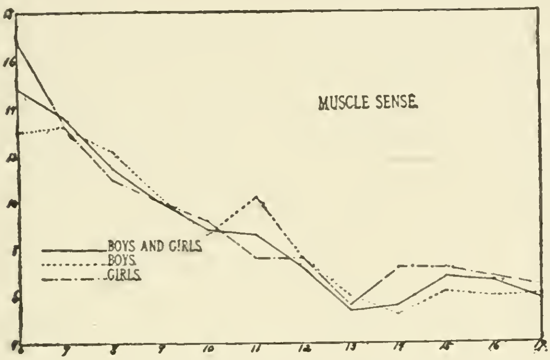


FIG. 57.—Decrease of Inaccuracy of Weight-judgments in School-children of Successive Ages.

passes unnoticed gives an idea of the accuracy of the judgment. This is generally said to be a judgment by the "muscle sense." The experiments on the New Haven school-children showed a steady gain in accuracy (Fig. 57).

We now measure the strongest grip we can make between thumb and finger. This we repeat at short intervals. It is evident that from the results we can obtain the curves of practice and habit and various other information by the methods illustrated in the chapter on reaction-time.[1]

In a voluntary act there are many mental factors involved. The will impulse is known to us directly; we know what we intend to do. What we actually do is known to us in many ways: *e. g.*, by sensations from the joints, muscles, and skin. We thus have at each in-

[1] For an account of the work with the dynamometer and the ergograph see my *New Psychology*, Ch. XV, London and New York, 1897.

stant the means of comparing what we intend with what we feel that we accomplish.

What is the relation between the force of will and the act itself? The force of the act we have measured in pounds or grams. Will, not being a mechanical process, cannot be measured by any physical force; it can be measured only in terms of will. Yet the following experiment shows how we can bring the two into relation. We will to make a weak voluntary act, then one twice as strong, then one three times as strong, etc. Our efforts of will were of the relative strengths 1 : 2 : 3 : etc. The force of the voluntary acts shows the same relations only occasionally. Each person has his own relations of scale between force of will and force of action, and these relations change under different circumstances. Although we shall not know the laws governing the relations between the two until further investigations are made, yet we can say that increased force in the act indicates increased force of will, and likewise increased accuracy in the act indicates increased accuracy in the will-impulse.

Are we justified in believing that an increase in the force of action indicates not only increased muscular power but also increased will power? Several facts seem to indicate an affirmative answer.

It has often been noticed in the gymnasium that an act will grow steadily stronger by training, although not the slightest change can be detected in the muscles. Moreover, the principle of "cross-education" (pp. 22, 66) applies here also. In one set of experiments the greatest possible effort in gripping was made on the first day with the left hand singly and then with the right hand ten times each. The records were: for the left, 15 pounds; for the right, 15 pounds. Thereafter, the *right* hand alone was practised nearly every day for eleven days, while the left hand was not used. The right hand gained steadily day by day; on the twelfth day it recorded a grip of 25 pounds. The left hand—which had not been used in the meantime—recorded on the same day a grip of 21 pounds. Thus the left hand had gained six pounds, or more than one-third, by practice of the other hand.

Experiments have shown also that the greatest possible effort depends on the general mental condition. The greatest possible effort is greater on the average among the intelligent Europeans than among the Africans or Malays. It is greater for intelligent mechanics than for common labourers who work exclusively, but unintelligently, with the hands. Intellectual excitement increases the power. A lecturer actually becomes a stronger man as he steps on the platform. A schoolboy hits harder when his rival is on the same playground.

It has even been observed that the power exerted varies according to what we hear, feel, or see. With the thumb-and-finger-grip the greatest pressure that could be exerted on one occasion during silence was eight pounds. When some one played the giant's motive from the Rheingold the grip showed 8¾ pounds. The slumber motive from the Walküre reduced the power to 7½ pounds. The effect of martial music on soldiers is well known.

Just how much of the inspiriting effect of music is due to the rhythm, the time, the melody, and the harmony, has not been determined. Plato emphasises the influence of the proper music on the formation of character. He goes no further than to specify the general scales in which music should be written. The high Lydian is plaintive, the Ionian and Lydian are soft and convivial, the Dorian is the music of courage, and the Phrygian of temperance. Aristotle agrees in general but considers the Phrygian music as exciting and orgiastic. It has long been supposed that the difference among the scales was one of arrangement of the intervals within the octave, corresponding to the major and the minor, but the more recent opinion is that the difference is one of pitch. The Lydian is a tone to a tone and a half higher than the Phrygian, and the Dorian is a tone below the Phrygian. The Dorian is neither too high nor too low, and expresses a manly character. It might be suggested that the special melodies as-

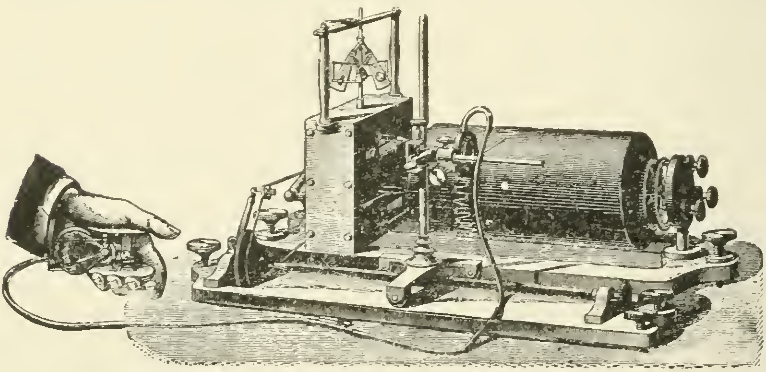


Fig. 58.—Dynamograph.

sociated with each scale may have had much to do with the case. Nevertheless it has been proven that the pitch itself has an effect on the greatest strength of grip.

In order to indicate the pressure continuously the dynamometer can be arranged in connection with the capsule of the graphic method (p. 61). One such arrangement is shown in Fig. 58. As the hand squeezes the dynamometer the pointer on the drum moves to one side. Every fluctuation in the squeeze is shown, and when the smoked paper is taken from the drum and varnished we have a complete record. Such a tracing from a hysterical person squeezing as hard as possible is shown in Fig. 59. The power of squeeze is changed by various disturbances. The

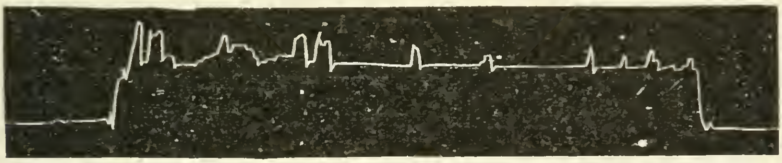


Fig. 59.—Record of Strongest Grip of the Hand by a Hysterical Person.

sudden jerks in the line of Fig. 59 are the results of the ringing of a gong. The sudden increases in power occur each time when the gong is struck.

Successive single contractions can also be registered

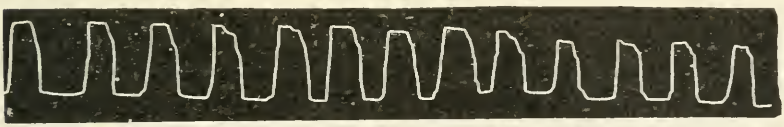


Fig. 60.—Record of Successive Squeezes during Ringing of a Gong and during Silence.

on the drum. Fig. 60 shows the successive squeezes of one person with the hand—first while a gong was being sounded, then in silence. The gongs on the trolley-cars cannot, however, be recommended as a strengthening tonic.

The colours also affect the squeeze with some persons, especially hysterical people. The strongest hand-squeeze in the case of one such subject is shown in Fig. 61. This suggests a new principle in the selection of colours for the house, for uniforms, etc.

FIG. 61.—Strongest Contractions while Looking at different Colours: *g*, green; *b*, blue; *o*, orange; *y*, yellow; *r*, red; *v*, violet.

Tastes and smells have different effects. Fig. 62 shows the effect of musk, which was smelled just as the last squeeze was made. Tobacco has a stimulating effect. Joy and anger increase the power, sorrow and fright decrease it. An entertaining novel is a will-stimulant; a prosy text-book actually weakens us.

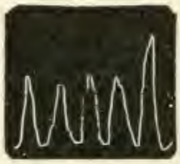


FIG. 62.—Influence of Musk.

CHAPTER VIII

TOUCH

HERE is a row of ten little disks, 3^{mm} in diameter, cut from elder pith. Each is suspended by a fine cocoon-fibre from a little handle. For portability the handles are stuck in holes in a support (Fig. 63). Now place your hand comfortably on the table and close your eyes. Tell me when and where you feel anything touch your hand. Without letting you know what I am doing I take the handle with the lightest weight and let the weight softly down till it rests on your hand (Fig. 64). You do not know that I have done so, and you feel nothing. Then I try the next heavier, and so on, till you feel the pressure. The little disks are graded in weight, thus 1^{mg}, 2^{mg}, etc., up to 10^{mg}.

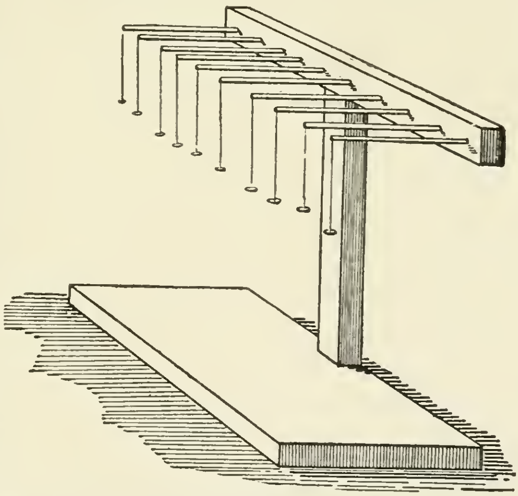


FIG. 63.—Touch-weights for Finding the Threshold

Now, if the fourth weight was the first you felt, then 4^{mg} was the least noticeable weight, or the weight just on the "threshold of intensity." This fact of the threshold is one that we shall meet everywhere in the study of mind.

The threshold of sensation for the sense of pressure in an average subject was 2^{mg} for forehead, temples, and back of forearm and hand; 3^{mg} for inner side of forearm; 5^{mg} for nose, hip, chin, and abdomen; 5^{mg} to 15^{mg} on inner surface of fingers; and 1000^{mg} on heel and nails.

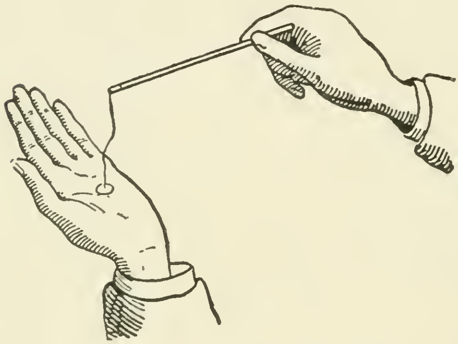


Fig. 64.—Finding the Threshold for the Palm of the Hand.

Some idea of the delicacy for distinguishing differences in pressure can be obtained by laying a hair on a plate of glass and putting over it ten to fifteen sheets of writing paper. The position of the hair can easily be felt by passing the finger back and forth over the surface.

Touching with movement gives much more delicate judgments than mere contact. A book-cover feels much rougher when the finger is moved over it than when it is merely touched.

Something very peculiar occurs when a light pressure is varied rapidly in intensity. If the tip of a tuning-fork in motion be lightly touched to the skin, it "tickles."

The tickling need not be a true wavy pressure; that is, it need not be perfectly regular. If any object, such as a feather or the finger, be held lightly against the face, a tickle is felt, due to the trembling.

The tickling thing need not stay at one spot, but may be moved along continuously. A feather drawn over the temples makes a strong tickle. A fly walking over the skin produces an unbearable tickle in exactly the same way. Stories of the Thirty Years' War relate how the soldier-robbers forced the peasant to reveal his treasure by subjecting him to unbearable tickling. Salt was spread on his soles and a cow was allowed to lick the salt.

When a pressure is already felt, it can be made stronger or weaker to a certain degree before the change is perceived.

Fig. 65.—Finding the Least Noticeable Change in Pressure.

The experiment can be made with a pair of beam-balances. The hand, supported by a block or cushion, is placed under the scale-pan so that when the scale is at rest, the pan-holder just touches the skin (Fig. 65). To avoid the coldness of the pan, a piece of cork or leather is placed between the hand and the metal.

The subject of experiment closes his eyes. A weight is placed in the pan above the hand. A sensation of pressure is felt. Sand is quietly poured into the same pan until the subject feels the pressure to be increasing. By putting weights in the other pan the amount of increase can be measured. Now start with the same weight as before and pour sand into the opposite pan until the subject feels the pressure to be lighter. The amount of sand that has been added represents the least noticeable *change*, or the threshold of change, in the pressure. Thus, if the weight at the start was 50^g and the amount of sand added was 35^g, the least noticeable change was 35^g, or $\frac{35}{50}$ of the original pressure.

Several facts will be noticed by those who perform this experiment. In the first place, the least noticeable change depends on the rate at which the change is made. Several funnels should be used, with the ends of different sizes. When one of these is filled with sand, the rate at which the sand flows out depends on the size of the opening; some funnels will allow the sand to flow rapidly, others slowly. When the same experiment is repeated with different rates of flow, it will be found that the slower the flow the greater the least noticeable change. With a very slow flow the weight can often be increased two or three times over before the change is noticed.

No one has ever tried to see if a great pressure can be applied to the human skin without its being noticed, provided the rate be extremely slow. A frog with the spinal cord cut off from the brain is quite sensitive to a touch; yet when a pressure is applied by screwing a rod down at the rate of 0.03^{mm} in one minute his foot can be crushed in 5¼ hours without a sign that the pressure was felt (compare with the experiment on the frog in Chap. IX).

The next point to be remarked is that the least noticeable change depends on the weight from which the pressure is started. Roughly speaking, if for a weight of 50^{g} the least noticeable change, at a certain rate, is 30^{g}, or 60 per cent. then the least noticeable change, at the same rate, for 25^{g} will be 15^{g}, or 60 per cent. also. These two classes of facts can be summed up in one general law: the threshold of change increases inversely as the rate of change but proportionately as the starting pressure.

The least noticeable difference is quite another matter from the least noticeable change. The usual method of experiment employs a series of weights successively growing slightly heavier or lighter from the standard.

Suppose we start with a weight of 20^{g} as a standard, and have a set of weights increasing or decreasing successively by steps of 1^{g}. The standard is first applied, say, to the palm of the hand—the hand being at rest on a cushion. It is then removed and, after about two seconds, the 21^{g} weight is applied for an instant. The subject tells whether he feels it lighter, heavier, or the same. After a short time the standard is again used; then the 22^{g} weight is applied. This is continued with 23^{g}, 24^{g}, etc., till the subject has several times in suc-

6

cession felt the weights to be heavier. The first weight of the unbroken succession of heavier weights gives the least noticeable difference. For example, suppose a set of experiments to give the following results: 21 equal, 22 heavier, 23 lighter, 24 equal, 25 heavier, 26 heavier, 27 heavier, 28 heavier. Then the threshold would be at 5^g.

In a similar manner the threshold of difference can be found with successively lighter weights. For a general threshold the average of the two can be taken. For example, if the threshold for 20^g toward lightness is 4^g and the threshold toward heaviness is 5^g, the average threshold is $4\frac{1}{2}^g$. When different weights are used as standards, it quickly becomes apparent that the threshold of difference does not remain at the same number of grams. For a standard of 200^g the difference of 5^g will not be felt at all. The threshold will be more nearly 20^g.

The results of such a series of experiments in lifting weights are given in the following table:

S	1	2	5	10	20	50	100	200	500	1,000	2,000	4,000
D	0.2	0.3	0.6	0.9	1.5	2.8	6.4	10.8	25	57	80	100
$\frac{D}{S}$	$\frac{1}{5}$	$\frac{1}{7}$	$\frac{1}{8}$	$\frac{1}{11}$	$\frac{1}{13}$	$\frac{1}{18}$	$\frac{1}{16}$	$\frac{1}{19}$	$\frac{1}{20}$	$\frac{1}{18}$	$\frac{1}{25}$	$\frac{1}{40}$

The figures in S give the different standards, those in D give least noticeable differences; those in $\frac{D}{S}$ tell the relation of the least noticeable difference to the standard. Thus, for a standard of 1^g the least noticeable difference is 0.2_g, or $\frac{1}{5} = 20$ per cent. For 1,000 it is 57^g, or $\frac{1}{18} = 5.7$ per cent.

It is evident that the least noticeable difference does not remain the same, but increases as the standard increases. The famous law of Weber would say that the least noticeable difference increases in the same ratio as the standard; in other words, that the least noticeable difference is always a certain fraction of the standard. This is not true for pressure, as is seen by the line of fractions for $\frac{D}{S}$; according to Weber's law they should all be the same.

This law of proportionality of differences is recognised in many tax laws. For example, the income tax demands that each person shall pay an amount in direct proportion to his income. The Mosaic tithe demanded a tenth. This is presumably all in the belief that a man with $100 feels a payment of $10 as much as a man with $100,000 feels one of $10,000.

In saying that like differences are not differences of the same amount, but are differences depending on the amount from which you reckon, the law is unquestionably true. But the relation of proportionality is much too simple to meet the facts.

It is a curious and interesting fact that much finer differences can be detected when the two weights are applied one to each hand at the same time.

Let us now find the "threshold of space" for the skin. An ordinary pair of drawing dividers (Fig. 66) can be used, but accurate work requires a better apparatus. The compass in Fig. 67 consists of a horizontal bar on which the two points slide. These points are held on springs so that

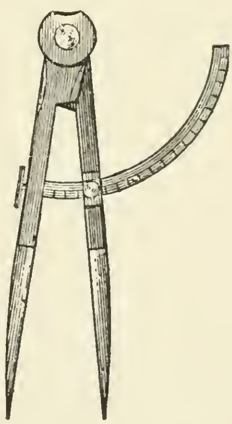


Fig. 66.—Simple Æsthesiometer

the experiments can be made at a constant pressure.

Place the two points at 1^{mm} apart. Take the æsthesiometer by the handle and gently press the points against the forehead of some one who has his eyes closed and who has not seen the adjustment of the points. He is to say whether he feels two points or one. At this distance he will feel only one. Adjust the points to 2^{mm} and try again. Proceed in this way till he feels the two points distinctly. Now start with a somewhat greater distance and proceed backward till only one point is felt. The average of the two results is the threshold of skin-space at the particular pressure for the particular place of the particular person experimented upon.

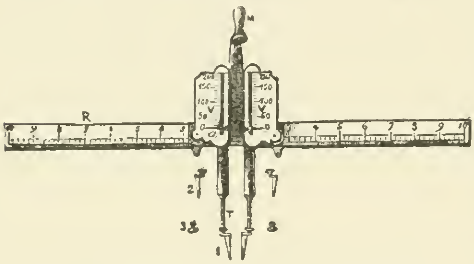


Fig. 67.—The Complete Æsthesiometer.

Here is a specimen table of results:

Tongue	1^{mm}
Inner side of first finger-joint	2^{mm}
Lips (red portion)	5^{mm}
Inner side of second finger-joint	7^{mm}
Lips (skin)	9^{mm}
Cheek, big toe	11^{mm}
Forehead	23^{mm}
Back of hand	31^{mm}
Leg	40^{mm}
Neck	54^{mm}
Middle of back, upper arm, thigh	68^{mm}

It is a remarkable fact that the skin can be educated by practice so that the threshold is much reduced.

The blind, who pay constant attention to their finger-tips, have very small thresholds. Curiously enough, their thresholds are also smaller on the back and on other places which they do not use more than other people. The superiority of the blind in that respect would seem to be due to increased attention to the skin. A further evidence of this explanation is the fact that education of one part of the body brings a special decrease of the threshold for the neighbouring parts and for the same portion of the opposite side of the body. There is a kind of transference of practice that resembles cross-education (pp. 22, 66, 72).

Our experience has taught us that the various portions of the skin stand in certain space relations. Thus we know that something touching the middle finger is further from the thumb than something touching the index finger. When the fingers are out of their places we are irrestibly driven to judge as if they were in proper order. This is illustrated by what is known as Aristotle's experiment. The middle finger is crossed over the index finger in such a way as to bring the tip of the middle finger on the thumb-side of the other. A pea or other small object, when inserted between the two, will appear as two objects. It is difficult to re-learn the arrangement of the skin in space. We thus see why a person whose nose has been re-formed by a piece of skin from the forehead, for a while feels all contact on the nose as if it were contact on the forehead.

Fig. 68.—Aristotle's Illusion.

A similar illusion is produced by placing a pencil between the lips and moving the under-lip to one side. There are apparently two pencils.

The distance between two points on the skin seems greater when the skin between these points is also touched. If four pins are pounded in a straight line into a stick at one-fourth of an inch apart, the distance between the end pins will appear greater than that between two separate pins three-fourths of an inch apart.

The distances apart of the various points that we feel are what we know under the names of smoothness and roughness. A billiard-ball is "smooth," that is, our sensations of touch are evenly distributed. Carpet is "rough," that is, it produces uneven sensations. Sandpaper is peculiarly "rough," because very intense and limited sensations from the sharp sand are mingled with smoother ones and gaps. Velvet, when felt backward, has a peculiar rough smoothness, because the separate points of the individual hairs produce separate sensations, yet are so near together as to resemble smoothness. Shortnap plush has a similar feeling.

CHAPTER IX

HOT AND COLD

IN the old days it was supposed that heat and cold were two different things; even to-day the every-day person cannot grasp the idea that coldness is simply the absence of heat, that a piece of ice is cold simply because it is not hot. But the modern development of physics has shown that heat consists of motion among the little molecules of which all bodies are supposed to be composed, and that as this motion becomes less the bodies are said to be cold. Thus a glass of warm water differs from a glass of cold water simply in the fact that the molecules of the water in the former are moving rapidly, while in the latter they are comparatively quiet.

Strange as it may seem, it was discovered a few years ago that the ordinary common sense of every-day people was right. Not that the science of physics was wrong, but that the conclusion drawn was incorrect. Hotness and coldness are two entirely different things from our point of view. A glass of water is warm because it gives us a feeling, or sensation, of warmth; another glass is cool because it gives us an entirely different sensation of coldness. The complete distinction of our feelings of hotness and coldness from the physical condition of the molecules of the object touched is emphasised by an experiment in which the same object feels both hot and cold at the same time (see below).

Our sensations of hot and cold come from little spots called hot spots and cold spots. To find the cold spots a pointed rod, *e g.*, a lathe centre, a pointed nail, or even a lead pencil, is cooled and then moved slowly and lightly over the skin. At certain points distinct sensations of cold will flash out while elsewhere nothing but contact or vague coldness is felt. These points are the cold spots; a specimen arrangement of them is shown in Fig. 69.

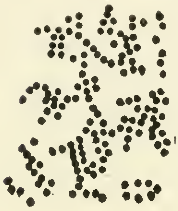


Fig. 69.—A Cold-spot Map.

To find the hot spots the metal point is warmed and applied in a similar manner. The hot spots are everywhere different from the cold spots. A specimen case is shown in Fig. 70.

At the art store get a few pounds of plaster for casts (the finely ground plaster, not the ordinary plaster of Paris). Mix it with water in a bowl. Pour out a portion into a tin pie-plate. Now press the hand (palm or back) down upon it, being careful to touch the plaster at every point. When the plaster has hardened sufficiently to permit the removal of the hand without sticking, carefully raise it. A perfect cast of the hand is obtained with every line expressed.

Fig. 70.—A Hot-spot Map.

Now prepare yourself with a glass of ice water, a glass of hot water, some red and some blue ink, a pointed metal pencil (or a sharp lead pencil), and a couple of tooth-picks. Cool the pencil in the ice water. Dry it and pass it over the skin. Whenever a cold spot flashes out, mark its position in blue ink with a tooth-pick on the cast. The fine creases in the skin will enable you to locate it exactly. Repeat this a few times, till you are satisfied that you have a map of all the cold spots. Warm the pencil in the hot water and find the hot spots in the same way. Mark them on the cast in red ink. When you have finished you will have a complete geography of your temperature spots on a relief map.

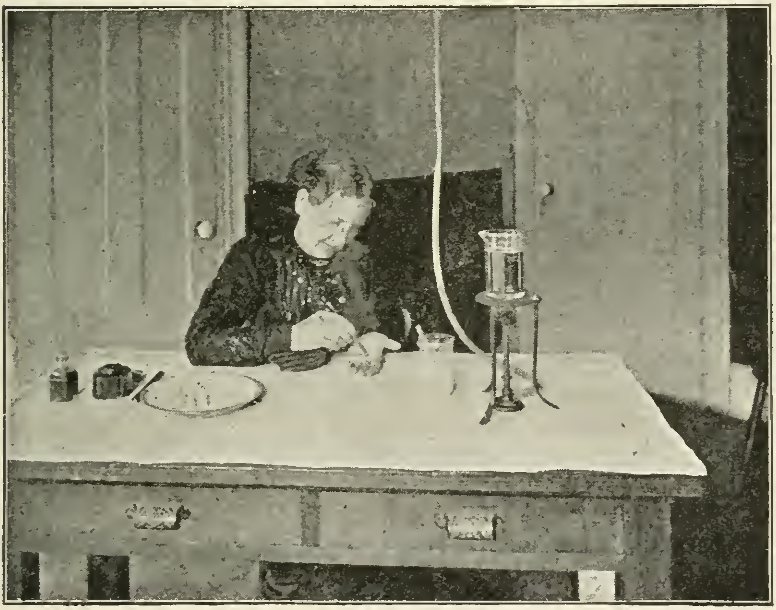


Fig. 71.—Finding the Hot and Cold Spots.

The hot spots are ordinarily not sensitive to coldness or the cold spots to heat. Yet a very hot point applied to a cold spot so as not to reach hot spots also will feel cold; of course, to a hot spot it is intensely hot. It is noteworthy that when the hand is applied to a very hot or a very cold object there is often doubt for a few moments whether it is hot or cold, because both sets of spots are stimulated.

The temperature spots answer to tapping by sensations of hot or cold. For an experiment, choose a sensitive cold spot and let some one tap it with a fine wooden point; it will feel cold. Thrust a needle into it; it will feel no pain.

In studying the subject of touch we had occasion to notice a certain law of change (page 79). Does such a law hold good for hot and cold? By experiments with a special apparatus I was able to prove that it did; the smallest noticeable change depended on the rate of change. But complicated apparatus is not necessary to illustrate the law; anybody can do it by means of a lamp and a spoon. Let some one else hold the spoon by the extreme end; you yourself put your finger about half way down the handle. The bowl of the spoon is now held over a lamp so that it will slowly become hot. After a while the handle of the spoon under your finger begins to feel slightly warm. Lift the finger and immediately place the same finger of the other hand on the same place. The spoon will be found to be quite warm or even painfully hot. When the heat was gradually increased it was scarcely noticed, but when suddenly increased, it was clear at once; in short, the sensitiveness to heat depends on the rate of change.

Although a frog jumps readily when put in warm water, yet a frog can be boiled without a movement, if the water is heated slowly enough. In one experiment (Fig. 72) the water in a bowl was heated by means of a little flame under the bulb which communicated with the bowl by a tube; the temperature rose at the rate of 0.002° C ($\frac{36}{10000}$ of a degree Fahrenheit) per second as indicated by a thermometer in the bowl. The frog never moved and at the end of two and one half hours was found dead. He had evidently been boiled without noticing it.

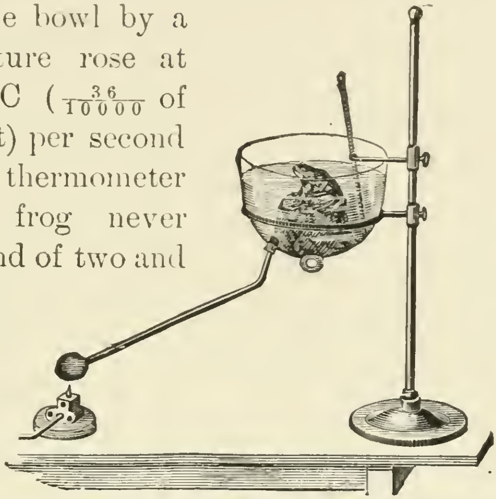


Fig. 72.—Boiling a Frog without His Knowing it. No Sensation with an Extremely Slow Rate of Change.

There is a curious connection between temperature and pressure. Cold or hot bodies feel heavier than bodies of equal weight at the temperature of the skin. For cold, take two silver dollars; keep one of them closed in the hand to give it the temperature of the skin, but cool the other. Apply them in succession to the palm of some one's hand. The cold one will seem much heavier. Heat does not make so much difference as cold. For a careful experiment take two wooden cylinders of equal weight and heat one very hot in an oven. Apply the cylinders on end to the back of the hand. This phenomenon illustrates the fact that a sensation of one kind often causes an apparent increase in the strength of another sensation.

CHAPTER X

SMELL AND TASTE

IN spite of the antiquity of language, we have no names for smells. When we notice an odour, we name it by the source from which it comes. We speak of the odour of violets, of new-mown hay, of onions, and so on, but we have no name for the odour itself. Such a lack is not present in sight, hearing, or even taste. We might say that certain things taste like sugar, certain others like quinine, and so on; but that would be only a roundabout way of saying they were "sweet" or "bitter." Instead of classifying the colours, as grass colour, dandelion colour, coal colour, etc., we say green, yellow, black, etc. But in smell we can only speak of cabbage odour, fishy odour, violet odour, and the like.

Not only do we have no names for odours, we do not know any reason why different things smell alike. Why should compounds of arsenic smell like garlic? If we mix sulphuric acid with water, we get an odour like musk. It is said that emeralds, rubies, and pearls, if ground together for a long time, give out an odour like that of violets. Again, ringworm of the scalp, the body of a patient sick with typhoid, and a mouse have similar odours.

Perfumes can often be placed in similar groups. The rose type includes geranium, eglantine, and violet-ebony; the jasmine type, lily of the valley and ylang-ylang; the orange type, acacia, syringa, and orange-flower; the vanilla type, balsam of Peru, benzoin, storax, tonka bean (usually sold for vanilla extract), and heliotrope; the lavender type, thyme and marjoram; the mint type, peppermint, balsam, and sage; the musk type, musk and amber seed; the fruity type, pear, apple, pine-apple, and quince.

What is the threshold of smell? There is a convenient but not highly accurate way of answering the question by means of the olfactometer, or smell measure.

The olfactometer (Fig. 73) includes a glass tube fastened on a narrow board. Inside this tube is a narrow strip of blotting-paper mois-

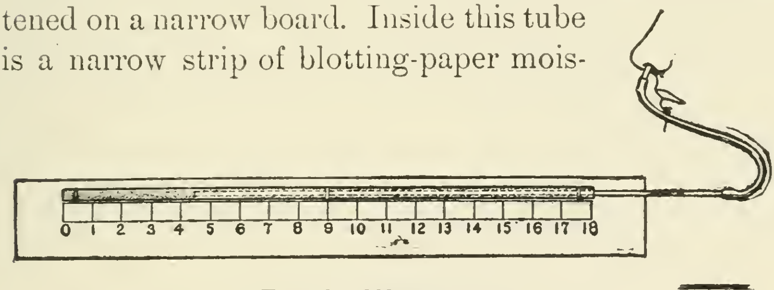


Fig. 73.—Olfactometer.

tened with the object to be smelled. A solution of camphor in alcohol is convenient; the solution dries, leaving the strip filled with small particles of camphor. Any other not too odorous liquid may take the place of the camphor solution. Inside the tube is a smaller one on the end of which is a piece of rubber tubing. A scale is marked on the board below the tubes.

The end of the smaller tube is pushed to the end of the larger one. The old air in it is blown out. The rubber tube is put to the nose. The smaller tube is now slowly drawn backward, while the person breathes air in through it. When he first perceives an odour, the distance through which the smaller tube has been drawn from the end of the larger one, is noted. Now, the further the tube is drawn back, the greater the distance over the blotter travelled by the air breathed ; consequently there is more of the camphor in the air. The number thus noted down gives an idea, though not a very accurate one, of the person's threshold of smell.

In the whole range of psychology there is nowhere to be found a more striking method of illustrating the difference between the different thresholds of knowledge. As the smelling-tube is pulled backward the observer at first notices no odour; the odour is said to be below the threshold. After a while he says: "I smell something, but I can't tell what it is"; a sensation is there, it is known as an odour, it has passed the "threshold of sensation," but has not reached the "threshold of recognition" (if I may use such an expression). The odour becomes stronger and stronger; finally the observer exclaims, "Now I know the odour; let me think a moment and I will tell you the name." Very frequently he recognises the odour without being able to recollect the name. The difference between the threshold of sensation and the threshold of recognition is often considerable. If the odour is still further increased, the name, for usual substances, is readily recollected.

Our sense of smell can be fatigued. Holding a piece of camphor for some minutes before the nose will raise the threshold for camphor. With an olfactometer charged with camphor the threshold as measured before fatiguing the sense of smell will be found to be much lower than the threshold afterwards. Sometimes the fatigue is so great that the smell of the camphor is entirely lost. Strangely enough the fatigue affects some odours and not others. If the sense be affected by camphor-fatigue, the smell of wax will be diminished or lost, but essence of cloves will appear undiminished in strength.

We have two senses of smell, namely, the two halves of the nose. When two different smells are received, one from each organ, we are driven to notice first one, then the other. When a rose is placed in one paper tube (Fig. 74) and a water-lily in another and the tubes are so arranged that the odours get to separate nostrils without mixing, we do not smell a combination, but alternately either rose or water-lily. We can smell either one in preference to the other by simply thinking about it (compare p. 21). It is a very curious fact that we are unable to think of the same odour steadily; our thoughts irresistibly turn from one to the other and thus the smells alternate.

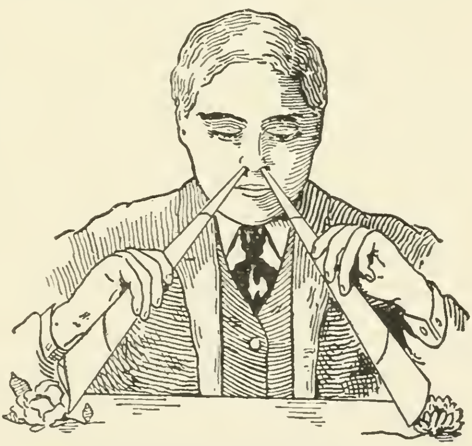


Fig. 74.—Alternation of Odours; or the Strife of the Two Nostrils.

The greater attention paid to sight and hearing has apparently caused a neglect of smell and a consequent deterioration. The acuteness of smell among animals is well known. Among certain persons this sense also attains great development. I have a case—reported by a perfectly competent witness who lived for years with the person mentioned—of a woman in charge of a boarding-school who always sorted the boys' linen after the wash, by the odours alone.

For the tastes we are much better off than for the smells; we have names for them. We say that something is "sour," that it is "sweet," etc., and do not need to name the taste after the object.

The great diversity of flavours of objects is due mainly to smell. When a cold in the head injures the ability to smell, the flavours of the dinner-table disappear for the most part.

Experiments on taste without smell can be made by filling the nose cavity with water while the head is in an inverted position; simply holding the nose without breathing is almost as good.

When the sense of smell is entirely lost, the ordinary flavouring syrups such as vanilla, currant, orange, strawberry, and raspberry give merely a sweetish taste with no distinction among them. Lemon syrup tastes sweet and sour. Candies flavoured in this way taste alike. Mustard and pepper produce sharp sensations on the tongue; there is no difference between them except that pepper is sharper; neither produces a real taste. Tea does not differ from water or coffee, Rhine wine from diluted vinegar. Ginger and cloves are alike. Powdered cinnamon, when placed on the tongue of a person whose eyes are closed and whose nose is held between the fingers, is considered to be like meal.

Wines owe their bouquet entirely to smell. The most exquisite Schloss Johannisberger does not differ from diluted vinegar as far as taste goes. Coffee likewise owes its flavour to smell. Boiled coffee has lost its aroma and is merely a combination of sour and bitter. Through unpardonable stupidity pepper is always served ground and consequently odourless, the little German pepper-mills being unknown in America.

When all smells and touch and temperature sensations are gotten rid of, the things we taste can be sorted into six different classes: sour, sweet, salt, bitter, metallic, alkaline, and their combinations. Characteristic examples of these are found in lemon juice, sugar, salt, quinine, zinc, and washing soda. The elementary tastes can be combined in countless ways. Thus, sweet and sour when combined produce a result that is neither sweet nor sour, but differs from either while resembling both. Unfortunately psychologists have not attempted to unravel the compound tastes into their elements.

Probably no more convenient or striking illustration of the threshold can be presented than in experiments on taste.

The threshold for sweetness can be found by using a solution of sugar of known strength. An ounce of sugar dissolved in twenty ounces of water makes a five per cent. solution. For simple illustration it is sufficient to place a spoonful of sugar in a small wine-glass of water. Some pure drinking water and two medicine droppers are to be provided.

A small glass is used, preferably a graduated medicine glass, containing one ounce of pure water. With one of the droppers a quantity of the sugar solution is taken up; one drop is allowed to fall into the water. The water is then stirred with the other dropper; a small quantity is taken up in it and one drop of this homeopathic solution is allowed to fall on the tongue of the person tested. He will not taste anything, owing to the extreme dilution. The experiment is repeated, adding one drop each time, till a taste is noticed. The number of drops used will indicate the threshold of taste. If the five per cent. solution and a graduated glass have been used, it is an easy matter to calculate just how strong this least noticeable taste is.

Similar experiments can be made with salt, quinine, acid, and alkali. The most convenient solutions to use are sugar, 5 per cent.; quinine, 0.002 per cent.; tartaric acid, 0.5 per cent.; salt, 2 per cent.; sodium carbonate, 0.1 per cent.

To avoid the effect of suggestion it is advisable to have more than one solution ready and not to let the person tested know which is being used.

How far the education of the sense of smell can be carried is shown by the tea-tasters who can tell the locality in China from which each chest of tea comes.

Our appreciation of a taste depends on its quantity. A single drop of sugar solution on the tongue does not seem so sweet as a mouthful.

It is a very curious fact that a weak sensation of taste of one kind can be made to strengthen a taste of another kind. If two glasses of water be equally sweetened, one of them can be made to appear sweeter by adding a minute quantity of quinine powder. Vanilla is added to strengthen most of the flavours of soda water. Some partially deaf persons can hear much better in the midst of a noise. This is usually explained on purely physiological grounds, but there is a possibility of an explanation on the ground that the mind would naturally lump in a very weak sensation of any kind with the stronger one.

Some of the peculiarities of flavours are due to feelings of touch on the tongue. Soda water and champagne stimulate the tongue by the fine bubbles that they give off. Pepper and mustard produce an agreeable irritation. Puckery substances, such as raw quinces, act as the name implies. All such touch sensations are not tastes, although they and the smells enter into the flavours of things.

Sour tastes are accompanied by touch. This can be brought out clearly in a series of experiments. We begin with a very weak solution of the acid, so weak that it seems like water when tasted. As it is made a trifle stronger, a slight puckery feeling first appears, even before the person experimented upon notices any sourness. By a little increase in the strength the sour taste is made to appear also. When the sour taste becomes very strong, a burning sensation is felt at the same time.

When we begin with a weak solution of salt and make it successively stronger, the taste appears first. Later a weak, burning sensation is felt; this steadily increases but never overpowers the taste as in the case of sour things.

With a solution of sugar made steadily stronger a feeling of softness appears before the taste. Then the taste is more prominent. With a very strong solution we get the feeling of slipperiness and stickiness, as in honey and syrup. With saccharine (an intensely sweet substance) the touch sensations are present but not so prominent.

With bitter solutions made successively stronger, a fatty, smooth sensation appears before the taste. Thereafter the bitterness is most prominent. With pure quinine the bitterness overpowers everything, no matter how strong the solution. With quinine sulphate or chloride the very strong solutions are more or less burning.

It is a curious but uninvestigated fact that temperature likewise has an influence. Let equal quantities of water be placed in two tin cups, and let one cup be heated. Then if the same quantity of lemon juice or any sour solution be dropped into each, the warmer solution will taste sourer than the cooler one. If a sweet solution be tried in the same way, the cooler solution will be the sweeter.

CHAPTER XI

HEARING

AMONG the many sounds that we hear we generally make a classification into tones and noises. Pleasant sounds, like those of a flute, we call tones; unpleasant ones, like those of escaping steam, rumbling waggons, or screeching parrots, we call noises. This is only a convenient way of sorting sounds. Very many—if not most—sounds are either tones or noises according to the point of view. A jumble of piano-tones is a noise. The scraping of a violin produces a noise in the hands of a beginner and passes gradually from noise to tone as skill is acquired. A block of hard wood when struck makes a noise; yet we call the same sound a tone when the block of wood is one of the notes of a xylophone.

In a simple tone three properties are to be noticed: (1) pitch, (2) intensity, (3) duration.

As the finger is slid up or down the violin string, we hear changes in the pitch of the tone. As the bow is drawn harder or softer against the string, we hear changes in the intensity, or loudness. As the tone is continued for a longer or shorter time, we hear changes in duration.

We are so accustomed to saying that tones are "high" or "low," that there seems to be really something high or low about them. We might, however, just as well call the bass tones high. This naming of the tones according to our notions of space is derived from the Middle Ages. The old Sanskrit terms meant "loud" and "soft"; the Hebrew was "audible" and "deep"; the Greek was "low" and "high" in exactly the opposite meaning to ours. The Latin was simply a translation of the Greek words for "acute" and "grave"; and the modern Romance languages, like the French, retain the Latin terms. In the Middle Ages it was customary to speak of ascending and descending the scale; it is from this that the German and the English probably derive the highness and lowness of tones.

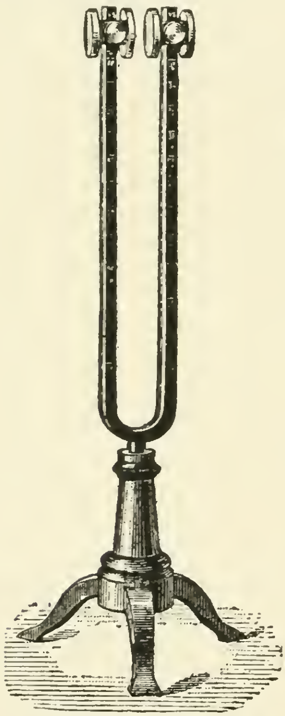


Fig. 75—Giant Fork for Finding the Lowest Audible Tone.

Starting from the middle of the piano, run the scale down toward the left. The lowest tone is very deep and shaky. Starting again, run the scale up to the right. The high tones sound shrill and tinkling. What would happen if the piano received lower and lower tones, or higher and higher tones, going on as long as we pleased?

To produce tones lower than the tones of the musical instruments a gigantic tuning-fork over a yard long has been made. The prongs are furnished with weights. As the weights are moved toward the ends the tone sinks lower and lower. In a short time weak puffs are heard in addition to the tone, each puff corresponding to a single movement of the prongs. Finally the tone disappears entirely, leaving nothing but puffs. The point at which the tone disappears is called the lower limit of pitch, or the threshold of pitch.

This lower limit is different for different persons. It is generally at about twelve complete vibrations per second. Some persons, however, have been found who cannot hear even the lower tones of the piano. Even the lowest tone of a large organ at thirty-two vibrations per second seems to some persons to be wavy.

Going upward in the scale we can proceed far beyond the piano. The test can be made with a set of small tuning-folks or small steel bars. It is most conveniently done with the Galton whistle (Fig. 76). This whistle can be altered in length by a screw-cap. As it is made shorter the tone rises. By means of a scale marked on the barrel the pitch of the tone can be calculated.

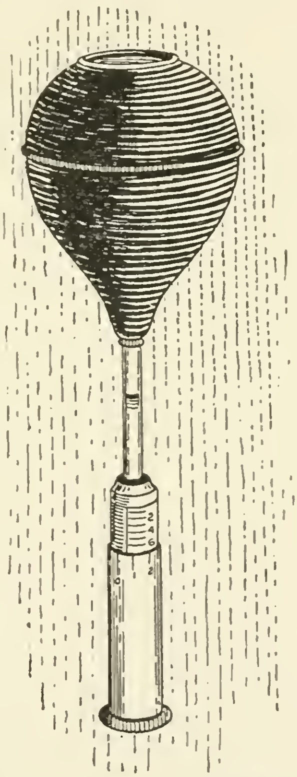
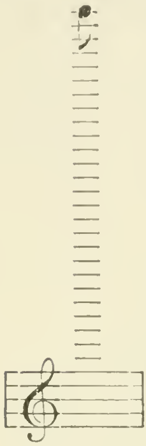


Fig. 76.—Whistle for Determining the Highest Audible Tone.

The highest audible tone has been found to be very different for different persons. To some persons even the highest tones of the piano are silent. Others again can hear even up to 60,000 vibrations or more per second. The position of such a high tone would be indicated by the musical notation given in the margin.



Robert Franz, the composer of the music to Burns's *My Highland Lassie*, in 1842 lost all the tones[1] from E^3 upward in consequence of the whistle of a locomotive. In the following years he lost two half-tones more, so that in 1864 he heard nothing above D^3.

The sound of a cricket is not heard by some persons. I cannot hear the squeak of a bat but believe, on authority, that it does make a sound. Many people cannot hear the shrill squeak of a mouse. When singing mice are exhibited, some people who go to hear them declare that they can hear nothing, others can hear barely something, and others again can hear much.

It has also been noticed that as a person grows older he loses his power of hearing high tones. The persons themselves are quite unconscious of their deficiency so long as their ability to hear low tones remains unimpaired. It is an amusing experiment to test a party of persons of various ages, including some rather

[1] The reader is reminded that the successive octaves of the scale are indicated by small figures. Thus C^{-2}, C^{-1}, C^0, C^1, C^2, etc., indicate the successive C's of the scale; C^1 is middle C. The other notes are treated likewise.

elderly and self-satisfied personages. They are indignant at being thought deficient in the power of hearing, yet the experiment quickly shows that they are absolutely deaf to shrill notes which the younger persons hear acutely, and they commonly betray much dislike to the discovery. Such persons should be comforted by the fact that every one has his limit. Sensitive flames have been found to be powerfully affected by vibrations that are too rapid for ordinary ears.

In some persons the upper limit of pitch is very low. It is related of Mr. Cowles, an American journalist, that it was not until he was twenty-five years of age that he became really cognisant of his defect. Up to this time he had treated all he read about the songs of birds as nothing more or less than poetical fiction. To him birds were perfectly mute; and he was perfectly deaf to the shrillest and highest notes of the piano, fife, or other musical instruments. At length, after considerable pains, he was convinced that he laboured under some defect of hearing. When put to the test in a room where a large number of canary birds were singing very loudly, he declared he could not hear the slightest sound, even when placed close to their cages. Moreover, it was found that all the sibilant sounds, such as *s*, of the human voice were equally inaudible. In all other respects his hearing was perfect.

Galton, the inventor of the whistle, relates that he has gone through the whole of the Zoölogical Gardens, using a cane with a whistle at one end and a bulb at the other. He held the cane near the ears of the animals and when they were quite accustomed to it he would blow the whistle. Then if they pricked their ears it showed that they heard the whistle; if they did not it was probably inaudible to them. Of all creatures he found none superior to cats in hearing shrill sounds; cats, of course, have to deal with mice and find them out by their squealing. A cat that is at a very considerable distance can be made to turn its ear around by sounding a note that is inaudible to almost any human ear. Small dogs also hear very shrill notes, but large ones do not. At Bern, where there appeared to be more large dogs lying idly about the streets than in any other large town in Europe, Galton tried his cane-whistle on them for hours together but could not find one that heard it. Nearly all the little dogs he met would turn around.

Curiously enough the height to which we can hear depends on the strength of the sound. The results of specially made experiments are shown in Fig. 77. The figures at the bottom indicate the relative intensities of the blast of the whistle; thus the strongest tone used, 250, was five times as strong as 50, the weakest one. The figures at the left indicate the pitch of the highest

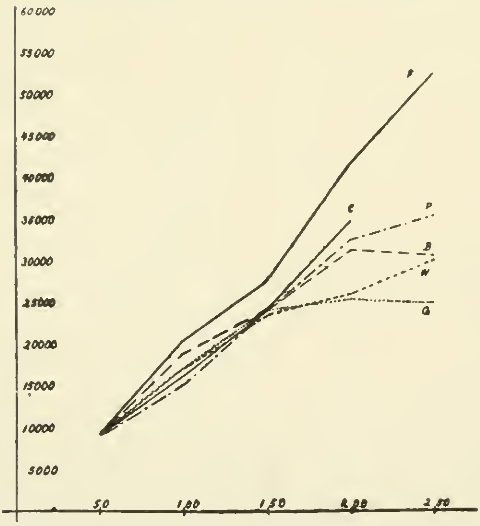


Fig. 77.—The Highest Audible Tone as Dependent on Intensity.

audible tone for six different persons. At 50 for the person F the tone was lost at 10,000 vibrations, all above that being unheard. At 100 he heard to about 20,000; at 150 to 27,000, etc.

Between the upper and lower limits of pitch the tones do not advance by steps as in the piano but continuously as in tuning a violin string. In other words, there is an unbroken range of tone, except for a few defective ears where portions of this range are lacking.

What is the least difference in pitch that can be noticed? Suppose that a violin is being tuned to another one or to a pitch-pipe, how nearly can we get it to an exact match? The fact that some persons cannot match tones as well as others is made plain by a few trials.

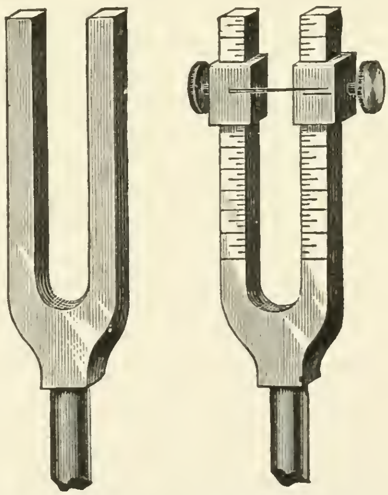


Fig. 78.—Forks of Adjustable Pitch for Finding the Least Noticeable Difference.

We wish, however, to get a measurement of the exactness to which we can judge tones, or, in other words, the accuracy with which differences between tones can be detected. This can be done by comparing a tuning-fork carrying an adjustable weight with one that remains always the same. As the weight is moved toward the ends of the prongs, the tone is lowered; as it is moved toward the stem, it is raised. Such a pair of forks is shown in Fig. 78.

The standard fork makes the same sound as the weighted fork when the weights are in the middle at 0. The standard fork is first sounded. Then after about three seconds the other is sounded. The person hearing them says at once whether he can detect a difference in pitch or not. If he says, No, the weights are moved a short distance toward the stem and the experiment is repeated. This is continued till he detects a difference, whereby the weighted fork is higher than the standard. This difference is called the least noticeable difference, or the threshold of difference.

Instead of a fork with adjustable weights a series of slightly differing forks can be used. To prepare such a series a dozen or more common tuning-forks all alike are obtained. The pitch of a fork can be raised by slightly filing the ends of the prongs; it can be lowered by filing the prongs near the stem. Select one of the forks as the standard. Strike the standard and another fork at the same time, making them sound more loudly by resting them on the table or holding them opposite the two ears. If they are in proper condition a single smooth tone will be heard. Now with a file slightly scrape the ends of the two prongs of the second fork, and sound them again. If the filing has been sufficient, the sound now heard will not be smooth and even, but will appear to wave between weak and loud; often the forks will appear to say, "wow-u-wow-u-wow-u," etc. This peculiar effect is called a beat. It is known that the number of beats in one second is the same as the difference in the number of vibrations in one second. By counting the beats for four or five seconds the difference between the two forks can be readily determined. If the second fork is too high in pitch, it is filed more at the ends; if it is too low, it is filed more at the stem. In this manner a whole set of forks can be obtained, differing by slight steps. For example, a convenient set is that of $A^1 = 435$ as a standard, with the other forks 436, 437, etc., as far as one has a mind to go. The preparation of such a series is somewhat laborious and, to fulfil all requirements, is somewhat expensive, owing to the large number of forks needed to provide for all ears from the finest to the coarsest. When the series is complete, the standard is compared with each in succession in the same way as with the adjustable fork until the just noticeably different fork is found.

Just as the threshold of difference is determined for a rise in pitch, so there is a threshold for a fall in pitch. The weights are started at the points where the two forks give the same tone. In successive experiments the weights are moved toward the ends so that the tone of the weighted fork is repeatedly lowered. Finally the difference becomes noticeable. This is the point at the threshold of difference downward in pitch.

As there is some difficulty in finding out just what the pitch of the fork is for each position of the weights, and as the performance of these experiments takes a great deal of time, a more convenient instrument, called a tone-tester, has been devised. It consists of an adjustable pitch-pipe B fastened to a plate A. To the regulating rod C a long arm D is fastened, which is moved by the handle E. As C is moved inward the tone of the pitch-pipe rises. As it is moved outward, the tone falls. Each movement makes a change

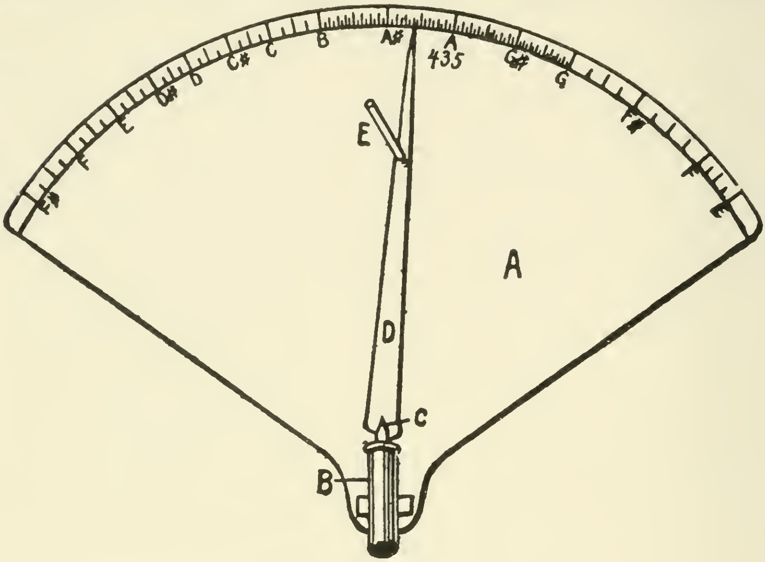


Fig. 79.—The Tone-tester.

in the position of the pointer. The tone-tester is compared beforehand with a carefully tuned piano to determine the position of the pointer when the pipe gives A of concert pitch. This position is marked at A 435 in the illustration. The figures mean that at this point the whistle makes a tone of 435 vibrations per second. In the same manner the succeeding notes are settled. The spaces are then subdivided by the eye into thirty-seconds of a tone.

To make the experiment, the pointer is placed at A and the pipe is blown for an instant. The pointer is then moved upward one mark, and after about two seconds the pipe is again sounded. The person experimented upon tells if he hears a difference. The experiment is repeated, starting with A every time, till a difference is heard. In a similar manner the difference below A is found.

In experiments made on a number of New Haven school-children the accuracy in detecting differences was found to increase with age. The results are shown in Fig. 80. The distance along the bottom indicates the age, beginning at six and ending at nineteen. The distance upward indicates the number of thirty-seconds of a tone that could be detected. The lower the irregular line is, the more acute was the hearing of the children.

Fig. 80.—Error in Hearing Decreases with Age from 6 years (at the left) to 19 years (at the right).

There is another and perhaps more important threshold to be found than the threshold of difference, namely, the threshold of change. Almost all the experiments of psychologists have been confined to the threshold of difference; I have lately called attention to this threshold of change and to the fact that it is an entirely different thing from the other.

The threshold of change can be illustrated by starting the tone at A and raising or lowering it continuously till a difference is noticed. I have succeeded in proving that the least perceptible change varies with the rate, as for pressure and temperature (pp. 80, 90), but have not been able to accurately determine the relation.

There is another mental fact closely related to the threshold of difference but not quite identical with it, namely, the accuracy of tone-judgment. Suppose we have two forks almost but not quite alike in pitch. If we sound them in succession, we sometimes detect the difference, sometimes not. It is evident that for the same pair of forks the sharper ear will detect the difference more frequently than the duller ear.

The experiment is performed in the following way. Three forks are provided; two of them are exactly alike, the third is slightly different. The person tested is seated with his back to the experimenter. The experimenter strikes two forks in succession; the person tested says at once whether they are the same or different. Suppose he says, Different; if they were really different the experimenter records one right answer. Suppose he says, Same; if they were really different the experimenter records one wrong answer. No record is made of the experiments with the two forks that are really the same, as they are introduced merely to avoid prejudice on the part of the person experimented upon. The experimenter finally counts up the total number of experiments with the two really different forks and the number of correct answers to these forks. For example, if there were twenty-five experiments in which the different forks were used and fifteen correct answers, the accuracy of judging this particular tone-difference can be stated for this particular person as $\frac{15}{25}$, or 60 per cent. With a greater difference between the two tones the percentage of correct answers will, of course, be greater. By using the same difference the relative accuracy for different persons can be ascertained.

The threshold differs greatly for different persons. Fine ears have been found that will detect a difference of less than half a vibration in tones between $B^0 = 120$ and $B^2 = 1,000$. Such observers can distinguish over 1,200 different tones within the octave B^1 to B^2.

On the other hand, it is not uncommon to meet persons who can hardly distinguish two neighbouring tones. In fact, one case is reported of a well-educated man who had been unable to learn music in any way. It was found that he could not tell the difference between any two neighbouring tones of the piano. Between the lowest tone and the highest he found a very great difference, but when the scale was run from one end to the other the change of tone appeared

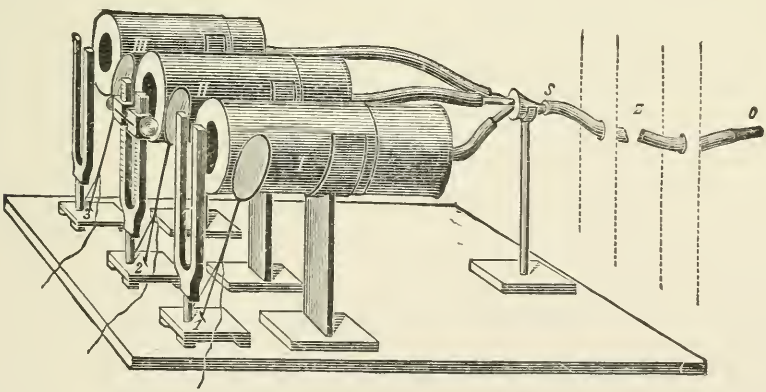


FIG. 81.—Apparatus for Finding the Middle Tone.

continuous and not by steps. In the middle regions of the scale he could not tell apart tones forming an interval less than a third; in the upper and lower regions the interval had to be a septime, an octave, or sometimes something still greater.

If a low tone be sounded, then a medium one, and then a high one, we can tell whether the middle one is half way between the two extremes or not. Musical instruments cannot well be used for this experiment as their tones are not simple but very complex; they introduce great errors into the result. By using tuning-forks perfectly pure tones are obtainable.

The arrangement for this experiment is shown in Fig. 81. Three tuning-forks, 1, 2, 3, are placed before adjustable boxes, or resonators, I, II, III. From each resonator a rubber tube leads to a general tube *s* which runs through double walls *z* to a distant room where the person experimented upon puts the end *o* to his ear.

In front of each box there is a movable cover which can be pulled aside by a string. Suppose the forks are sounding, the observer in the distant room hears nothing till one of these covers is pulled aside.

Fork 1 is selected as a low fork, fork 3 is selected as a higher one, and fork 2 is adjustable by weights. The forks are sounded in succession, 1, 2, 3 or 3, 2, 1. The observer tells whether fork 2 is properly adjusted to be in the middle or not.

The results indicate that our estimates do not follow the musical scale. For example, if the extreme tones be $C^1 = 256$ vibrations and $C^2 = 512$ vibrations, the middle chosen will on the average be $G^1 = 384$ vibrations. This is, counting by vibrations, just half way, but, according to our musical scale, it is nearer the upper tone. Likewise, if the extremes be

$C^1 = 256$ and $C^3 = 1{,}024$, the middle will be about $C^2 = 840$ and not $C^2 = 512$.

Let us now turn to a study of the intensity of tones. The first requirement is a tone whose intensity can be varied. The simplest plan is to use an electric tuning-fork with an induction coil (Fig. 82). A magnet between the prongs of the fork keeps it in motion electrically. The electric current is broken at every vibration of the fork. As it passes through the wire coil, it sets up electrical currents in the other wire coil near it. When a telephone is connected to this second coil, a tone can be heard by placing the telephone to the ear. This tone can be weakened by moving the second coil away from the first one.

Fig. 82.—Finding the Threshold of Intensity for Hearing.

The person to be tested puts the telephone to his ear. The second coil is placed far from the first; no sound is heard. It is gradually moved nearer till the tone is heard. The distance apart is noted. Then it is placed close to the first coil, a loud tone being heard, and is gradually moved away till the tone is lost. The average of the two results gives a figure for the deafness of the person.

For rough tests a watch is often used. The watch is steadily brought nearer to one ear (the opposite one being closed) till the tone is heard. The distance of the watch from the ear indicates the threshold for sound, or the degree of deafness. This method is very unreliable, the chief difficulty being the disturbance by outside noises.

A special notation has been invented to indicate tones. The first complete notation for pitch is attributed to Guido Aretino in the eleventh century. Three centuries later the notation for duration was introduced by Jan de Meurs. Naturally the presence of exact means of expression for these two quantities afforded opportunity for progress in the artistic execution on the one hand and for scientific research on the other. The subject of pitch has reached a high degree of development. The duration of tones is also a matter of technique that has been carried to a great degree of precision in practice.

We are all familiar with the staff notation for pitch and duration. Each note indicates a certain tone of a definite pitch lasting through a definite time.

The intensity of tones has been neglected; it must be remembered that we are not speaking of the semi-conscious use of the different degrees of intensity in the execution of a piece of music, but to a deliberate use of the shades of intensity. In music the consideration is confined to the five vague expressions, *ff*, *f*, *m*, *p*, *pp*. When a group of tones is to be made rather loud, put an *f* over it. How loud? just as the performer feels. All of the same loudness? just as the performer is inclined. Are all the tones without these letters to be of the same strength? just as the performer is disposed. These five vague grades cover only a few tones out of the thousands in a piece of music. The composer is powerless to give any indication of the wonderfully delicate shadings in the intensity of the different members of a group of tones; the performer is left without help. Two good performers on the organ will execute the same music with utterly different effects, because they do as they please with the intensity of the tones. Which effect did the composer intend? Nobody knows.

It is to overcome this difficulty that I propose a system of notes to include shades of intensity. Suppose, for the present, that we agree upon nine grades of in-

Fig. 83.—Method of Indicating Intensity in Notes; Loudest by Black, Weakest by White.

tensity between the weakest and the strongest the instrument is successfully capable of. Then we can introduce a system of shading the heads of the notes to indicate grades of intensity just as the heraldist uses shading to indicate colours. Such a system is shown in Fig 83.

The head of the note ought not to be used to indicate duration. In the present system duration is shown by the hooks on the stems of the notes, except in the case of the whole and half-notes, where a difference is made in the head of the note. This change in the head of the note is unnecessary for the indication of duration and can be employed to indicate intensity. A very slight change is thus necessary in the present notation; we can retain the usual method of indicating pitch and the usual signs for duration with the exception of the two for the whole note and the half-note. These can be indicated by two lines across the stem of the ordinary quarter-note for the whole note and one for the half-note. Consequently the series of notes as regards duration will be that shown in Fig. 84, representing the whole, half, quarter, eighth, sixteenth, and thirty-second notes respectively.

FIG. 84.—Series of Notes According to Duration.

Now we can use the head of a note to indicate its intensity, and even its form. Suppose we wish to indicate a half-note of medium constant intensity, we have ; or an eighth-note of loud intensity and staccato form, ; or a whole note, weak, but of crescendo form, .

Where are the tones we hear? With one ear closed the sounds we hear have no definite position. We know that a certain rattling must be down on the street, because waggons cannot be up in the air: the song of a bird cannot be under our feet. But a plain tone is nowhere, or rather, anywhere. Take a seat in this high-backed chair; let some one hold your head firmly so that you cannot turn it. Put your finger tightly in one ear and close your eyes. Now I make clicks with a snapper sounder, or I strike a glass with a spoon. Point to where the sound is. If I vary the intensity of the sound so that you cannot reason the the matter out, your answers are generally wrong.

By turning the head you can get an idea of the place because you know that sounds straight out sidewise are stronger than in any other direction.

Open both ears but keep the eyes closed. Now you can tell me just where the sound is. You draw, unconsciously, an inference from the relative intensity of the two sounds from the two ears. But whenever I snap the sounder equally distant from the two ears, you are always wrong. Imagine a sheet of glass passed through the body dividing it into two halves symmetrically. For all sounds in this plane you are utterly at a loss. I snap my sounder under your chin; you declare that it is behind your back. I snap it at your feet; you say it is in front of your nose.

CHAPTER XII

COLOUR

THE number of different colours that we can distinguish in nature probably amounts to several hundred thousand. Suppose we had all of them to arrange in a consistent system. We find among them a series of colours ranging from white through grey to black, that show no traces of red, green, blue, or other of the what we have been accustomed to regard as the specific colours. These are the "neutral" colours. With white at one end and black at the other all the neutral colours including the greyish whites, the medium greys and the greyish blacks would be indicated by points along a line (*WBk*, Fig. 85).

Fig. 85.—System of Greys or Neutral Colours.

Now let us pick out all the brightest and purest colours and arrange them by likeness. Beginning with red we put next to it a slightly different red, again a slightly different one, and so on; soon we find that we have passed to orange. From orange we pass to yellow, then to green, blue, and purple. If we use several hundred different colours, the differences between successive ones will be almost imperceptible. We note that beyond purple the colours become reddish until we

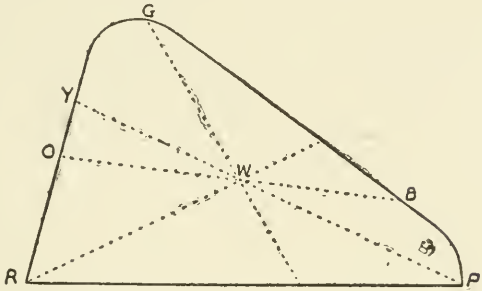


FIG. 86.—System of the Brightest Colours and the Tints.

reach the original red. Such a system of the brightest colours—or "hues"—might be a square or a pentagon or any other arbitrary closed figure. Let us choose the curve shown in Fig. 86; the reason for the choice will be given later. The letters on the curve indicate the colours, red, orange, yellow, green, blue, and purple. The term "violet" is often used instead of purple, but this is not recommended.

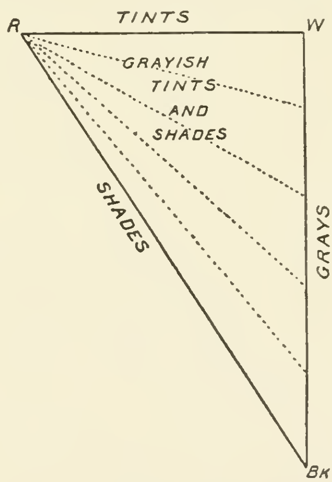


FIG. 87.—Systems of Greys, Shades, Greyish Tints and Greyish Shades.

The greys (Fig. 85) and the brightest colours (Fig. 86) are only a few out of the vast number before us. Starting with any colour, say red, we can pass by small steps through whitish red (or pink) to white without a trace of any other colour; such whitish colours are called "tints." We can do the same from orange, yellow, etc., or from any one of the brightest colours. To indicate this we place white in the middle of the closed curve (Fig. 86) and place each one of the tints on a line from white to its respective hue.

In a similar way we find "shades" of each colour passing imperceptibly to black, and finally "broken" tints and shades passing imperceptibly toward every degree of grey. Thus for red we would construct a diagram like that in Fig. 87. This we have to do for every hue.

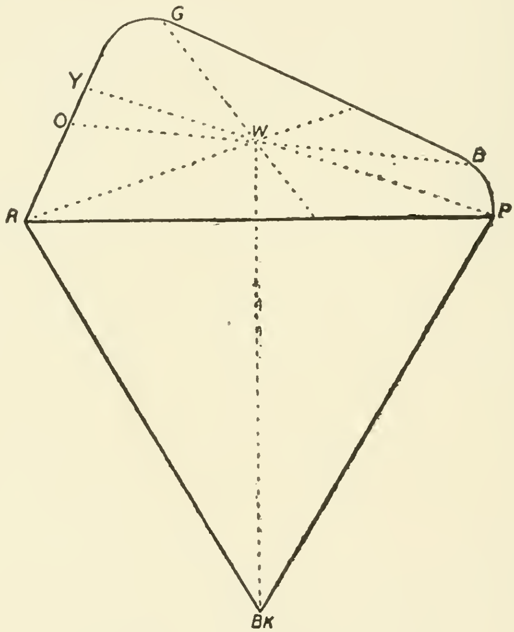


FIG. 88.—System of all the Colours.

The entire system of the colours will be represented by a solid figure (Fig. 88) whose axis is taken from Fig. 85, whose top from Fig. 86 and whose content is made uo of systems like that of Fig. 87 made for every hue. Each colour in nature will be represented by a point within this figure.

Many colours can be produced by mixture. This can be conveniently done by disks on a colour-top (Fig. 89), or a colour-wheel (Fig. 90). Each disk has a hole exactly in the centre, and a radial slit. To put two disks together they are slid over each other by means of the slits (Fig. 91). They are then placed on the axle of the top or the wheel and rotated rapidly. The colours combine for the eye. Different

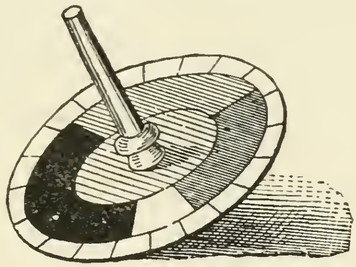


Fig. 89.—The Colour-top.

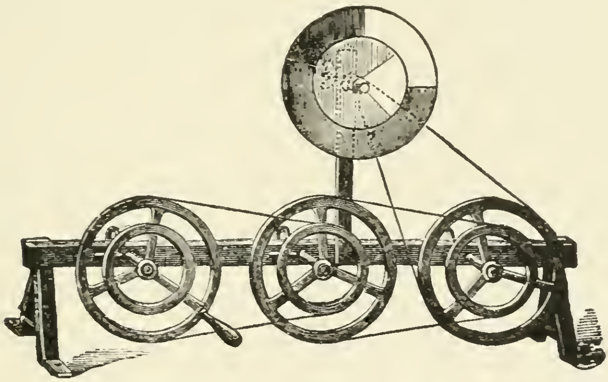


Fig. 90.—The Colour-wheel.

colours are produced by adjusting the proportions of the two disks that are exposed; when a desired colour is obtained, the amounts are read off by applying a scale (Fig. 92). Some colours require only two disks; others require more.

The greys can be produced by using white and black disks in various proportions.

The colours must now be accurately defined.

The standard white light is that which reaches the earth's surface at mid-day from the sun in a cloudless sky. A pure white pigment, that is, one that reflects the standard white practically untinged with any hue, is found in magnesium oxide; this can be readily pro-

FIG. 91.—Putting Two Disks Together.

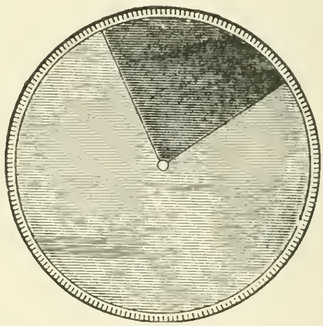


FIG. 92.—Two Disks with Scale.

duced by burning a strip of magnesium tape so that its white smoke is deposited on a piece of metal or mica.

When an opaque object is placed in front of a white surface, a grey shadow is produced; it becomes darker as the light is more completely intercepted. The interception of all light, as in a perfectly darkened room, leaves blackness. All objects, even the blackest, reflect some light; the nearest approach to a surface that will appear perfectly black when illuminated is attained by lining the bottom and sides of a cylinder with black velvet.

The purest colours—that is, the brightest hues with the least whitishness—are found in the spectrum. This is a band of colour that may be produced by placing a grating (Fig. 93) or a prism, in a beam of sunlight.

The radiations from the sun consist of vibrations of the optical ether. The spectrum comprises the vibrations between 760 and 380 millimicrons long. A millimicron is the millionth part of a millimeter.

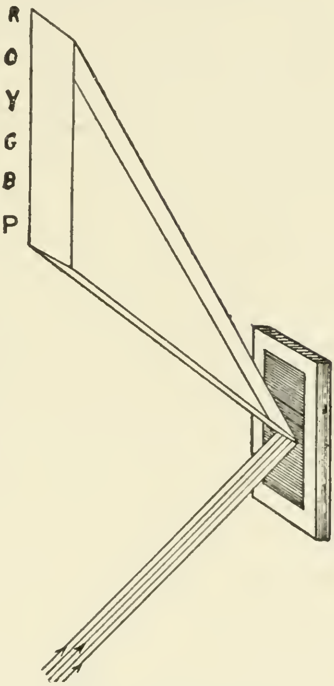


Fig. 93.—Spectrum from a Grating.

With the spectrum we can perform more accurate experiments in mixing colours than with the colour disks.

We must note the following results.

White can be produced by using any hue of the spectrum and one other hue in the appropriate intensities. Two hues that can be thus used are called "complementary colours." Some of the complementary colours are:

red	656	———	greenish blue	492
orange	608	———	blue	490
yellow	567	———	purplish blue	465
greenish yellow	564	———	purple	433

The figures indicate millimicrons. Fig. 86 is so constructed that complementary colours lie at the opposite ends of lines drawn through *W* and at such distances from *W* as indicate the amounts of each hue required for the mixture to make white with its complementary.

When colours not complementary are used, the results depend on the proportions. Red and yellowish green give all the variations through reddish orange, orange-red, orange, orange-yellow, yellowish orange, yellow, and greenish yellow. These colours lie on the straight portion at the left of the curve in Fig. 86. Red and purple give all the intermediate purples; these colours lie along the straight line at the bottom of the same curve. Red and green give all the variations through orange and yellow, but they are all whitish; they lie along a straight line drawn from red to green, which passes nearer to white than the line from red to yellowish green. To find what are the results of combining any two colours a line is drawn between their positions in Fig. 86 and the character of the resulting colours is noted.

Three colours can also be combined by disks or spectrum colours. The result is the same as if two had been first combined and then the third added. The position in the colour diagram of Fig. 86 is worked out in the same way.

By using three spectrum colours, red, green, and purple, we can produce nearly all the hues of the spectrum with fair approximation. This suggests that the system of colours may be reducible to three elementary colour-sensations. These sensations cannot be colours of the spectrum because the results of spectrum mixture are generally somewhat whitish.

The study of abnormal forms of colour vision known as colour blindness (see below) indicates that our three fundamental sensations are far more saturated colours than those we find in the spectrum; the green in particular is a far purer green than we ever actually see, the green of the spectrum being very whitish. The red is not very different from the end-red of the spectrum but the other colour is a deep indigo-blue and not a purple. These fundamental sensations find places in the colour diagram at the corners of the large triangle in Fig. 94.

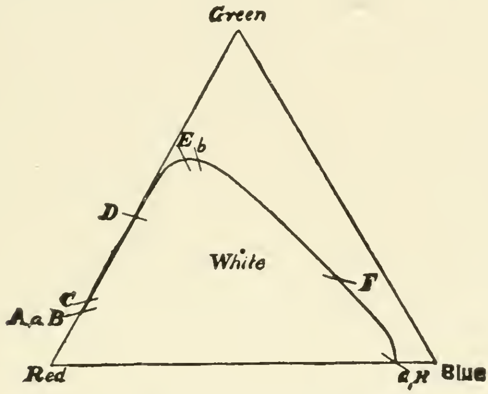


Fig. 94.—The Colour Triangle.

The combinations of pigments, such as paints, often give very different results from the combinations of the colours. If we mix the paints with which two paper disks have been coloured, a paper coloured by the mixture will never be of the same colour as the resultant from a direct mixture of the colours of the two disks by means of the colour-top.

This can be illustrated by a disk prepared as in Fig. 95. The shaded portions are to be painted with blue, the light portions with yellow, and the central portion with a green formed by a mixture of half blue and half yellow. When the disk is rotated, the blue and yellow directly mixed never produce green but a greyish colour with a blue or yellow cast.

When increasing quantities of yellow *paint* are mixed with the blue paint, the colour passes through various shades of bluish green, green, and yellowish green. When yellow and blue *colours* are mixed, the resulting colour passes through greyish blue, grey, and greyish yellow. With some blues the grey has a very slight greenish tinge.

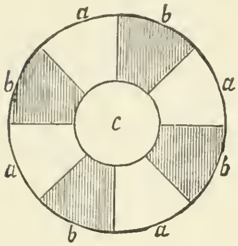


FIG. 95.—Mixing Yellow and Blue.

The reason why blue and yellow pigments give green can be illustrated by using blue and yellow glass. When two such pieces of glass are placed together, all light passing through both of them is green. Blue glass is blue because the glass absorbs the red, orange, and yellow light and allows the blue light to pass. Yellow glass absorbs the blue and allows the red, orange, and yellow to pass. Each of them allows a portion of the green to pass. When both of them are together, the blue keeps out the red, orange, and yellow, while the yellow keeps out the blue. Consequently only the green gets through.

Blue paints are blue because the minute particles of which they are composed send back to the eye mainly colours from the blue end of the series of hues. Yellow paints send back mainly those from the red end. Both send back some green. When they are mixed, the blue paint absorbs all the red end and the yellow absorbs all the blue end, leaving only green to be sent back. Similar results are obtained from the other paints; their mixtures are matters depending on their particular composition and not on their colours.

These accidents of the action of paints formerly led people to suppose that colours followed the same laws. Thus red, yellow, and blue were formerly called the fundamental colours. The artist often speaks of his paints as his "colours;" his laws of combination of the fundamental "colours" are quite correct, if by "colours" we understand paints. To avoid confusion with the other use of the word colour, it is preferable not to use it to mean paint or pigment. Red, yellow, and blue are the fundamental pigments, and red, green, and blue are the fundamental colours.

CHAPTER XIII

COLOUR SENSITIVENESS

WE are frequently called upon to distinguish small differences in colour; how accurately can we do it?

The colour-top furnishes one method of answering the question. Suppose we take as a definite question: How accurately can we judge the mixture of small portions of blue with a large mass of red? The little red disk is placed in the centre of the top; it remains unchanged during the experiment. The large red and blue disks are placed together so that a minute portion of the blue appears. The top is spun; no difference is detected. A little more blue is added and the top is again spun. This is repeated till the difference is noticed. The amount of blue can be measured by the graduated disk (Fig 92). Suppose it covers $\frac{10}{100}$ of the whole circle. The red must cover $\frac{90}{100}$, or nine times as much as the blue. Therefore we can add one part of blue to nine of red before the difference is detected.

The result depends upon the sensitiveness of the person. A dyer will detect minute differences that escape ordinary individuals; persons who have paid little attention to art are often incapable of detecting large differences.

There are persons for whom the hues of the spectrum can be approximately matched by combinations of less than three colours; such persons are commonly said to be "colour blind."

To show the differences in different persons two smaller disks, white and black, w and d, should be placed over the larger disks, R, G and B (Fig. 96). The white and black make a grey, and the larger disks should be adjusted to make a grey also. A finer adjustment is obtained by making both greys alike.

FIG. 96.—Getting the Grey Equation.

The relative proportions of w and d may be disregarded and grey in general may be indicated by m. Suppose one person gets

$$m\ [=60\ w+40\ d]=35\ R+30\ G+35\ B$$

and another

$$m=5\ R+45\ G+50\ B$$

It is evident that the second one is much less sensitive to red; in fact, such a person would be called red-blind.

Roughly speaking, humanity falls into four great classes: the trichromats; the dichromats of two kinds, and the monochromats.

Trichromats form about ninety-five per cent of the males and almost all the females. The colours they see can be produced by combinations of three fundamental colours, red, green, and blue. The relative proportions are indicated in Fig. 97.

The dichromats form about five per cent. of the males. The colours they see can be formed from two fundamental colours which we may call "warm" and "cold."

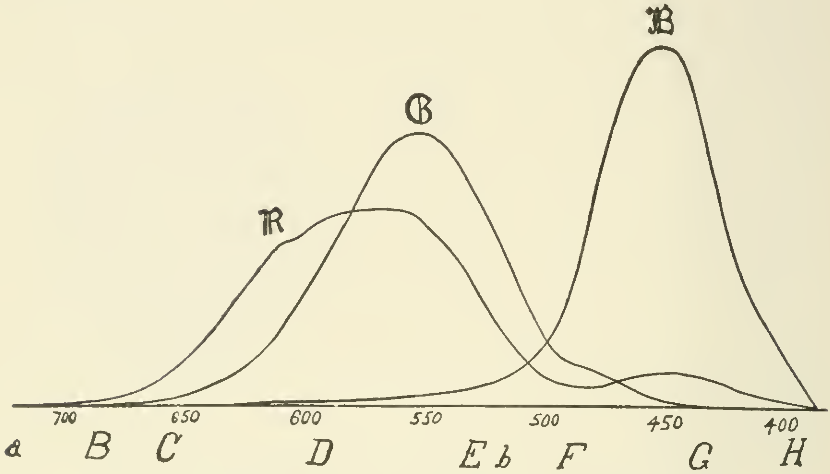


FIG. 97.—Trichromats. Proportions of the Fundamental Colours in the Spectrum Colours.

It may be regarded as settled that the "cold" colour is the same as the blue of the three-colour persons. The "warm" colour has been supposed to be green in one case and red in the other; the two-colour persons are therefore usually termed "red-blind" or "green-blind." It is probable, however, that the warm colour is yellow.

The proportions of the two fundamental colours, "warm" and blue, required to match the hues of the spectrum are indicated for the first form of dichromasy in Fig. 98. On the assumption that the warm colour is yellow the spectrum appears to begin with a dark yellow (700 millimicrons), change to bright yellow (600 millimicrons), pass through whitish yellow to white (500 millimicrons), then to whitish blue and blue (450 to 400 millimicrons).

For the second from of dichromasy the distribution of the two colours is shown in Fig. 99. On the

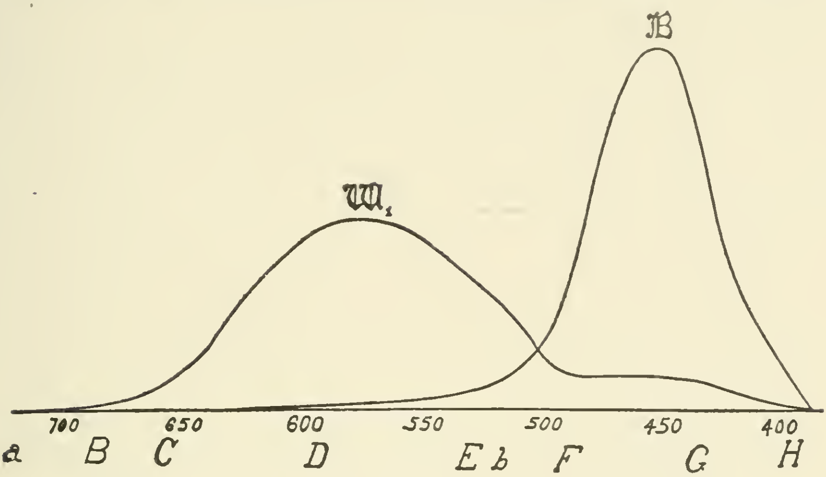


FIG. 98.—Dichromats of the First Class. Proportions of the Fundamental Colours in the Spectrum Colours.

assumption that the warm colour is yellow a large part of one end of the spectrum appears as a very dark yellow. The colour then changes to bright yellow (550), whitish-yellow, white (500), whitish-blue and blue (450).

Since all the colours of nature are derived from the solar spectrum, the dichromatic person sees the world as combinations of the two colours, yellow and blue; red, orange, and green are unknown sensations. The various colours that he has been taught to call by the names red, green, etc., are to him varieties of yellow. The strawberry and its leaves are both shades of yellow; a dark leaf cannot be distinguished from a berry. For the same reason a piece of sealing wax (red to the trichromat) appears of nearly the same colour as grass. An orange, a lemon, or a beet, differ only in shade from spinach. The two classes of dichromats differ in seeing these objects in different shades of yellow.

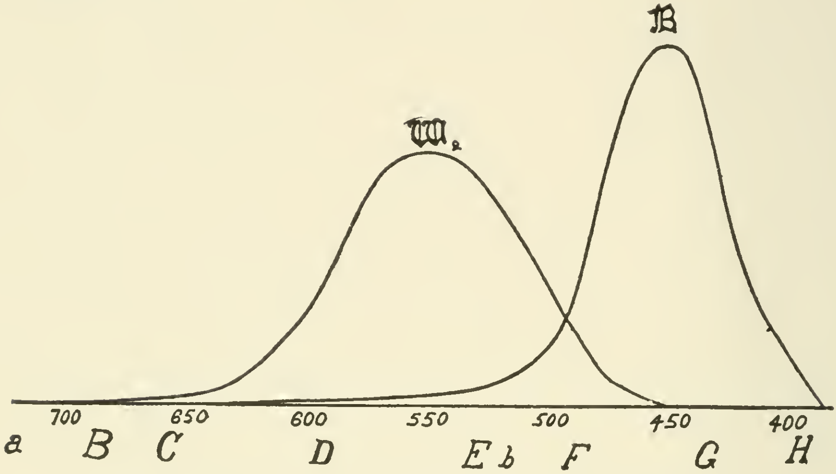


FIG. 99.—Dichromats of the Second Class. Proportions of the Fundamental Colours in the Spectrum Colours.

Three other forms of colour vision arise from the loss of one of the three fundamental sensations. The loss of green produces green-blindness. All colours are then seen as combinations of red and blue; the composition of the spectrum colours would be indicated by the diagram in Fig. 98 by changing 𝔚 to ℜ. The loss of red produces red-blindness. All objects are seen in combinations of green and blue; the composition of the spectrum colours would be indicated by the lines in Fig. 99 with 𝔊 instead of 𝔚. In blue-blindness all objects are seen in combinations of red and green; the composition of the spectrum colours would be indicated by the line in Fig. 97 with 𝔅 omitted. To the green-blind person the strawberry and its leaves are red; to the red-blind they are green; to the blue-blind they are red and green.

The persons usually designated as colour blind (green blind and red blind) are really dichromats of the first and second classes; the cases of real green-blindness, red-blindness, and blue-blindness, are rare.

The monochromat sees everything in light and shade, presumably grey. His world is to the world of most people what a photograph or an engraving is to the colouring of nature. These persons are quite rare.

One case is related of an architect's assistant who did not understand in the least what was meant by colour; he said that the colours appeared to him as simply shades of white and black. He had to use colours in preparing the plans of buildings but was guided by the name on the paint. One of the clerks once purposely scraped off the names and he used the colours wrongly. A friend of his had a house with dark oaken timbers and orange plaster. He asked, when looking at the house, why the plaster was so much darker than the wood. His friend told him that the plaster was very much lighter than the wood, but he refused to believe it. In a photograph which was afterwards taken the plaster came out much darker than the oaken timbers.

FIG. 100.—Monochromats. Proportion of the Fundamental Colour in the Spectrum Colours.

An idea of how the world appears to persons with various forms of colour vision may be obtained by considering how the American flag appears to them; this is indicated in the following table:

Trichromats:	red and white stripes;	white stars on blue field
Dichromats I:	dark yellow and white stripes;	" " " " "
Dichromats II:	black and white stripes;	" " " " "
Green-Blind:	red and purple stripes;	purple " " " "
Red-Blind:	black and greenish blue stripes;	greenish blue stars on blue field
Blue-Blind:	red and yellow stripes;	yellow stars on black field
Monochromats:	black and white stripes;	white " " grey "

Owing to their inability to distinguish red and green except as different degrees of yellow, the dichromats cannot be safely employed in many positions on railways and on shipboard. A red signal is generally used to mean "danger," green to mean "all right" (or "caution" in some cases) on the railway. On the water a red light is on the port side of the boat, a green one on starboard side; a pilot knows which way a vessel is sailing by seeing red or green.

The steamship *Isaac Bell* collided with the tugboat *Lumberman* near Norfolk, Virginia; ten lives were lost. The pilot of the *Lumberman* was afterwards examined and found to be colour blind; there was a rumour that the other pilot was also colour-blind.

The pilot of the steamer *City of Austria*, which was lost in the harbour of Fernandina, Florida, was proved to be colour blind. He mistook the buoys, and his mistake cost the owners $200,000.

Captain Coburn reports: "The steamer *Neera* was on a voyage from Liverpool to Alexandria. One night shortly after passing Gibraltar, at about 10:30 P. M., I went on the bridge, which was then in charge of the third officer, and competent in every way. I walked up and down the bridge until about 11 P. M., when the third officer and I almost simultaneously saw a light about two points on the starboard bow. I at once saw it was a green light, and knew that no action was called for. To my surprise the third officer called out to the man at the wheel, 'Port,' which he was about to do, when I countermanded the order, and told him to steady his helm, which he did, and we passed the other steamer safely about half a mile apart. I at once asked the third officer why he had ported his helm to a green light on the starboard bow; but he insisted it was a red light which he had first seen. I tried him repeatedly after this, and although he sometimes gave a correct description of the colour of the light, he was often incorrect, and it was evidently all guess-work."

A similar account is given by Capt. Heasley, of Liverpool: "After passing through the Straits of Gibraltar, the second officer, who had charge of the deck, gave the order to port—much to my astonishment, for the lights to be seen about a point on the starboard bow were a masthead and green light; but he maintained that it was a masthead and red, and not until both ships were nearly abreast would he acknowledge his mistake. I may add that during the rest of the voyage I never saw him making the same mistake."

The accidents due to colour blindness have been made quite uncommon by tests of all railway employees and mariners who have to do with signals.

The test employed in most countries is that of sorting coloured worsteds according to likeness. A light green skein is laid down and the person is told to pick out of a miscellaneous heap "all the colours like it." Names of colours are not used. If he picks out greys, brownish greys, yellows, orange, or faint pink, he has defective colour vision. Then a purple skein is laid before him. If he picks out grey or green, he is a dichromat of the first kind; if blue or purple, of the second kind. A red skein is then used; light greens and browns picked out as like this indicate the first kind of dichromasy; dark greens or dark browns, the second kind. Most cases of defective vision are detected by this test, but it fails in quite a number of cases; moreover the task of matching colours is so unusual for most men that some candidates fail from nervousness.

The well-known fact that many men of defective colour vision pass the worsted test may be illustrated by a letter published from an English railway man. "I have been on the railway for thirty years and I can tell you the card tests and wool tests are not a bit of good. Why, sir, I had a mate that passed them all, but we had to pitch into another train over it. He could n't tell a red from a green light at night in a bit of a fog."

The best form of test is one that copies as closely as possible the signal lights in actual use under the varying conditions of distance, dimness, fog, etc. A convenient apparatus for this purpose is found in the colour-sense tester, (Fig. 101) an arrangement of coloured glasses, like those of the signals, seen through various shades of grey glass and in various combinations. The instrument is placed before a light and the person is required to call off the names of the colours he sees, the colours being the simple ones, red, green, blue, yellow, etc. The person who makes no mistakes has a "safe" colour vision. This instrument detects cases of colour-weakness and dichromasy that pass the Holmgren test. One of my students could pass the Holmgren test perfectly and really distinguish the colours, yet he could not tell the difference between a red and a green light on a car more than two blocks away. Another student, who was known to be a dichromat, could not be caught by the Holmgren test. Both these cases, as well as others, revealed themselves at once with the tester.

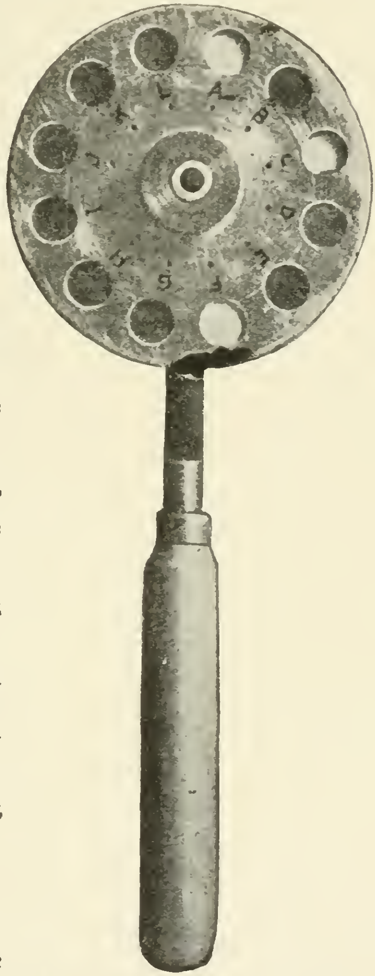


FIG. 101.—Colour-sense Tester.

The foregoing are the typical forms of colour vision. A considerable number of trichromats have a green sensation rather different from that of the majority; the colours of nature appear slightly different to the two classes. In getting the grey equation (Fig. 96) in a dark room illuminated only by sodium light (orange-yellow) I find 5 to 10 per cent. of my students to differ from the rest in the results. There are also forms of colour vision in which the red or the green sensation is weaker than usual; these may be said to be "colour weak." One of my students showed no defect in judging colours near by, but could not tell red from green at a distance. Such persons pass the wool test perfectly but are caught by the colour sense tester.

It is, of course, absolutely impossible for a colour blind person to obtain any idea how the world looks to other people. Everything appears to a dichromat as some variety of yellow, white, blue, and black; what red, orange, and purple are he cannot even imagine. Most such people become aware that they have a colour defect, but some will insist that it is simply due to lack of training in colours. One school superintendent maintained obstinately that two skeins of wool that he had classed alike were really somewhat different and that the fact that I thought them very different was due to a better training. To my eye, however, one skein was grey and the other green; to his they must have both been greyish tints of yellow.

Colour blindness is nearly always a defect of birth; it can never be remedied. About four in a hundred men are colour blind, but only about one in five hundred women. This has nothing to do with education in colours; it is simply a fact of sex.

Colour blindness is hereditary, passing along both lines but showing itself only in the males. Among the Quakers, the proportion of colour blind persons has long been about one-half greater than among other people. Nearly every Quaker is descended on both sides solely from a group of men and women who separated themselves from the rest of the world five or six generations ago. One of their strongest opinions is that the fine arts are worldly snares; their most conspicuous practice is to dress in drabs. It is possible that many of the founders of Quakerism happened to be colour blind; it is more probable that the doctrines directed against bright colours and works of art would repel persons of normal vision and attract the colour blind proselytes. In fact, the enthusiasm of most people for paintings, stained-glass windows, bright decorations, and the like, must appear utterly unreasonable to the colour blind. The productions of many of our artists must appear actually hideous to the colour blind persons who cannot tell the difference in colour between a strawberry and its leaves. Such people would be likely to join a sect maintaining the doctrine that such things are wasteful or sinful. Again, the desertions from Quakerism would naturally be of persons in whom natural instincts and abilities were stronger. Dalton, the discoverer of colour blindness, was a colour blind Quaker. It is said that he consented to receive an Oxford degree only when he was assured that the bright scarlet hood that he would have to wear would be replaced by a sombre one. It is related of a prominent Quaker that he returned from town one day with a bright red tie, a perfect abomination to his family. It spite of the trouble aroused, it was not a case of heresy but merely of colour blindness.

A colour, as we see it, depends on the colour of the neighbouring objects. If two designs are executed in the same grey, they will appear different if the grounds are of different colours. If the grounds are red and yellow respectively, one ornament will appear somewhat green and light, the other somewhat blue and dark. The effect is increased by placing tissue paper over them. Yet both greys are exactly alike. The colour of the surrounding ground affects the grey.

Bits of grey paper laid on coloured paper show the same result. If the coloured paper is tipped so that the small piece slowly slides off, the coloured tinge of the grey can be seen to slip off as the paper goes over the edge.

This influence of one colour over another is called "contrast." The effect of the influence of a colour is to spread the complementary colour in its neighbourhood. Place a small piece of grey paper on a piece of coloured paper. When a piece of tissue paper is laid over the whole, the grey paper appears distinctly coloured. The tissue paper is used to whiten the colours, the result being greatest with whitish colours.[1] Disks to illustrate contrast can be prepared as in Fig. 102, where the lined portion is to be coloured. When such a disk is spun, the ring formed by the mixture of the black and white should be grey; it is, however, the colour complementary to the colour on the other portion.

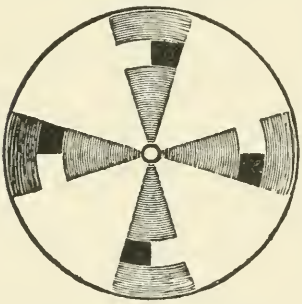


Fig. 102.—Disk to Illustrate the Effect of Contrast.

[1] When two small bits of grey paper are laid on the two colours in the frontispiece and covered with tissue paper, they will appear tinged with purplish pink and pale blue.

Plain red, purple, and blue woven cloths were on one occasion given to manufacturers for ornamentation with black patterns. When the goods were returned, the complaint was made that the patterns were not black; those on the red were decidedly greenish, those on the violet were dark greenish yellow, and those on the blue were copper-coloured. By covering the cloth in such a way as to expose only the patterns without the colours, they were seen to be truly black. It was an effect of contrast.

The colours that we see are not constant; they vary through fatigue. Look steadily at any coloured surface, for example, the last figure in the Frontispiece, for a while; then rest your eyes by winking; on opening the eyes you will notice that the colour seems brighter.

Now look *steadily* at the adjacent black square (Fig. 103) with white circle for twenty seconds; then look at a plain white surface. You will see a square of *brighter* white while the circle will appear like the white of the paper. The white around the original square and the circle had fatigued the eye while the black portions had rested it; on looking at plain white paper the whiteness was brighter over the unfatigued part; therefore the square appeared whiter than the rest of the field of vision.

FIG. 103.—Figure for After-Images.

Look steadily at the last figure in the Frontispiece for twenty seconds; and then at a plain white surface You will see a purplish pink oblong. Why? The green oblong had fatigued the eye for that colour. When the eye looks at a white surface, it is not equally sensitive to the red, green and blue that compose white; removing the green leaves red and blue, and these combined produce purple. On the oblong you will see two pale blue stars. Why? Since the green was not very bright it did not entirely fatigue the eye for that colour and so some of the green light from the white paper had an effect; this mixed with the purple produced purplish pink. Experimenting with red, yellow, blue and purple in a similar way you will see their "after images," which are bluish green, blue, yellow and green respectively. The "after images" have, therefore, colours complementary to the originals.

CHAPTER XIV

SEEING WITH ONE EYE

LET us look at the world with only one eye. What we see consists of patches of colour arranged in wonderfully complicated forms. It is our duty to determine some of the laws of this arrangement.

The first fact that strikes us is that we are looking at some particular point. This is the "point of regard." In looking at this dot ● your point of regard is the dot. As you read onward, your point of regard changes from one letter to another. If you look at a person on the street, the point of regard is that person.

Keeping the eye steadily looking at the dot, notice that you can read the words close around it although they are somewhat blurred, and that, although you can see over a whole region, including the page and part of the room, all this region is quite indistinct. The fairly clear part around the point of regard is the region of distinct vision; the blurred part is the region of indistinct vision. The whole region seen is called the field of vision.

The boundaries of the field of vision are determined by moving objects from outside the field toward it till they are seen, and by moving them from the centre outward till they disappear. The subject of the experiment is seated in a chair; one eye is closed; the other looks, without moving, straight ahead at a spot. The experimenter places a small piece of white paper on the end of a knitting-needle or a stick, and starting behind the subject, slowly pushes it forward at about one foot from his head till he catches sight of it. The paper is then started where it is seen and is drawn back till it disappears. This marks the limit of vision in that direction.

The limits of the field of vision are determined and recorded rapidly by means of perimeters. One form is that shown in Fig. 104. The small piece of paper is moved out along the curved arm in one direction till the limit is found. The arm is placed in various positions and the experiment is repeated. The number of degrees is read off each time and is marked on a chart. A line drawn through these points indicates the boundary of the field of vision. An average eye will have a field extending outward (*i. e.*, away from the nose) about 85°, inward 75°, upward 73°, downward 78°.

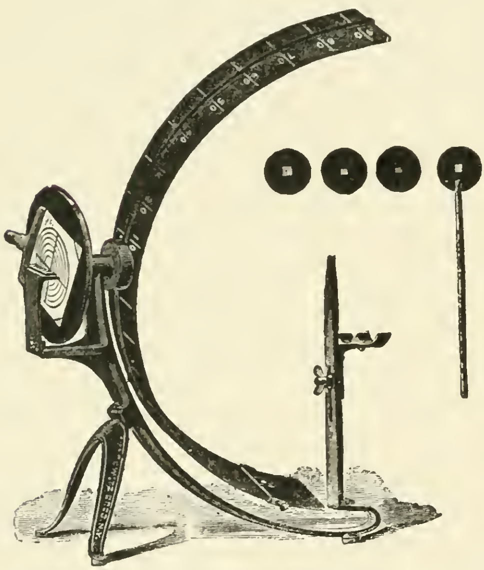


Fig. 104.—Perimeter, for Measuring the Field of Vision.

If the experiments on perimetry are made with coloured objects, it will be found that in a narrow region along the edge of the field of vision the person will see the object without seeing its colour. In fact, in this region we are all totally colour blind; we see everything in an indefinite grey colour.

Inside this one-coloured border the object takes on a colour, but the colour is seldom the same as that which it has when seen directly. The limits at which

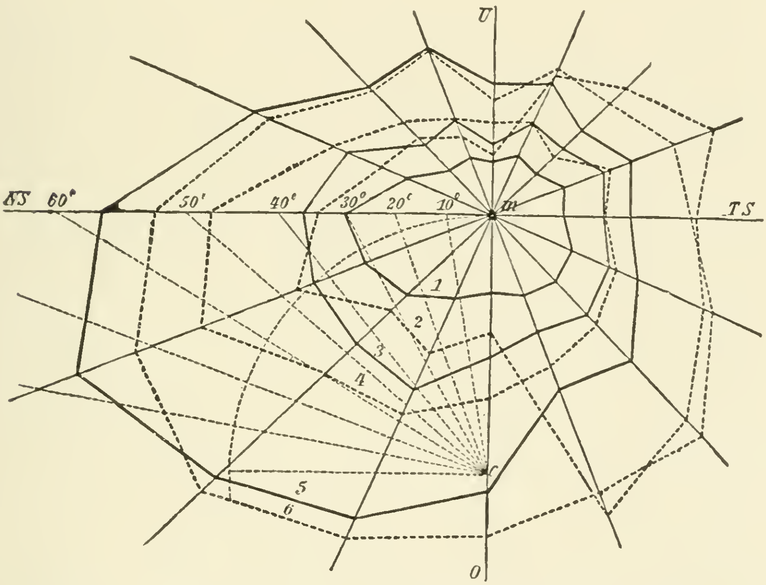


FIG. 105.—Perimeter Chart. Limits beyond which the Colours Disappear: 1, Violet; 2, Yellow; 3, Green; 4, Red; 5, Orange; 6, Blue.

objects of various colours lose their "true" colours, *i. e.*, the colours when directly seen, are indicated for a typical person in Fig. 105.

Curiously enough, the field of vision with children is apparently not so great as with adults. They cannot see over so much for any position of the eye. The reason probably is that they are incapable of attending to the outer regions; they confine themselves to the region near the point of regard.

In the field of vision there is one place at which nothing is seen; this is called the blind-spot.

With the left eye shut, hold the book at arm's length and look with the right eye at the cross in Fig. 106 The letters are also seen indirectly. Bring the book slowly toward you, keeping the eye fixed on the cross. At about a foot from the eye the B will disappear

Fig. 106.– Diagram for Finding the Blind-spot.

entirely. If the book is brought still closer, the B will reappear, but the O will disappear, leaving a blank space between A and B. To try the left eye hold the book upside down. There is therefore one portion of the field of vision on which you are absolutely blind. This is called the blind-spot.

Although man and his animal ancestors have always had blind-spots as long as they have had eyes, these spots were not discovered till about two hundred years ago, when Mariotte caused a great sensation by showing people at the English court how to make royalty entirely disappear.

The blind-spot can be drawn directly on paper by keeping the eye fixed on the cross while a pencil is moved from where it cannot be seen outward till its point is just seen. In this way a dotted boundary line for the spot is obtained. The blind-spot lies to the temporal side (opposite the nose) of the point we are looking at. It corresponds to the place where the optic nerve enters the eye. It covers a region equal to the face of a man seven feet distant, or eleven times the size of the full moon.

What do you see at the blind-spot? Everything disappears that is put in the region covered by it. Yet there must be something there; for, if the O in Fig. 106 be made to disappear, the letters A and B are no nearer together than when the O is seen. The blind-spot must be seen as white, for the whole region appears unbroken. Yet if this experiment is made on coloured paper the whole region is of the same colour. Papers or cards of various colours can be readily prepared to illustrate this. We are thus forced to the conclusion that although we are blind over this region, we fill out the lacking space by an unconscious act and that it is filled out in accordance with the surrounding region.

Let us, however, try to puzzle the blind-spot. A card is prepared with a white circle on two colours as shown in Fig. 107. Let the white circle fall on the

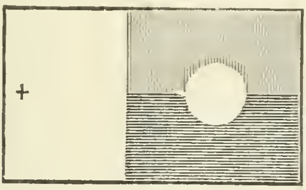


Fig. 107.—Putting a White Circle on the Blind-Spot.

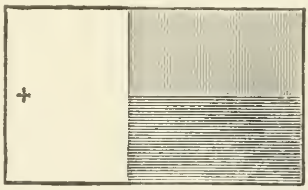


Fig. 108.—The Circle is Replaced by the Colours.

blind-spot. The card will appear as in Fig. 108 (see Frontispiece).[1] Try a card coloured as in Fig. 109

[1] The coloured diagram for Fig. 107 is given as Fig. A. of the Frontispiece. Hold the book lengthwise about a foot from the

If the circle falls on the blind-spot it will be filled out as in Fig. 110.

Now try a card like Fig. 111, with the two bands in different colours. At last the spot is puzzled. One moment the horizontal band will run across the vertical one; at another the vertical will run across the horizontal. Sometimes after many trials the spot seems to despair and the person owning it declares that he really sees nothing there.

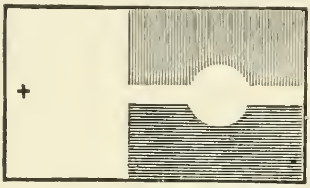


Fig. 109.—What Will Happen Now?

In looking at a printed page the portion that falls on the blind-spot appears to be printed with indistinct letters, as though it were pretending to read.

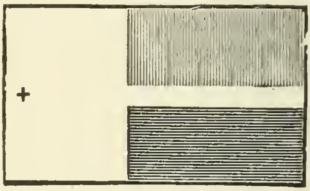


Fig. 110.—The Result.

It is noteworthy that the space around the blind-spot is not contracted. If the circle in Fig. 107 falls on the blind-spot, the sides of the figure are no nearer together, although quite a space has apparently been removed.

---

face. Close the right eye. Look steadily at the + on the right hand side of the page. Bring the book slowly nearer till the letter A disappears. Then move the book slowly nearer or further till the entire white circle disappears. It will be replaced by orange and green as indicated in Fig. 108. Holding the book in the same way, close the left eye and look steadily at the + on the left. Move the book until the circle around the letter B disappears. The result will be as indicated in Fig. 110. The coloured diagram for Fig. 111 forms the middle of the Frontispiece. With the left eye closed C′ is observed; with the right closed, C″. The book is brought near until the middle of the cross disappears. The diagrams appear blurred because they must be held so near the eye on account of their smallness.

The last figure in the Frontispiece shows an interesting illusion. When we look with one eye—or with both eyes—steadily at the white dot D, we see the orange stars at first but finally one disappears and is replaced by the green of the field. Sometimes both disappear. The star returns again for a while and then disappears. This is repeated as long as the figure is observed. The disappearance may not be apparent at first to the observer because he finds difficulty in looking steadily at D while watching the stars. He should stare as in reverie, and repeat the experiment a number of times. My explanation of the phenomenon is that the orange stripe fatigues the eye, producing a temporary blind-spot, which is filled according to the usual principle.

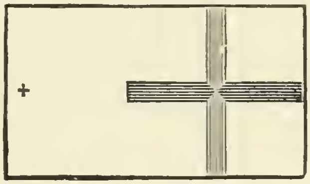


Fig. 111. A Puzzler for the Blind-Spot.

We notice that what we see with one eye "occupies space." Let us notice some of the peculiarities of this "monocular space."[1]

Put a blank sheet of paper on a board and place a dot in the middle. Holding it directly in front of the eye so that the dot is at the point of regard looking straight forward, draw four apparently equal lines, as indicated in Fig. 112. On measuring them the vertical one above the dot will be found shorter than the vertical one below. Both will be shorter than the horizontal lines; the horizontal lines will generally be equal. We can

[1] More extended treatment of the facts of monocular and binocular space is to be found in the various books on psychology; I have given special attention to them in my *New Psychology*.

thus conclude that space above the point of regard is overestimated as compared with space below; that space in the vertical direction is overestimated as compared with horizontal space; and that horizontal space inward or outward is about the same. This explains why *c* and not *b* seems the continuation of *a* in Fig. 113.

Placing a dot on the paper in the same way, draw a square around it. By turning the square sidewise you will see that you have really made it too short. Turn this book upside down. What do you notice in regard to the letter s and the figure 8? Why are they made so?

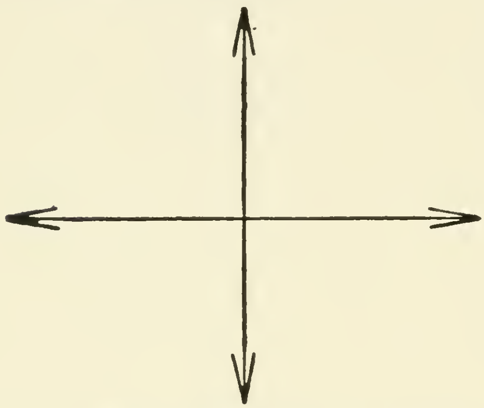


FIG. 112.—What the Eye Considers to be Equal Distances.

When the point of regard moves upward it has a tendency to move outward; when it moves downward, it moves also inward. Looking at the edge of the room, you will notice as you look rapidly along it toward the ceiling that the whole edge seems to tip sidewise. With the right eye it tips toward the left, with the left eye toward the right. As you look rapidly downward toward the floor, the edge appears to tip in the opposite direction. This tipping is very dis-

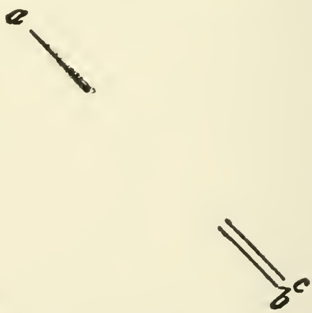


FIG. 113.—Which is the Continuation of *a*? Why?

agreeable in the cities of tall buildings. If you happen to look at them from one side of the eye, they seem to

Fig. 114.—Illusion of the Interrupted Distance.

be leaning dangerously over the street; if from the other, they seem to slant back as if disdaining the streets below them. The amount of this tipping in the eye can be measured. Rule a horizontal line on a sheet of paper; then lay the edge of the ruler across it at what you judge with one eye to be a right angle

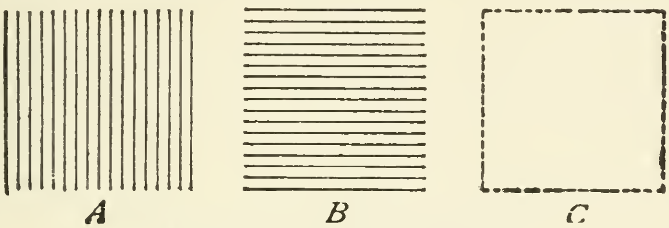


Fig. 115.—The Distorted Squares.

and draw the line. On another sheet of paper do the same for the other eye. Your two right angles will disagree to a small extent.

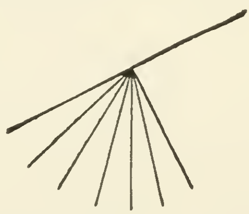


Fig. 116.—The Enlarged Angle.

Distances are judged by the difficulty in traversing them; if the road is hard, or if you make many stops by the way, it is much longer than otherwise. The distance between the two dots A and B in Fig. 114 is apparently greater than that between B and C. The intervening dots are like tempting seats by the wayside. The journey is really made harder and apparently longer because your attention is caught at each one. For the same reason the square A in Fig. 115 appears too long and B appears too tall. Fig. 116 shows the same illusion for angles.

Fig. 117.—Illusion of Filled Space.

It is evident from these facts why women like to have as many bows, ribbons, buttons, etc., as possible on the dress. The more the surface of the dress is broken up, the taller the person. The illusion is heightened by the diversity of colours employed.

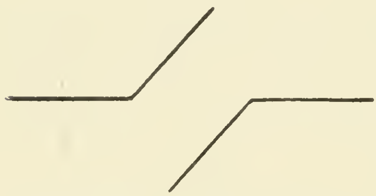


Fig. 118.—Displacement by Inclined Lines.

The open distance in Fig. 117 is apparently less than the line-distance. It is harder to walk on a straight and narrow path than to go as you please; you may go perfectly straight anyway, but with no directing line you are free from constraint.

In viewing two lines meeting at an angle, the smaller angle is overestimated as compared with the larger. The effect is to press the sides of the smaller angle outward. It is a general law of mental life that small things are thought greater than they are in comparison with large ones. The two horizontal lines in Fig. 118 do not seem to be parts of the same straight line because the acute angles are overestimated and the lines are apparently bent from the horizontal. A striking method of showing this illusion is to draw a horizontal line on a slate and then after drawing two inclined

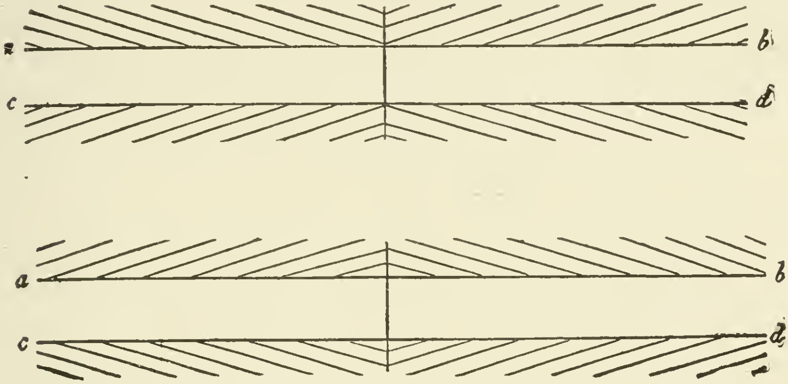


FIG. 119.—Breaking Parallel Lines.

lines, as in the figure, to erase the middle portion. In spite of the fact that the two horizontal lines are known to belong to the same straight line the illusion is

FIG. 120.—Tipping Parallel Lines.

irresistible. This tipping of a line in the direction in which an acute angle points is intensified when a number of angles are made, as in Fig. 119. The top line, for example, has acute angles above it which tip

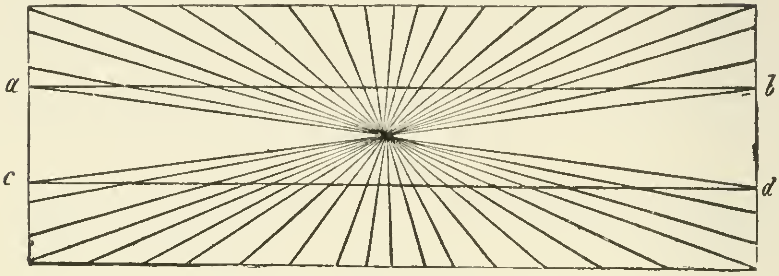


FIG. 121.—Bending Straight Lines.

it downward toward the ends. The second line is affected in the opposite way. The horizontal lines are really parallel. See also Fig. 120. A continually increasing change of direction is shown in Fig. 121. The two horizontal lines appear curved. The illusions in Figs. 122, 123, and

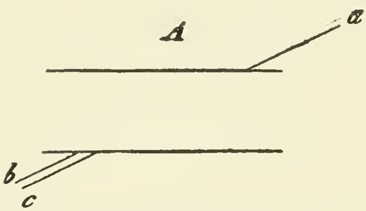


FIG. 122.—Which is the Continuation of *a*? Why?

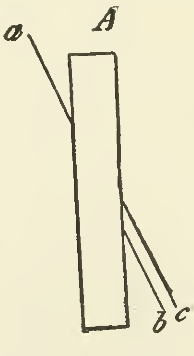


FIG. 123.—Continuation of *a* seems to be *c*. Why?

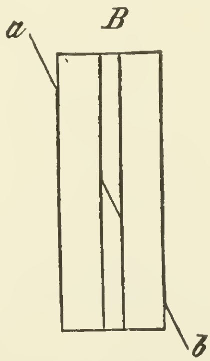


FIG. 124.—Why?

124 arise from the same phenomenon combined with that illustrated in Fig. 113.

All the illusions from Fig. 114 to Fig. 124 can be explained by the law that the apparent size of an object depends on the amount of attention it receives. The interrupted distance receives more attention and is therefore mentally greater. An angle includes a space and two inclosing lines; diminishing the amount of space does not diminish the amount of attention required for the inclosing lines.

Fig. 125.—Changing the Length of a Line by Different Cross-lines.

There is still another class of illusions resting on a mistake of attention. The vertical lines in Fig. 125 are all of the same length, although apparently quite different. The reason for this illusion appears most clearly in the coin illusion (Fig. 126). For this illusion a person is required to place three coins in such a way that the distance between the left hand edge of one end coin and the right hand edge of the middle coin is the same as between the right hand edge of the middle coin and the left hand edge of the other end coin; in other words the distance between the opposite sides of the two left hand coins is the same as the distance between the adjacent sides of the middle and right hand coins. The arrangement in Fig. 126 appears about correct, but measurement shows 4^{cm} ($1\frac{5}{8}$ inches) for the distance that includes the coins and $2\frac{1}{10}^{cm}$ (1 inch) for the empty distance. The explanation is that although we think we are attending to points on the edges of the coins, we are really thinking considerably of the whole coin; we consequently arrange the coins as if we were adjusting for points much inside of the edges. Likewise in

Fig. 126.—The Coin Illusion.

Fig. 125 we are really using the areas inclosed by the slant lines instead of the points at the apexes.

The appearance of Fig. 127 depends entirely upon attention. At one moment it appears like a stairway, at the next like an overhanging cornice. The picture

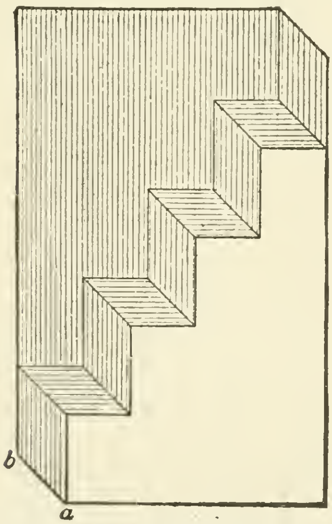


Fig. 127.—An Overhanging Cornice or a Stairway?

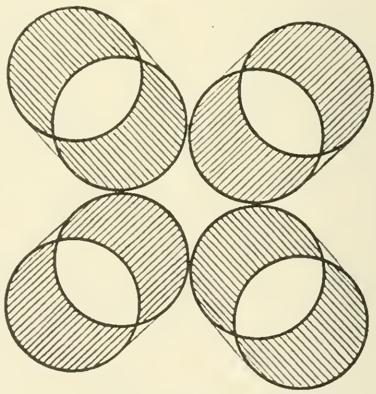


Fig. 128.—The Changing Rings; Which is the Front End of the Rings?

is itself flat; the relief is due to suggestion. As there are two conflicting suggestions, one or the other prevails accordingly as we attend to it. Similar illusions are numerous; one other is shown in Fig 128.

Up to this point nothing has been said about the depth or distance of objects. Is the world of one eye a flat surface?

On entering into a strange house with one eye bandaged, it is difficult to obtain an accurate idea of the distance of objects. The whole place seems almost flat. Looking out of a window with one eye, the view appears almost as if painted directly on the window-pane.

We know from experience that objects decrease in size as they recede. From the rear platform of a railway train, the houses, signals, persons, tracks, etc., can actually be seen to shrink together. If we know the actual size of an object we can estimate the distance; if we know the distance we can estimate the size.

In estimating the distance of unknown objects we are guided greatly by the view of the ground in front of them. Thus a tree seen down the road can be roughly estimated in height because the objects along the road afford an indication of the distance.

Since our opinion of the size of an object depends on the apparent distance, any illusions of distance will produce illusions of size.

The fact that subdivided distance appears greater than undivided distance was illustrated in Fig. 114. In looking toward the horizon, the glance meets innumerable objects that break up the space, whereas in looking directly upward we find a perfectly clear space. Consequently objects in a horizontal direction appear more distant than objects in a vertical direction.

For this reason the sky does not appear like the inner surface of a ball, but like the under side of a watch-glass. The amount of this flattening is readily determined. Stars lying 23° above the horizon are

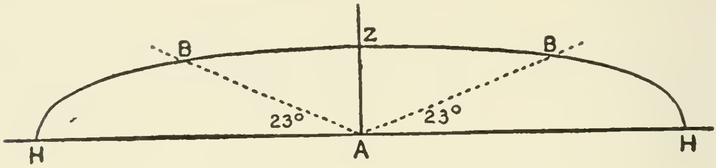


FIG. 129.—Shape of the Sky.

apparently half way toward the top. In Fig. 129 you are standing at A. Lines are drawn from A at an angle of 23° to the flat ground HH on which you stand. The sky must therefore appear of such a shape that a line drawn from H to B is half the distance from

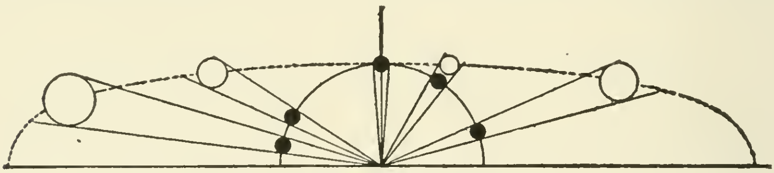


FIG. 130.—The Moon Illusion.

H to Z. Such a surface is indicated by the curved line.

Owing to the apparent shape of the sky, the moon appears to be much further away when it rises than it does when it is overhead with nothing between. The moon is seen by the eye as the same in both cases, but the moon near the horizon is apparently larger because it seems further away.

Another means of judging distance is found in shades and shadows. With one eye closed and with the back to the light, hold a mask, preferably painted inside, so that the seeing eye looks directly into the inside. If no shadows are cast, the eye is unable to tell whether it is looking at the inside or the outside. The nose will at one moment appear to be a hollow nose pointing away from the observer and at the next a solid nose pointing toward him. But the moment a shadow is allowed to fall by a change of light, the eye knows at once that the hollow side is turned toward it.

Another influence regulating our estimate of distance and therefore of size is the unclearness of the air. The air nearly always contains a quantity of mist which makes objects bluer and more indefinite as the distance increases.

In perfectly clear air, such as is common in the dry regions of the Rocky Mountains or in portions of Maine and Canada, the distance of objects is often quite a puzzle. A canoeist on a lake in such an atmosphere cannot tell whether an island in front of him is one mile or ten miles away.

The coast-dweller is subject to the opposite illusion in the mountains, and innumerable tales are told of travellers who start for a before-breakfast walk to a neighbouring hill which is really twenty miles away.

Those who have come into a cloud while ascending a mountain will remember that a small wood-pile looks like a barn, a cow appears larger than an elephant, men are giants, etc. Painters use "atmosphere" to show the distance of objects in a landscape.

There are also illusions of both size and distance due to association. Clocks and flags on towers appear much smaller than they really are, because we are accustomed to house clocks and moderately sized flags.

The clock of the Battell Chapel as seen from the Yale campus at a distance of two hundred feet appears about two feet in diameter; its actual size is ten feet.

A tall object casts a longer shadow than a shorter one. During the greater part of the day the shadows cast by the sun are of moderate size, but early in the morning or late in the evening they become enormously large. This exaggeration we cannot resist, and so at those times trees and houses appear much taller than usual.

There is another influence to which I think no one has ever called attention, namely, the emotion produced by the object. In dim light, as at night, most persons feel an indefinite uneasiness, which in nervous persons and children often actually amounts to fear and terror. This uneasiness and fear exaggerates the size of the object. On a dark night the mountains around an inclosed lake, *e. g.*, the Lake of Como, assume an overwhelming aspect and appear far higher than in broad daylight or in pleasant moonlight. The stories of frightened children are not exaggerations, but true comparisons of the apparent sizes of terrifying and non-terrifying objects. A similar reason may explain the "snake stories."

CHAPTER XV

SEEING WITH TWO EYES

WHEN the eyes are opened and closed rapidly in succession, objects seem to form different pictures for the two eyes. When both eyes are opened, a third view is obtained. The world as seen with the left eye differs from the world as seen with the right eye; the world as seen with both eyes is again a different matter.

In our usual experience we see the world as a single world, although we have two eyes that see differently. When we lose control over our vision, as in a state of intoxication, the two eyes are liable to act independently and things are seen double.

The view with the right eye is what would be seen with the left eye if it were moved a short distance to the right, and likewise the left eye sees what the right eye would see if moved toward the left. The pictures differ only in the point of view.

Fig. 131.

Fig. 132.

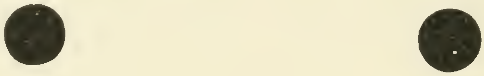
The view with both eyes has a relief, a rotundity, that is wholly lacking in the one-eye views.

In looking at a book with the right eye we get the flat view as in Fig. 131; with the left eye we get the flat view as in

Fig. 132. But with both eyes the book appears in relief. We imagine we see the book as in Fig. 133. What we really see is shown in Fig. 134.

This union of two different flat views into a single solid view is the fundamental fact of two-eyed seeing, or binocular vision. The union is unconsciously performed and is irresistible. Let us trace the process step by step.

Holding the head directly above these two dots, let



the eyes stare as in reverie, *i. e.*, looking far behind the paper. Four dots will be seen, each eye seeing two dots. If, however, you look at some imaginary object not far behind the paper, the two middle dots will come together. There will then be three dots, the middle one being a combination of one dot from each eye. This can be very plainly seen by sticking the two dots on a window-pane or a piece of glass; when you look at some object at a proper distance beyond the glass, the two middle dots fuse together.

Fig. 133.

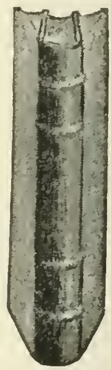


Fig. 134.

After the union of the two middle pictures into one the two outer ones are still seen. To be rid of these outside pictures all that is needed is to place a strip of paper from the nose to the middle point between the two dots. This makes it evident that the single dot seen is a compound of the dot from the right eye with the dot from the left.

Exactly the same fact is illustrated in Fig. 135 where the problem is to put the bird in the cage. A visiting card is placed from the line A to B to the nose, the eyes are relaxed and the bird goes into the cage without difficulty.

Most persons find it tiresome or difficult to observe views in the way just described. The presentation of

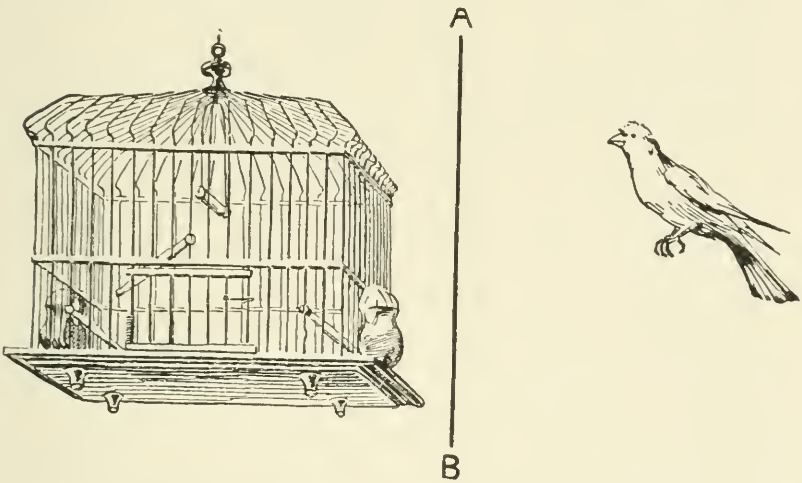


Fig. 135.—Put the Bird in the Cage by Binocular Vision.

pictures to the eyes separately is most conveniently done by the stereoscope, of which one kind is shown in Fig. 136. A card containing the two pictures is placed on the bottom. The left eye sees only the left-hand picture, the right eye only the right.

The principle of the stereoscope consists in bringing together the middle pictures for each eye and in avoiding the outer ones. This is most commonly done by means of prismatic lenses.

The prism stereoscope contains two glass prisms n, p, with a partition between and in front of them.

An object which is at *m* when directly viewed, apparently changes its position to some such place as *c* when seen through the prism. Two prisms can be so chosen that for the left eye a picture at *m* is transferred to *c* and for the right eye a picture at *o* is transferred to the same place. The two impressions from different eyes will then be united.

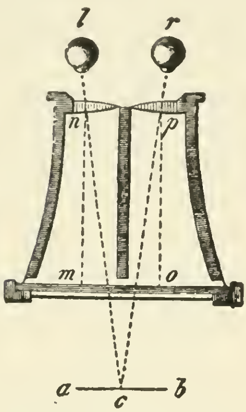


FIG. 136. — The Prism Stereoscope.

It is desirable that the prisms should at the same time be lenses, for the following reason. In experimenting with the two dots it will have been noticed that when the gaze was directed to a point beyond them they seemed blurred around the edges. There are very few people who can make each eye look straight forward and yet see near objects distinctly. When looking at distant objects their eyes are far-sighted for near objects. As it is necessary to have the stereoscopic pictures near at hand and yet have the lines of regard parallel, the far-sightedness is corrected by lenses. The two prisms must thus also be magnifying lenses.

FIG. 137.—The Book Stereoscope; How to Use it.

The series of stereoscopic figures in this chapter are ready for the application of the stereoscope directly to the book. The simplest method is to unscrew the back portion of any stereoscope and hold it to the eyes directly before the picture in the book, as shown in Fig. 137. Another method is to cut off the end of the stick of the stereoscope till the book, when placed against the end is at just the proper distance.

When two like pictures are placed so that the prisms cause them to fall exactly on the same spot, the images are seen as one. There is no effect of solidity. The two heads in Fig. 138 appear as one flat drawing.

When the two pictures are not alike, they make a

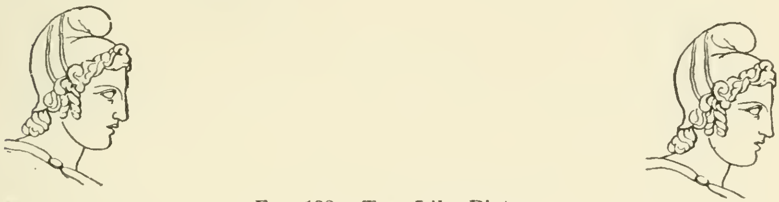


Fig. 138.—Two Like Pictures.

compound figure, as in Figs. 139, 140. When the two pictures are farther apart than the distance of the middle points of the prisms, they fall beside each other. In Fig. 141 the horizontal projections are at the proper distance for union, whereas the vertical bars

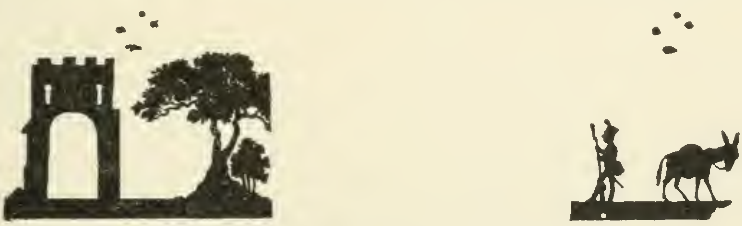


Fig. 139.—Unlike Pictures to be Combined.

are too far apart. The result is an H. The outline of the horizontal bar is darker because the black line of one picture falls on the black line of the other, whereas the black line of the vertical bar in one picture falls on the white space in the other.

Up to this point the results of two-eyed vision have

Fig. 140.—Prometheus.

been flat pictures. The production of the effect of objects in relief is not quite so simple.

Let two pencils be held upright before the eyes in a line directly in front of the nose and at about four

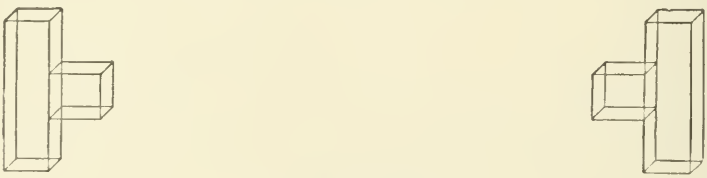


Fig. 141.—The **H.**

inches apart. When looking at the farther pencil you see two nearer pencils, as in Fig. 142. The image L belongs to the left eye because it disappears when that eye is closed; R belongs to the right eye. This condition of the extra images is called crossed disparity; it is to be remembered that objects nearer than the point of regard are seen with crossed disparity.

On looking at the nearer pencil, the farther appears double (Fig. 143). By closing one eye it is evident that the farther pencil is seen with uncrossed disparity.

Fig. 142.—Crossed Disparity.

Fig. 143.—Uncrossed Disparity.

Thus when we look at any point, the objects nearer than that point are seen with crossed disparity, those farther than it with uncrossed disparity.

Now hold a single pencil with one end pointing to the nose about two feet away and the other straight in front. Looking at the farther end, you would expect the nearer one to be seen as two ends in crossed disparity (Fig. 144); looking at the nearer end you would expect to see two farther ends in uncrossed disparity (Fig. 145); looking at the middle you would expect to see both ends double in opposite ways (Fig. 146). Since the pencils are continuous to the ends, you would expect the double vision to extend down the point of regard. What you actually see is one pencil *in relief* (Fig. 147). The continuity of the object transforms the double image into a single one with a new property.

The fundamental law of binocular relief is this: *Two different flat pictures of the same object will be combined into a relief, if each picture is such as would be seen by the corresponding eye singly.*

If the two pictures in Fig. 148 are seen with the stereoscope, the result is a union of the two views into

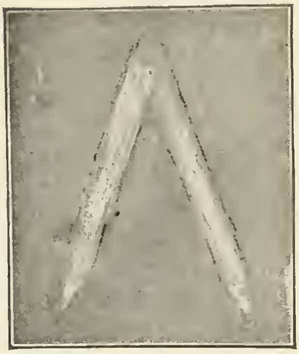


Fig. 144.—What we would Expect when Looking at the Farther End.

Fig. 145.—What we would Expect when Looking at the Nearer End.

Fig. 146.—What we would Expect when Looking at the Middle.

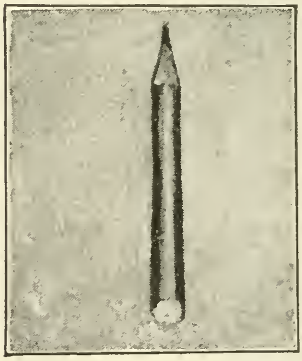


Fig. 147.—What we Actually See.

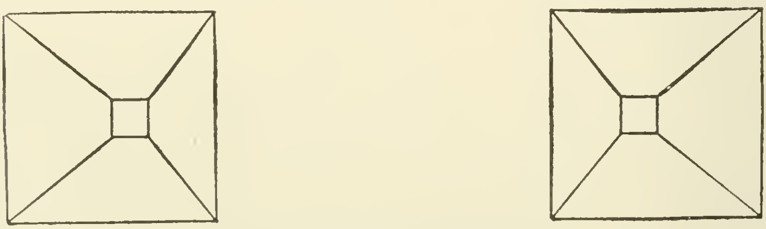


Fig. 148.—The Pyramidal Box.

one solid pyramid because the two views are drawn as such a pyramid would appear to the eyes used singly.

Fig. 149.—The Funnels.

Fig. 150.—The Crystals.

If the outer squares are drawn so as to be seen in crossed disparity (as by exchanging the two diagrams in Fig. 148), the larger end of the square is nearer than the smaller end and we are apparently looking at the pyramid from the bottom.

It is possible to tell beforehand whether the pyramid is seen from the top or from the bottom. As the small squares are at the regular distance apart the point of regard is found in the small end. The large squares are

Fig. 151.—The Multiple Star.

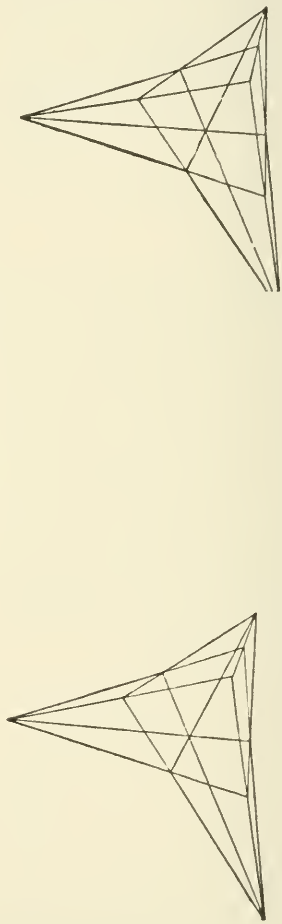


Fig. 152.—The Complicated Pyramids.

too far apart and are not crossed; this end of the pyramid must be seen in uncrossed disparity. But objects seen

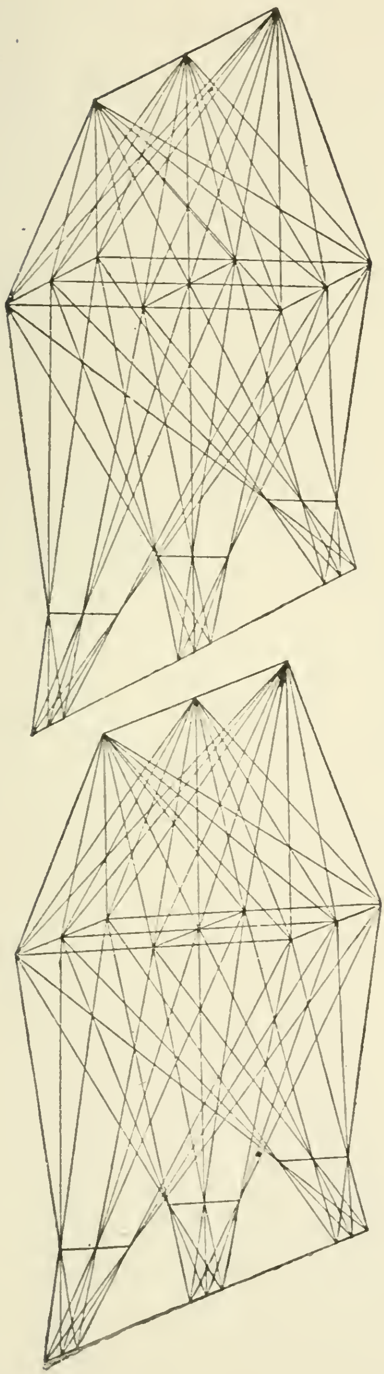


Fig. 153.—The Thread Figure.

in uncrossed disparity are farther away than the point of regard; consequently the large end is farther away. We are therefore looking at the pyramid from the top.

These relations are shown in Fig. 149. The outer circles for each pair are at the proper distance apart and unite to form the base at the point of regard. The smaller circles are seen in different relations of disparity, with the effect that the pictures form a series of funnels, the bottom one being long and pointed toward the observer, the next being shorter but likewise pointed, the middle one being a flat disk, the fourth being short and pointed away, and the topmost one being long and likewise pointed.

From these principles it will be easy

to explain the diagrams shown in Figs. 150-153.

The stereoscopic views of buildings, persons, and landscapes, such as can be obtained everywhere, are resolvable into the same principles aided by the shading, shadows, and perspective.

In addition to the effect of relief which we gain by stereoscopic vision there are several other important results of two-eyed seeing. Among them are: (1) binocular strife, (2), binocular lustre, and (3) binocular contrast.

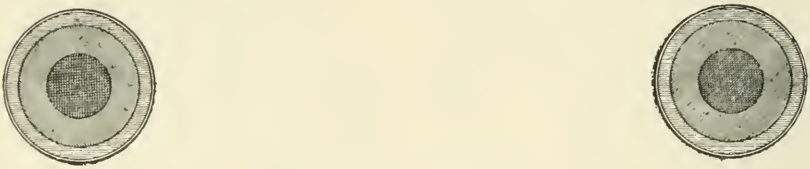


Fig. 154.—Binocular Strife.

Binocular strife is produced when the two different views are separately presented to the two eyes. In Fig. 154 the various rings are filled with lines in different directions; what happens when they are combined with the stereoscope? One of the rings is filled with shading which slants in one direction for the left eye and in the other direction for the right eye. The result is peculiar. Very rarely do the two sets of lines combine to form crossed shading. Sometimes the left-hand shading alone appears, sometimes the right-hand shading wins; generally the two alternate frequently and irregularly. If you happen to think of one kind of shading, that appears. But you cannot keep either kind for more than an instant; the other will replace it. It seems to be largely a matter of attention.

Yet, the most frequent aspect of all is that the shading is in patches; the left-hand picture predominates in parts while the right-hand one occupies the rest. And the queer thing about it is that these parts are continually changing. The inner circle behaves in the same way. It is in truth a strife between the two eyes.

Binocular lustre, or polish, is so called from the resemblance of the effect to actual polish. A polished object contains a contradiction in itself. Its little marks, irregularities, and corners remain the same, although changes in the position of the light and in the objects near it are followed by changes in the reflection. A polished doorknob differs from an unpolished one by partially reflecting the lights from surrounding objects; there is a strife between the colour and general appearance the knob would have if unpolished and the appearance of reflection of surrounding objects.

Fig. 155.—Binocular Lustre. The Translucent Crystal.

In Fig. 155 the left eye receives an impression of a white crystal and the right eye one of a black crystal; when viewed with a stereoscope, the same space is covered by a different colour for the two eyes. The result is a beautiful lustrous, translucent crystal, showing changes of light and dark as the binocular strife enters into effect.

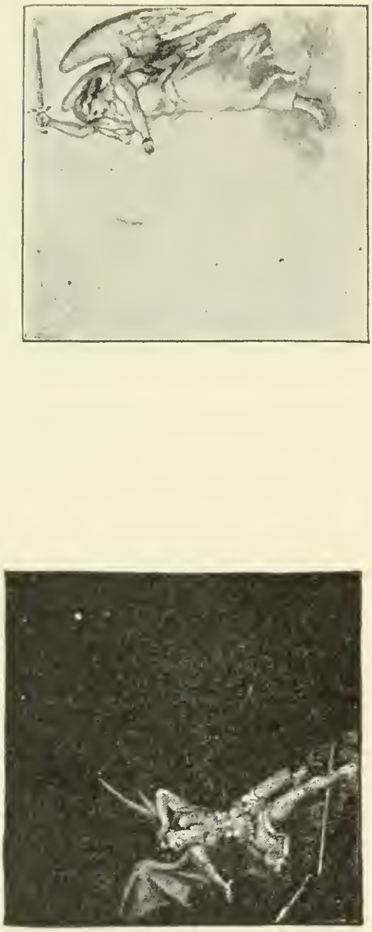


Fig. 156.—A Binocular Illustration to Milton's *Paradise Lost*, Book VI.

Binocular contrast is so called because the result of a binocular strife depends somewhat on the surroundings. In Fig. 156 we would expect an effect of binocular lustre and binocular strife. We do get them, but, in the neighbourhood of the most prominent points of each figure, the corresponding colour overpowers the other. Thus, in the neighbourhood of the angel Michael the white is strongest, while around Lucifer the black overpowers the light.

CHAPTER XVI

FEELINGS, EMOTIONS, MOODS

THE word "feeling" is employed in many meanings. We speak of feeling hunger and thirst, and of feeling pain; we often say a thing feels hot or cold, or hard or soft. We also say that love and hate, joy and sorrow, care and hope, are feelings; and we tell of feelings of the beautiful and the ugly, of feelings of truth, honour, and virtue.

The first group of these are what are termed "sensations" and "percepts"; the second group we will call the "emotions." Here we will limit the term "feeling" to six different and apparently simple facts that we experience, namely, like and dislike, stimulation and depression, tension and relaxation.

The feelings can be investigated by noting what sensations and percepts arouse them. For example, we can note what colours and colour-combinations please us most, or we can pick out first the most pleasing combination of colours, then the next pleasing, etc.

Let us consider first some of the facts concerning our feelings of liking and disliking that can be learned by introspection. The state of our feelings depends on the strength of the impression that arouses them. For example, a moderately sweet taste, as of sugar, is agreeable; an intensely sweet taste, is disagreeable. A moderate degree of saltiness is pleasant, but a strong degree is distasteful. Even a faint bitterness, as in beer, is liked by many persons, while the intense bitterness of quinine is revolting.

Feelings are connected with all sorts of experiences. Muscular exertion, or action of any kind, may arouse feelings. Moderate activity is generally pleasurable; but tiredness, over-exertion, and unhealthiness, may bring about intense unpleasantness.

From nearly every organ in the body we receive some sensation. The stomach makes itself known by hunger or repletion; the throat is heard from when thirsty. Each of these sensations may arouse feelings. Thus, hunger and thirst are disagreeable; repletion and quenching of thirst are agreeable. Other sensations, such as of the liver, were originally very strong, but with advancing evolution they have to a large extent disappeared; the feelings, however, still remain strong. An overloaded stomach or a disordered liver is liable to make us look upon the world in a very dismal light; the disagreeable feeling from such a source has overpowered all the others.

The influence of touch and temperature on our likings for tastes is so entirely overlooked that scientists have been deceived into supposing that there was some actual chemical differences corresponding to the differences in agreeableness of taste between things whereas the differences arise from the mixture with various touch and temperature sensations.

A draught direct from the old oaken bucket has a taste quite different from that of the same water drunk from a glass. Water from a tin cup is intolerable, yet coffee from a tin cup is far superior to coffee in any other way. The reason is a purely psychological one; the different sensations of touch and temperature mingle with the sensations of taste to produce agreeable combinations.

Various objects are liked or disliked according to their characters. Strong bright colours are always liked. Anyone looking at the rainbow colours would be tempted to exclaim: "All colours are beautiful!" This effect is very pronounced when the eye looks directly at the light thrown back by a spectrum-grating (p. 125); all the colours from red to violet and purple are of an indescribable beauty.

White itself, when not too strong, is just as beautiful. Since we cannot look directly at the sun, the light must be weakened by reflection. The white surface of snow possesses a beauty as great, if not greater, than the rainbow colours.

When the colours are mixed with white, less beautiful colours are obtained. No pink can be produced that is equal to pure red; no pale green that is as beautiful as pure green. The whitish skies of our colder climates cannot be compared with the deep blue sky of Italy. When a colour or white is darkened, *i. e.*, made less strong, its beauty is lessened. Greys and shades are not comparable with full colours. It is when colours are mixed with white and are also weakened that indifferent or disagreeable colours are obtained. Greyish pinks or greyish browns or drab blues are sombre and unpleasant.

In general we can say: pure white sunlight, when not too strong, is beautiful; the rainbow colours are beautiful; these all become less pleasing when less strong; the colours become less pleasing when mixed with white; the most disagreeable effects are produced by mixtures of grey (weaker white) with shades (weaker colours).

We have thus far spoken only of single colours. When colours are combined, the combination may produce an agreeable or a disagreeable effect, depending on the relation of the two colours.

In the first place, any combination of the rainbow colours is agreeable. In the rainbow or the spectrum they are all there together. In fact, when colours approach the brilliancy of the rainbow colours, as in stained glass, almost any combination appears fairly good. This is one reason why the patterns in a kaleidoscope have been of so little value in decorative art; when the colours are most carefully imitated in coarser materials they are apt to lose their brilliancy and to produce disagreeable effects. To a lesser degree this applies also to silk; many colour combinations worked out in this material are tolerable on account of their brightness, while the same designs if made in wool or cotton appear very poor.

Nevertheless, even with the brightest spectrum colours, some pairs are more pleasing than others. If the colours of the spectrum be arranged in a circle so that complementary colours (page 125) are opposite each other, it can be laid down as a rule established by experiment that a combination of two colours is the more agreeable the more nearly they are complementary.

When two greys are combined together, the effect is more pleasing the more they differ. White and black —the extremes of grey—are the most pleasing of all pairs. When a colour is combined with grey, or when two colours of different shades or tints are combined, the most pleasing effect is obtained when the difference is greatest. A light red and a dark green will be better than a moderately light red and a moderately dark green. Yet even this last may be better than a light green and a dark blue, because red and green as colours give better effects than green and blue. To get the full effect we should use double contrast: (1) of complementary colours, and (2) of light and dark. For example, we should combine bright red with dark bluish green or dark red with light bluish green, bright orange with dark blue or dark orange with bright blue, etc.

It must be confessed that these statements are rank heresies in decorative art. Still, they are the combinations preferred by unprejudiced individuals. The bright colours and strong contrasts are preferred by children, by savage tribes, by the peasantry, and also in former periods of art.

Why should we not be allowed to enjoy the combinations of colour as nature shows them to us? Nature decorates her fields, hills, and skies with the most gorgeous colours; we northern nations decorate our towns, ou rhomes, and our persons with the dullest combinations we can find. Any one who attempts to put a little life into our colours is decried as an uncultured being. As Ruskin says: "The modern colour enthusiasts who insist that all colours must be dull and dirty are just like people who eat slate-pencil and chalk and assure everybody that they are nicer and purer than strawberries and plums. The worst general character that decorative colouring can possibly have is a prevalent tendency to a dirty yellowish green, like that of a decaying heap of vegetables. It is distinctively a sign of a decay of colour appreciation."

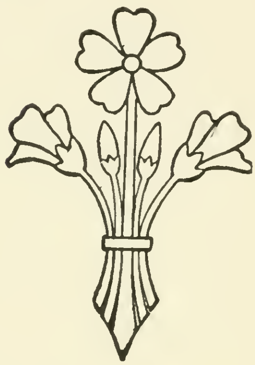


Fig. 157.—Single Symmetry, Horizontal.

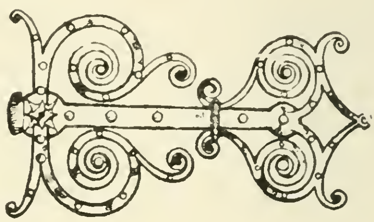


Fig. 158.—Single Symmetry. Vertical.

The products of art please or displease us not only on account of their colour but also on account of their form. The elements of space as exciting pleasure can be classed into the division of forms and the direction of bounding lines.

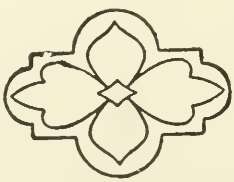


Fig. 159.—Double Symmetry.

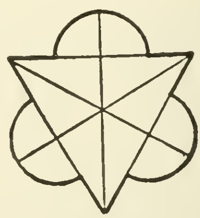


Fig. 160.—Threefold Symmetry.

In regard to the division of forms, we notice first that regular forms are preferable to irregular ones.

The simplest kind of regularity is symmetry, *i. e.*, the likeness of the two halves. Horizontal symmetry, *i. e.*, likeness of parts on each side of a vertical line, is the most preferred. Double symmetry is better than single. The more complicated the symmetry becomes, the better we like the result. The degree of symmetry is denoted by the number of lines that can be drawn through the centre whereby the half of the figure on one side of the line is just the opposite of the half on the other side. A plain circle is in perfect symmetry in every direction, but it becomes much more pleasing when made into a rosette.

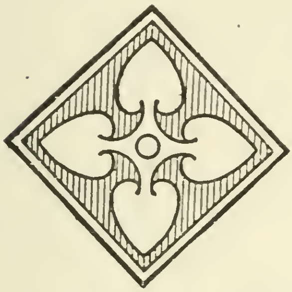


Fig.161.—Fourfold Symmetry

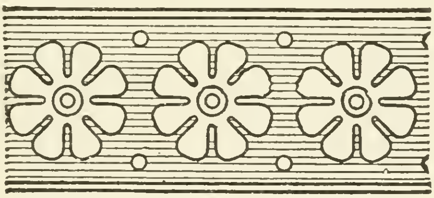


Fig 162.—Eightfold Symmetry.

Another kind of regularity is found in a definite relation of height to breadth. The perfect square is very displeasing because, owing to the overestimation of the vertical direction (page 187) the figure appears to be slightly too tall; it seems to impel us to make it correct. As the actual square is shortened we dislike it less, and, finally, when it appears to be a perfect square, we consider it

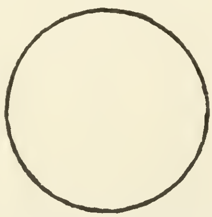


Fig.163.—Perfect but Simple Symmetry in All Directions.

a very pleasing figure. Of course, by actual measurement it is no longer a square, but it is a square as far as we are concerned.

If a square be changed to a rectangle, it is less pleasing than before, unless there is a certain relation between the length and height. Suppose in Fig. 165 the square at X to be successively lengthened in the direction X. Careful experiments have proven that the degree of pleasure follows some such course as indicated by the line SG. When the relation of the two sides is actually 1 times 1 the figure is very displeasing. When it is equal to an apparent square the pleasure is considerable, S. As it grows in length the pleasure at first decreases, then increases till at a relation 1 : 1.618 it is at a maximum, G.

Fig. 164.—Combinations of Symmetry.

We have now reached the border-land between psychology and the æsthetics of form, and at the same time we have come to the end of our definite experimental knowledge. The writers on architecture, painting, drawing, and decoration have produced numberless speculations on the psychological principles underly-

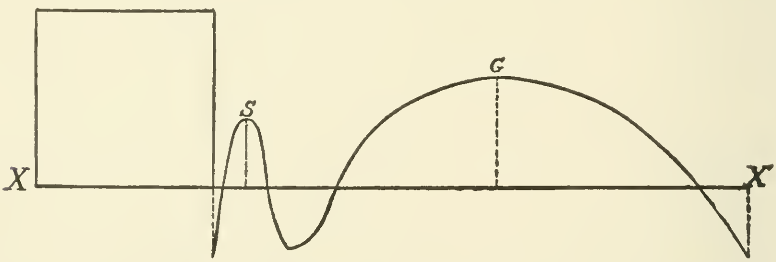


Fig 165.—The Law of Pleasing Relations of the Dimensions of a Rectangle.

ing the beautiful and the ugly. How far each is right we cannot say; as psychologists we have no call to meddle till experimental evidence can be produced.

The recognition of four forms of feeling in addition to liking and disliking we owe to Wundt; the rest of the chapter is based on his work.

We are all accustomed to characterise various experiences as "stimulating," others as "quieting" or "depressing." To the former we usually reckon bright colours, high tones, lively melodies, etc.; to the latter dull colours, low soft tones, soothing melodies.

The third pair of feelings can be illustrated when we listen at the telephone for the answer to our call. The thought of the answer arouses a steadily growing feeling to "tension," which is changed to one of "relaxation" when the answer actually comes.

The six feelings are often combined. Tension is sometimes pleasurable; the cat plays with the mouse before eating it. Tension may, however, be combined with dislikes, the peacock who lived next door to De Quincy almost maddened him by the expectation of the coming scream; the actual scream was a relief. It is related that a guest on going to bed dropped his shoe noisily on the floor, but, remembering that his host was a very nervous man, he put the other down noiselessly; not long afterward the latter appeared excitedly at the door, exclaiming "Why in thunder don't you take off the other shoe?" The disagreeable tension was stronger than courtesy.

The feelings can also be investigated by studying their effects on the breathing, on the heart, and on the blood vessels. For the study of breathing a rubbertopped receiving capsule is so placed over the abdomen or the chest that the recording capsule connected with it (Fig. 43) will register the breathing movements.

Records of the action of the heart and the blood vessels may be obtained with the sphygmograph or the plethysmograph. In the sphygmograph the receiving capsule is so placed over the wrist that the rubber top receives impulses from the pulse-beat; the recording capsule is arranged as usual so that the pulse-beat is registered on a smoked drum.

In the plethysmograph the arm is placed in a cylinder and a rubber cuff is tightened around it; the cylinder is then filled with water. A recording capsule is connected to it. When blood is drawn from the arm, it shrinks in volume, and air is drawn from the recording capsule; when more blood flows to the arm, the reverse occurs. Thus the plethysmograph furnishes records of variations of the amount of blood in the arm. These variations arise from contraction and relaxation of the blood vessels (arteries and capillaries). At the same time the plethysmograph registers the pulse-beat.

The effects of the feeling of tension may be illus-

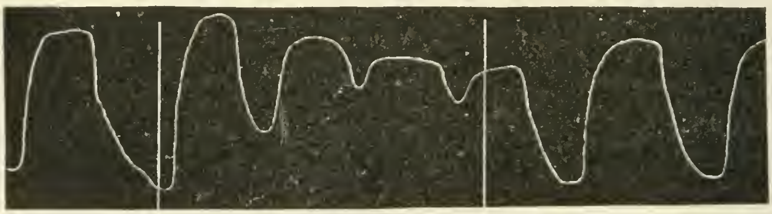


FIG. 166.—Effect of Attention on Respiration.

trated by Fig. 166. The line registers the chest breathing. The first two breaths are before the ex-

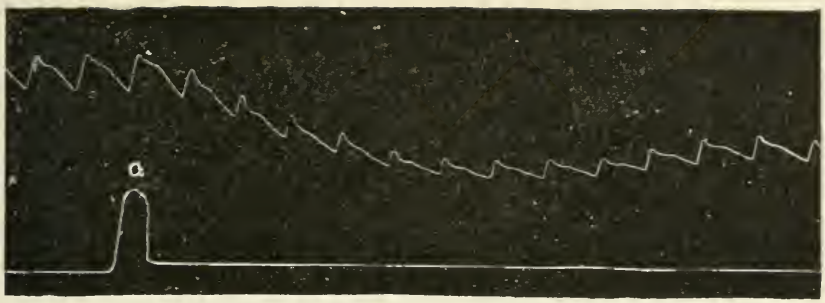


FIG. 167.—Effect of Attention, Plethysmograph Record.

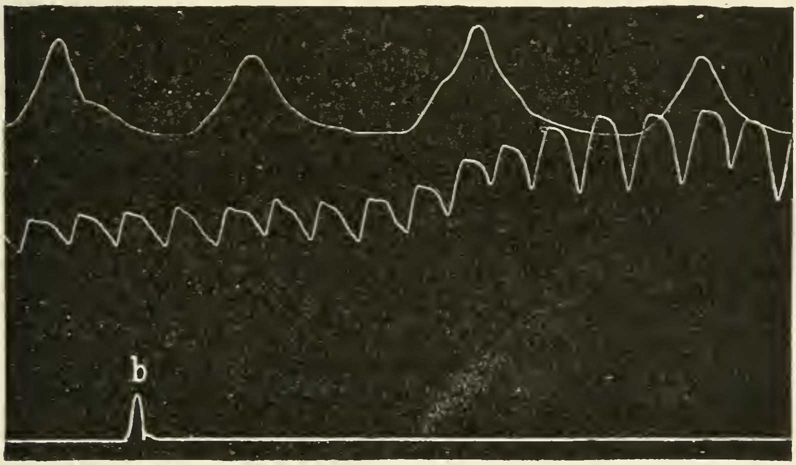


FIG. 168.—Respiration and Arm Curve during Tension and Relaxation

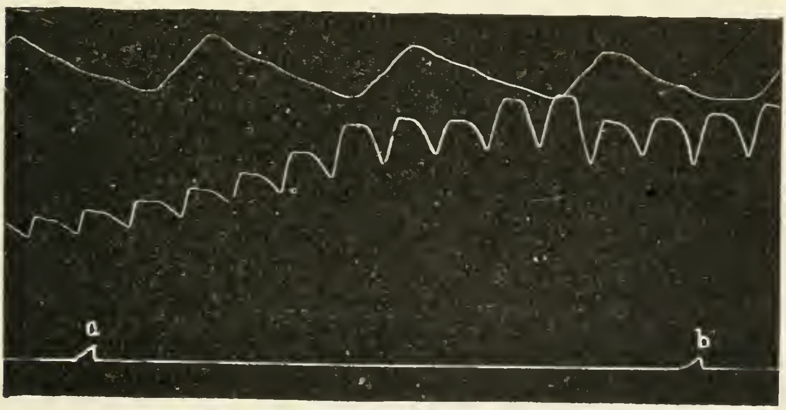


FIG. 169.—Effect of a Stimulating Thought

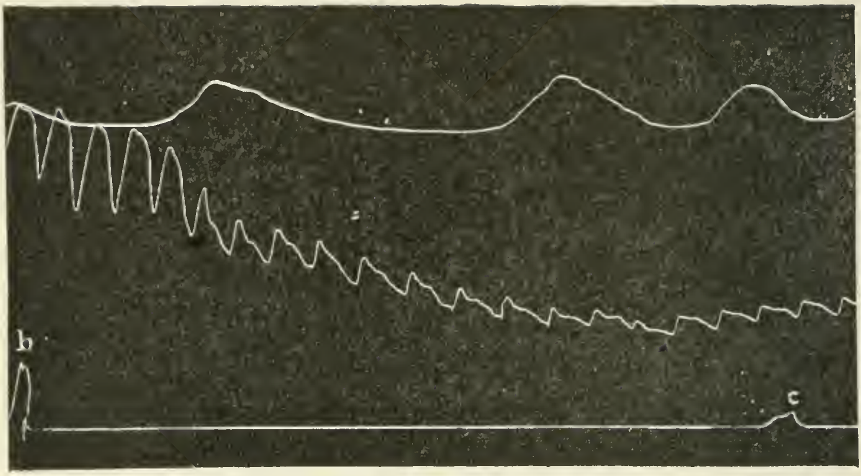


FIG. 170.—Effect of a Depressing Thought.

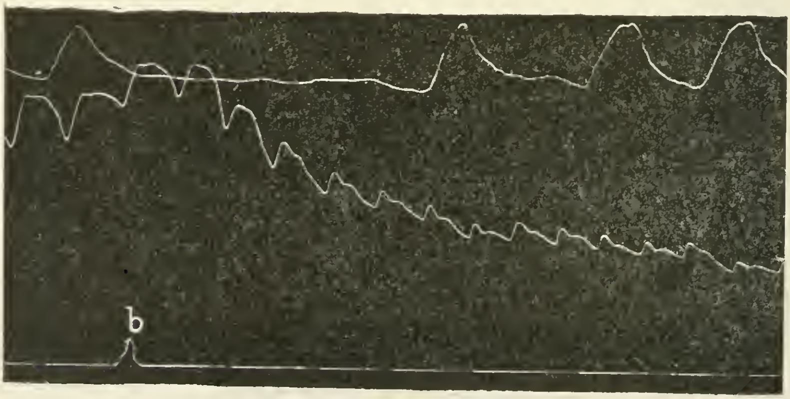


FIG. 171.—Effect of Dislike

periment begins. At the moment marked by the first line the subject begins to count mentally a group of dots; at the second line he finishes. The curve shows that during his counting his inspirations become lessened; this is due to a general tension of the breathing muscles.

The plethysmograph record in Fig. 167 shows the effect of attracting attention by lightly touching a person. The volume of the arm diminishes owing to general contraction of its blood vessels; the pulse-beat becomes less and its time slower.

The feeling of relaxation is readily studied by requiring the subject to do some mental addition or multiplication. The breathing and plethysmograph curves at the end of one experiment are shown in Fig. 168. At *b* the subject has finished multiplying 93 by 78. The top record shows that his breathing becomes stronger. The other record shows that the volume of the arm and the height of the pulse beat increased, but the time of the pulse beat remains the same.

Fig. 169 shows breathing and plethysmograph records after a stimulating thought occurring at *a*. The pulse is strengthened, but not essentially changed in period; the respiration is strengthened but not otherwise altered. Exactly the opposite is seen in Fig. 170. A depressing thought was present from *b* to *c*. The pulse is weakened (the slight acceleration is due to the feeling of dislike). The breathing is shallow and very irregular. After the thought passes at *c* the breathing rapidly becomes normal, and the pulse slowly so.

The feelings of stimulation and depression are usually mixed with those of tension and relaxation. For example, when a person is solving an intellectual problem he has often feelings not only of tension but also of stimulation (or excitement); the excitement often lasts when the tension has been replaced by relaxation. The pulse curve in such a case shows stronger beats during the first period instead of the weaker ones that accompany tension alone; during the relaxation they are increased more than usual because the stimulation continues to be present.

A record during dislike is shown in Fig. 171. The disagreeable taste at *b* produces a sudden stoppage in the breathing which was followed by deeper and slower breathing. The volume of the arm becomes less; the pulse becomes less marked and slower. Records during the feeling of liking show just the opposite.

The results in relation to breathing and pulse may be summarised as follows:

	BREATHING	PULSE
Tension :	slowed, strengthened	slowed, weakened
Relaxation :	accelerated, strengthened	accelerated, strengthened
Stimulation :	accelerated, strengthened	unchanged in period, strengthened
Depression :	slowed, strengthened	unchanged in period, weakened
Like :	accelerated, weakened	slowed, strengthened
Dislike :	slowed, weakened	accelerated, weakened

When a strong feeling arises in connection with any percept or thought, it may have an effect on our following thoughts and acts, which persists for some time. Thus, the sight of a certain person may cause a feeling of dislike to arise, and both may then initiate a train of thoughts, feelings, and expressions that we call anger.

The entire complex of feelings, thoughts, and expressions we may call an "emotion."

According as the elements of liking or those of disliking predominate, we have agreeable emotions, such as pleasure and joy, or disagreeable ones such as chagrin and sorrow. Strangely enough our language has no term for that most common emotion: the opposite of pleasure. Suppose that you unexpectedly find an autograph letter of George Washington among old papers in your attic; this would give you great pleasure. Now suppose that you lose it: your emotion would be—what? You might say "sorrow," but the emotion is certainly not the same as if you had heard of the death of a parent. "Pain?"—the emotion has no resemblance to the sensation of pain from the point of a needle except in having the element of dislike in it. "Displeasure" might be the term, but it is used only when the opposite of pleasure refers to some one's act.

The predominance of the feeling of stimulation or depression produces the stimulant and depressant emotions; to the former belong joy and anger, to the latter sorrow and fear. The feeling of tension predominates in the tonic emotions, joy, anger, terror; that of relaxation in sorrow and despair.

Under "moods" we may classify conditions of mind that colour all our thoughts, emotions, and acts. We find two characteristic principles in the moods. The first we may term "tonality;" its positive extreme is "exaltation," its negative one "depression." The other we may term "activity," with "excitability" as one extreme and "apathy" as the other.

Excitability indicates over-readiness to respond to stimuli of all kinds: impressions, thoughts, feelings. Apathy indicates lack of response.

Exaltation shows itself in increased facility and rapidity of thought, in preponderance of the positive feelings (liking, stimulation, tension), in increased rapidity and energy of action, increased estimation of one's self, in optimistic views of persons and events, etc.

Depression is characterised by the negative feelings in slowness and difficulty of thought, in weakness, uncertainty, and slowness of action, in self-depreciation.

CHAPTER XVII

ATTENTION

WHAT is this difference between attention and inattention, between expectation and surprise? How can we turn inattention into attention?

When you first move into a new neighbourhood, you notice every house, every tree, almost every stone, as you pass to and fro. As you grow accustomed to the surroundings, you gradually cease to notice them. Finally you pay so little heed to them that you are unable at the end of a walk to tell what you have just seen by the way. This fact is expressed by saying that at first you attended to what you saw and afterwards did not.

I can illustrate this process of attention in another way. You are now reading the sentences on this page; you are giving full attention to what I say. But at the same time you are receiving touch impressions from the book in your hand and from the clothes you wear; you hear the waggons on the street or the howling of the wind and the rustling of the trees; you smell the roses on the table. Now that I have mentioned them you notice them—or pay attention to them. When you were attending to what you were reading, they were only dimly present.

I will suppose that you are attending to what you are reading; all those sounds, touches, smells, etc., are only dimly in the *field* of your experience while these words are in the *focus* (or burning-point) of experience.

Probably you can gain a good idea of the difference between the focus and the field of present experience by taking an analogy from the art of photography. When the ground glass of a camera is adjusted so that the picture of a person in the middle of the room is sharply seen, all the other objects are somewhat blurred, depending on their distance from him. When the position of the glass is changed by a trifle, the person becomes blurred and some other object becomes sharp. Thus for each position of the glass there is an object, or a group of objects, distinctly seen while all other objects are blurred. To make one of the blurred objects distinct, the position of the glass must be changed and the formerly distinct object becomes blurred.

Fig. 172.—Focus and Field of Attention.

In like manner we fully attend to one object or group of objects at a time; all others are only dimly noticed. As we turn our attention from one object to another, what was formerly distinct becomes dim.

The illustration with the camera is not quite complete. You can keep the objects quiet in the room, but you cannot keep your thoughts still. The mental condition would be more nearly expressed by pointing the camera down a busy street. You focus first on one thing, then on another. The things in focus pass out of it, others come in. Only by special effort can you keep a moving person or waggon in focus for more than a moment.

Let us ask a few practical questions.

In the first place, How many objects can be attended to at a time? Objects can, of course, be more or less complicated. A house, for example, is a single object if we do not look into the details; it is a multitude if we count the windows, doors, roof, chimneys, etc., as separate objects. By the word "object," then, we will understand any thing or group of things regarded as a single thing. Thus, the natural tendency would be to regard the letters M X R V as four objects, namely, four letters, whereas MORE would be regarded as one object, namely, a word, unless we stop to consider the letters separately.

Experiments are made by exposing pictures, letters, words, etc., to view for a brief time. One way of doing this is to prepare slides for the projection-lantern and throw the view on the screen for an instant.

A more convenient way is to fix the pictures or letters on cards or to prepare a table on which actual objects are placed. A photographic camera with a quick shutter is aimed at them. The person experimented upon is so placed that he cannot see the objects, but can see the ground glass. Various other methods for brief exposures have been used.

Experiments of this kind show that four, and sometimes even five, disconnected letters, numerals, colours, etc., can be grasped at the same time. When the objects are so arranged that they enter into combinations that make complex objects, many more can be grasped. Thus, two words of two syllables, each word containing six letters, can be grasped as readily as four single letters.

This ability to grasp and remember complicated objects increases with age. Children seem to grasp only the details separately and to be unable to gain a general view with the parts in proper subordination. In drawing a horse unskilful persons begin with the head, proceed with the back, then the rear legs, etc., thinking of only one thing at a time; the result is generally that the various parts are out of proportion. The details are often so isolated in the child's mind that he will draw parts entirely separated from one another. This is the case with the child that drew an oblong and a square separately to stand for the two sides of a box seen in perspective.

Let us consider next the methods of forcing attention to an object, or as is frequently said, of forcing the object into attention.

The first law I shall state is: *Bigness regulates the force of attention.* Young children are attracted to objects by their bigness. Advertisers know that one large advertisement is worth a multitude of small ones. A certain life insurance company puts up the biggest building; a newspaper builds the highest tower. Churches frequently vie in building, not the most beautiful, but the largest house of worship.

The second law of attention which I venture to propose is the *law of intensity or brightness*, according to which *the intensity of a sensation influences the amount of attention paid to it.* Here also we have no experimental results; we must for our examples, rely on the art of psychology rather than on the science.

The shopkeeper well knows the effect of a gilded sign. The druggist's bright light forces you to notice him. The headlight on the trolley-car serves a purpose in addition to lighting the track.

The clanging gong, the excruciating fish-horn, the rooster's crow, and the college yell are all for the purpose of attracting attention. **Full black letters** for paragraph headings or advertisements are more effective than ordinary type or outline letters.

Cleanliness is not the only reason why a man-of-war is kept in a high degree of polish. The furnishings could be just as clean if painted with black asphalt, but the effect on the officers and men would be quite different. It is difficult to get full attention to duty and discipline in a dingy vessel.

This same principle is applied in instruction. An old or rusty piece of apparatus cannot command the same attention from the students as a brightly varnished and nickel-plated one.

Students in a chemical laboratory do not pay nearly as good attention to their manipulations if they work over scorched, stained tables and black sinks. The director of one laboratory in Belgium covers his tables with fine, white lava-tops. The expense is at first great, but the increased attention more than repays the cost. Experience has shown that the students working at those tables keep their glassware cleaner and do their chemical work with more care than those who work at the ordinary wooden tables.

The third law I shall call the *law of feeling;* it can be stated in this way: *The degree of attention paid to an object depends on the intensity of the feeling aroused.* The feeling may be either of liking or disliking.

Painful sensations arouse a strong dislike. "The burned child dreads the fire"; it is equally true that a burned child watches the stove. The very name of croup strikes terror into the mother and the slightest hoarseness arouses her attention.

Few feelings are so intensely pleasurable as those of the young mother. Watch the *tension*—the *at*tention—to every movement of the child.

In former days beautiful objects were accompanied by intensely pleasurable feelings. When Giotto wished to give Florence a remarkable tower, he made it of wondrous beauty. When the Parisians wished a striking tower for their exposition, they got M. Eiffel to make it the tallest one.

To celebrate the victory of his chorus in the theatre of Bacchus, Lysikrates erected in Athens his famous choragic monument. Exquisitely wrought, graceful in its proportions, rich in decoration, perfect in its material, it is the wonder and admiration of the world. True, it is only thirty-four feet tall, and to-day in competition with the Ferris wheel would not attract the slightest attention—unless it could be used as the ticket-office.

In fact, our crude western civilisation, our puritanical love of the ugly, and our blind worship of bigness have deprived us of any feeling for beautiful objects. If an appeal is to be made for attention through feeling, it must be done in some other way. The other way is generally by use of the comic, the grotesque, or the hideous; for example, the alleged jokes that are interspersed all through our newspapers, the cartoons of a political campaign, and the silly coloured supplements of the Sunday papers.

Personal pride is accompanied by a strong feeling which brings attention to anything necessary for its proper maintenance. Vanity is an excessive degree of personal pride; it is a most powerful incentive to attention.

The culminating point in education is the power to attend to things that are in themselves indifferent by arousing an artificial feeling of interest. There is hardly anything of less intrinsic interest to the student than analytical mathematics, such as algebra; the treatment is purposely deprived of every concrete relation. Yet we know that the power of attending to such a subject can be cultivated.

The fourth law of attention which I shall propose is the *law of expectation*—I had almost said of curiosity.

A step at the front door arouses a memory of a bell-ring; the ear is prepared to hear it. Whether the matter concerns us or not, this condition of expectation forces our attention.

The peacock which lived next door to De Quincey almost maddened him by the expectation of the coming scream. The actual scream was a relief; thereafter the attention became steadily more and more intense till the moment of the next scream. The law of expectation is used in a masterly way in Dickens's *Mutual Friend.* It is a characteristic of successful newspaper writing that the opening paragraph shall arouse expectation, and therefore attention. The same principle underlies the art of writing headlines.

Scientific men are famed for strict and ardent attention to their investigations. The fascination of research and discovery lies in the vague expectation of something new. The essence of all science is curiosity—the plain every-day, good old homely curiosity that impels Farmer B——'s wife to learn just how many eggs are laid by her neighbour's hens, that makes Robbie pull apart his tin locomotive to see how it works, or that induces a cat to stick her paw down a knot-hole in the floor.

Unsatisfied curiosity arouses still more attention. Many papers still maintain puzzle columns, well knowing that unsatisfied curiosity is a more intense form of unsatisfied expectation. The reason of the great attention paid to Stockton's *The Lady or the Tiger* is to be found here.

It is a principle of serial stories that each instalment shall end with an unsatisfied expectation. This contributes more than the merit of the story to arousing the attention of the reader, who, because he keeps thinking of what may happen, is forced to buy the next number of the periodical in order to be relieved of the tension.

The fifth law of attention is the *law of change*, or the law of unexpectedness; *the degree of attention depends upon the amount and on the rapidity of the change.*

Things indifferent and even things unpleasing may leave their impress by the severity of the shock they give. A flash of lightning or a low door-lintel commands notice. There is an old saying that wonder is the beginning of philosophy. Various things may be meant by wonder, but one thing is the shock of mere surprise or astonishment; at any rate an impression is made.

In our reading we expect only straight lines. The advertiser arouses attention by tipping them slantwise. The advertiser makes frequent use of this law combined with the law of curiosity by putting in his notice upside down.

A prominent effect of attention is to shorten reaction-time and thought-time and make them more regular. The commands of a military captain are really signals for reaction. The first part of a military command is arranged to serve as a warning signal to insure good attention; "Shoulder—ARMS!" "Right—FACE!" The acts of the men are simple reactions. They are not associations; therein lies the reason why a command is not given as a single expression. If the command were "Forward-march," delivered as one expression, the soldier would be obliged to discriminate, associate, and choose among twenty or thirty possible commands. We have already seen that these processes not only take a very long time but are very irregular; moreover, no warning would have been given. The company could not possibly step forward as one man, whereas the command "Forward—MARCH" causes all the mental processes except simple reaction to be performed beforehand; every man in the company has but one thing to do, his attention has been properly prepared by the warning and the whole company should start together.

A notable effect of attention to one idea is the lack of attention to other ideas. Henry Clay was obliged to speak on one occasion when in very delicate health. He asked a friend who sat beside him to stop him after twenty minutes. When the time had passed, the friend pulled Clay's coat, but he continued to speak. His friend pinched him several times and finally ran a pin into his leg. Clay paid no attention. He spoke for more than two hours and then, sinking exhausted, he upbraided his friend for not giving him a signal to stop at the proper time. The signals had been given but his mind was so intensely attentive to his discussion that everything else was neglected. It is a well-known fact that we can forget griefs, pains, even the toothache, when reading a fascinating book or watching a forcible drama.

Going still further we find abnormal cases: arithmomania, where the patient is continually asking why houses are so large, why the trees are so tall, or where he is continually counting the number of paving-stones in the street or the number of rivers in a country; metaphysical mania, where the patient cannot hear a word like "good," "beautiful," "being," etc., without irresistibly speculating on the problems of ethics, æsthetics, and metaphysics. These and similar cases are included under the term of "fixed ideas." The acute stage of excessive attention is found in ecstasy.

CHAPTER XVIII

MEMORY

BY "memory" we refer to the relation between two ideas occurring at different times, whereby the second is intended to be like the first. In some schools of design the model is shown for a short time, whereupon the pupils are required to draw from memory. The original impression, sometimes called the sense-perception, was that of the model; the memory picture is the mental picture from which the drawing is made. The relation between the two pictures is the problem of memory.

There are numberless entertaining stories concerning great and peculiar memories, but it is much to be doubted if anything of any value is gained by repeating them. Instead of following the beaten path it will be better to enter at once into the experimental work on the subject.

Memory can be investigated in two ways: by measuring the difference of the repeated idea from the original, or by counting the number of successfully repeated ideas out of the total number.

Memory for actions is a good subject to begin with. How accurately does the arm remember a straight movement? With the eyes closed draw on the first sheet of a pad of paper a vertical line of any agreeable length. Without opening the eyes tear off this sheet; it is very convenient to have the pad fixed firmly to the table. After waiting five seconds (if you have no ticking clock at hand, some one can tell you the time), with the eyes still closed draw a second line which you judge equal to the first. Tear off the sheet as before. After waiting five seconds again, draw a third line of the same length as the *second* (you need not attempt to recall the first). Continue in this way till eleven lines have been drawn from memory.

With a millimetre scale (or a ruler divided into sixty-fourths of an inch) measure each line. The difference between each line and its predecessor gives the amount of error in remembering after the particular five seconds. Thus, with a line about 100 millimetres long, we might get a series of errors of -2, -1, $+1$, -1, $+2$, -1, -3, -2, -3, -1, where $+$ indicates that the second line was too long and $-$ that it was too short.

In memory there are two changes that go on: first, an actual change in the idea remembered; and, second, an increasing uncertainty.

If we average up all the errors, taking into account the signs, we shall get the average change. Thus, the average of the set we have just noticed is

$$\frac{-2-1+1-1+2-1-3-2-3-1}{10} = \frac{-11}{10}$$

$$= -1\tfrac{1}{10} \text{ or } -1.1^{\text{mm}}.$$

This is the average change introduced by the lapse of five seconds.

What is the uncertainty of our judgment? This we find by averaging all the separate errors without regard to sign; thus

$$\frac{2+1+1+1+2+1+3+2+3+1}{10}=\frac{17}{10}$$
$$=1\tfrac{7}{10}\text{ or }1.7^{\text{mm}}.$$

We would thus say that the average uncertainty introduced by a lapse of five seconds is 1.7^{mm}.

By repeating the experiments with an interval of ten seconds, we find the average memory-change and the average uncertainty due to that interval. Likewise we can use intervals of fifteen seconds, thirty seconds, one minute, five minutes, etc.

From the results of experiments of this kind that I have made the fundamental law of memory can be deduced as follows: The average change is an individual matter depending on circumstances, but the average uncertainty increases in a definite relation to the time.

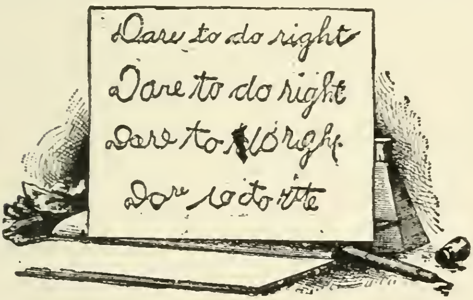


FIG. 173.—A Leaf from Daisy's Copy-book.

In learning to write by means of a copy-book the eye gets the mental image and then, looking down, guides the pen. As the distance from the copy to the line grows larger, the eye has time to partially forget the exact form of the lines in the copy (Fig. 173).

The memory for the force of action can be investigated with the dynamometer, described on page 69. The pull is executed to any desired weight. After five seconds it is repeated to apparently the same weight. The amount of the error is recorded by some other person. Again after five seconds the pull is repeated, and so on. The average change and the average uncertainty are calculated as before.

Then ten seconds, fifteen seconds, and so on, are used as intervals. We finally obtain the law of memory for force. The results of an investigation lately made show a rapid increase both of the average change and the average uncertainty.

The very curious fact of cross-education has been noticed on pages 22, 66, 72, and 85; there is also a "cross-memory."

If the original line in the experiments on page 240 be drawn with, say, the left hand, it can be remembered with the right hand. If the original pull on the dynamometer be made with one hand, it can be remembered with the other.

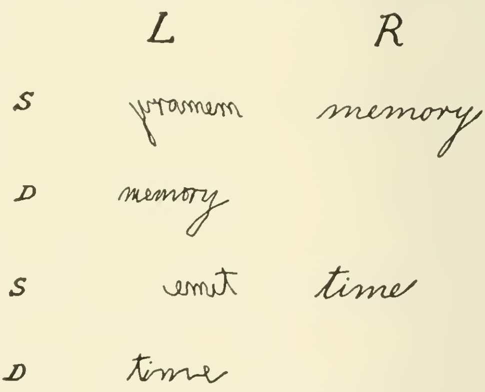


FIG. 174.—Symmetrical and Direct Cross-memory.

A most curious fact about this cross-memory is that the memory for movements is symmetrical and not identical. We learn to write with the right hand; when we attempt to write with the left we succeed fairly well by writing outward (*i. e.*, backward), just as the right hand wrote outward, but we cannot write as well in the regular direction. Here are two specimens (Fig. 174). By looking at the words with a mirror it will be seen that with the left hand those written outward are better than those written inward. When the eyes are open during this experiment, the preponderance of the visual picture produces better direct writing with some persons. When the eyes are shut, the same may happen through preponderance of visual memory. In most persons, however, the movement sense predominates and the results are as in Fig. 174.

Some experiments, not extended far enough to enable me to put the law in a quantitative statement, seem to indicate its general form as follows: The average change produced by cross-memory is composed of two parts, that due to the crossing and that due to the interval of time; the average uncertainty is always much greater than in memory without crossing and increases much more rapidly.

The method used in these experiments was the same as that used on page 204. The original line was drawn with one hand, and was repeated with the other, alternately symmetrical and direct. In the particular set of experiments referred to the results were as follows: The remembered line was, on an average, sixteen per cent. shorter in the symmetrical movement and twenty-four per cent. shorter in the direct movement. The average uncertainty was nine per cent. in the symmetrical and nine per cent. in the direct.

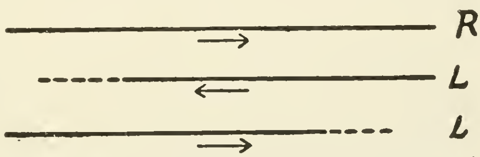


Fig. 175.—Measurements on Symmetrical and Direct Cross-memory.

These results can be indicated as in Fig. 175. The top line is the standard, drawn by the right hand in the direction of the arrow. The two other lines are averages of those by the left hand; the portions in dashes indicate the regions within which these lines ended. The irregularity is the same for both, but although both movements differ from the standard, the unsymmetrical one is the less correct of the two.

Memory for tones can be measured in a similar way to that employed on pages 107 and 108, in determining the least noticeable difference. In fact, all the experiments on the least noticeable difference might be considered as experiments on memory with a very small interval of time between the two impressions compared. There we used an interval of two seconds; by changing this interval to five seconds, ten seconds, etc., we get the record of the size of the least noticeable difference as depending on the lapse of time. The matter is so simple that further explanations hardly seem necessary. A valuable set of experiments might be performed with the tone-tester, described on page 110.

The method of percentages of correct answers may also be employed. The experiments described on page 112, are to be repeated with different intervals.

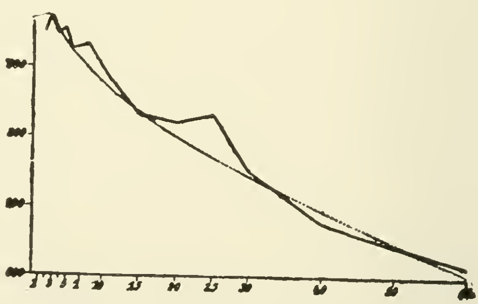


FIG. 176.—Law of Forgetting Tones.

The results of an investigation of this kind are shown in Fig. 176. Here the figures on the horizontal line indicate the number of seconds that elapsed between two tones to be compared, and those on the vertical line indicate the percentages of right answers.

It is seen that the maximum certainty is reached at two seconds. Thereafter it decreases. At an interval of sixty seconds the uncertainty is so great that the answers are nearly half right and half wrong; since mere chance would make them half right, the uncertainty is almost complete.

This is a characteristic case for most unmusical persons. Individuals differ, of course. There are intelligent persons who cannot recognise a tone repeated twice in close succession. On the other hand, we find Mozart and later piano-players who can carry in mind the slightest differences. Probably the most accurate tone-memory on record is that of Mozart. Two days after playing on a friend's "butter-fiddle" (as he called it on account of its soft tone), the seven-year-old Mozart, while playing on his own violin, remarked that the butter-fiddle was tuned to half of a quarter of a tone lower than his own. And this was found to be the case.

We might make similar experiments on touch, temperature, smell, etc. In fact, memory is no real process; it is merely a way of considering and comparing two impressions at different times. This is what we did with a small interval on many occasions in the earlier chapters of this book. When the interval is so small as to be negligible we speak of simultaneous impressions.

Numerous sets of calculations of the number of letters or words forgotten out of the total number seen, heard, spoken, etc., have been undertaken. Letters and words are very complicated affairs, and the results will vary completely by a slight change in the word, in the arrangement, in the time, in the loudness or illumination, in the intonation or the size, etc., etc. The sources of error are so great that a scientist, *i. e*, a careful worker, must spend years of labour in getting them under control. The first carefully executed experiments in this line show that when a set of meaningless syllables has once been learned, the time required for learning them on a second occasion increases as the interval between the two occasions, according to a definite law.

This law runs in the way shown in a specimen table of results:

Interval . .	0.3	1	8.8	24	48	144	744 hours
Per cent. of work required for relearning	42	56	67	66	72	75	79

At first there is a rapid loss, more than half during the first hour; then the loss is steadily less rapid and finally becomes almost constant. Between the second day and the thirty-first day there is almost no change.

Further experiments with letters under various conditions of rate, repetition, lapse of time, rhythm, etc., have been in progress for many years, but the final results have not been reached.

The education of the memory powers has ever been a subject of interest to practical people. More or less fabulous accounts of the prodigies of memory may be found in various psychological story-books. Even when the records of the results to be obtained are to be credited, the accounts of how the freaks educated their memories are mostly to be regarded as unconscious fiction. For practical purposes statements on the development of memory should be founded on observation of and experiment on ordinary people.

The fundamental laws for the cultivation of memory are: intensifying the image by attention, and keeping it ready by conscious repetition.

In the first place, intensify the impression. See, hear, do what you wish to remember. You cannot expect to remember a picture when you have not really seen it. It is said that the Nürnbergers never hang a man till they have caught him, and yet many a teacher expects his pupils to remember a lesson without really learning it.

How shall we intensify the impression? Any method that increases the amount of attention will help to intensify the impression; these methods have been considered in Chapter XVII. But it is not sufficient merely to pay attention; something further must be done if the impression is to be retained. No experimental work in the laboratory has been done on this problem, but some of the most energetic experimenting has been carried on by advertisers on account of the business interests involved. The very principles they have discovered are just the ones we should make use of on ourselves and in teaching others.

A powerful principle employed for memorising a fact is that of the ridiculous. You cannot forget the absurd pictures by means of which publishers and players advertise their new wares; or the musician's hair, whose echoes last longer than those of his playing.

A subordinate principle belonging to the ridiculous is that of the pun. A good pun is an æsthetically ridiculous contradiction; a bad one is intensely irritating but is ridiculous ridiculousness. If you wish your class to remember the story of Waterloo, make a pun about it, and a bad one, too. (You all know the horrid one to which I refer.)

A second principle of memorising is that of rhyme. We all know how much easier it is to learn rhymed poetry than blank verse or prose. Rhymed couplets or verses can frequently be employed to memorise difficult facts. The farmer's calendars in olden times were based on the memorial days of the saints. To remember when the sowing, reaping, etc., should be done, an appropriate couplet was rhymed with the day. The same method is employed in some aids to learning history. Those who have studied formal logic will remember the mediæval memory-verse beginning, "Barbara, Celarent," etc.

The principle of rhyme when combined with the ridiculous can be carried so far that couplets and stanzas *cannot* be forgotten. Those who have read Mark Twain's story about "Punch, Brothers," etc., will remember a case.

The principle of alliteration, *i. e.*, of words beginning with the same sound, was largely used in olden poetry. Memory was doubtless greatly assisted thereby. It is in use to a certain extent to-day in book-titles, catch-words, advertisements, etc.

Another very efficient principle is that of the puzzle. Dissected maps, the game of authors, the solution of mathematical conundrums, are cases.

To retain things in memory they should generally be repeated a number of times. With a very intense first impression the repetition may be unnecessary; with weak impressions it may be required frequently. The relation of intensity to repetition has, however, never been experimentally determined.

The fundamental fact to be observed is that the repetition must be conscious. Nearly everybody supposes that a series of facts, a group of names, a collection of dates, can be learned by simple mechanical repetition. But in "learning by rote" we soon cease to think of what we are saying. Yet we remember the connection between two words only when we pay attention to the fact of such connection. For example, suppose we wish to remember that Aristotle was a tutor to Alexander. The fact strikes us at once and will have some power of persistence in our memories. Any amount of mechanical repetition of "Aristotle-teach-Alexander" will not assist. But if each repetition be a conscious, attentive connection of the three facts, there is a distinct gain. The difficulty lies in making the repetition conscious and not mechanical.

The methods of doing this may be described as direct and mediate. In the direct method the individual calls up each time by an effort of will a characteristic picture of Aristotle teaching Alexander.

The mediate method consists in finding some word naturally connected with Aristotle which by another natural connection brings up another word and so on till "teach" is reached, after which the same process stretches from "teach" to "Alexander." For example, we may make the following series of connections:

Aristotle—aristocracy	teach a class—teach a lass
aristocracy—better class	alas!—alack!
better class—teach a class	alack!—Aleck
teach a class—teach	Aleck—Alexander

Again suppose we wish to remember that the car with a red light goes to Westville. We may construct the associations:

red—sunset
sun sets in the west
west—Westville

In selecting the connecting links we choose those that are most striking. It is convenient to look for similarities of sound (all of those used for Aristotle—teach—Alexander except one are of this sort) or of meaning (aristocracy—better class), or for contrasts, or for modifiers of color (red—sunset), size, place (in the west), quality, quantity, etc, or for activities, etc· (sun—sun sets).

Two important principles are involved in this method of memorising. The first is that of forcing attention to the things to be remembered. Thus, in searching for a word to connect with "Aristotle," we are obliged to think of the name intently and often. When we have found "aristocracy," we are forced to think of it in its connection. The harder we have to search for connecting links, the more we are forced to attend to the words. This *principle of forced attention* is, in fact, the object of the method.

The objection made to such associative systems is that they are too cumbersome when anything is to be recalled. While practising with one of these systems I noticed the tendency of the middle links to fall out; no matter how many intermediate words were inserted between "Aristotle" and "teach," after a while the two were involuntarily associated, with no thought of the middle links. This principle, which is in harmony with facts previously discovered concerning the association of ideas,[1] might be called the *obliteration of intermediate associations.*

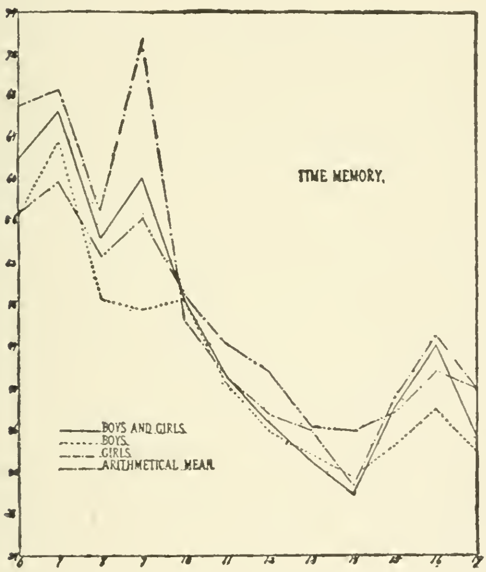


Fig. 177—Dependence of Time-memory on Age.

Like all our mental life, memory depends upon age. In a series of experiments on school children a tone was sounded for two seconds, then it was started again and the child was required to stop it when it had lasted as long as before. In all cases the second sound was made too short; the younger children often made the sound by memory only one fourth of

[1] The original experiments on mediate association of ideas are reported in my *New Psychology*, Ch. XIII.

its true length. As they grew older, the memory became more accurate.

Concerning the ages above seventeen no experiments have been made. We know, however, that old people gradually lose their memories. Indeed, we might say that memory is the ostensible friend who insists upon presenting us with a house bountifully furnished with the skeletons of past sins, but who in old age turns us out into the cold night of forgetfulness when we would gladly remember even the sins.

CHAPTER XIX

SUGGESTION AND EXPECTATION

IN his memoirs Robert-Houdin begins with a description of the effects of suggestion from the time of day:

"Eight o'clock has just struck: my wife and children are by my side. I have spent one of those pleasant days which tranquillity, work, and study can alone secure—with no regret for the past, with no fear for the future, I am—I am not afraid to say it—as happy as man can be.

"And yet, at each vibration of this mysterious hour, my pulse starts, my temples throb, and I can scarce breathe, so much do I feel the want of air and motion. I can reply to no questions, so thoroughly am I lost in a strange and delirious reverie.

"Shall I confess to you, reader? And why not? for this electrical effect is not of a nature to be easily understood by you. The reason for my emotion being extreme at this moment is that, during my professional career, eight o'clock was the moment when I must appear before the public. Then, with my eye eagerly fixed on the hole in the curtain, I surveyed with intense pleasure the crowd that flocked to see me. Then, as now, my heart beat, for I was proud and happy at such success.

"Do you now understand, reader, all the reminiscences this hour evokes in me, and the solemn feeling that continually occurs to me when the clock strikes?"

Some years ago I began experiments on the power of suggestion to produce hallucinations and illusions. One of the first arrangements is shown in Fig. 178. It consists of a plunge battery which sends a current through a resistance-wire whenever the circuit is completed by bringing the ends together in the hand of the experimenter. The person experimented upon takes the resistance-wire between his fingers; the experimenter, holding his hand out of sight, brings the ends of the circuit together and sets the battery in action by shoving down the plunger. The person experimented upon feels the wire become slightly warm after a few moments. The experiment is repeated a few times. After that the experimenter breaks the circuit by opening his hand unknown to the subject. The plunger is put down as before, and the unsuspecting person experimented upon inevitably feels the wire become warm, although it really does not do so.

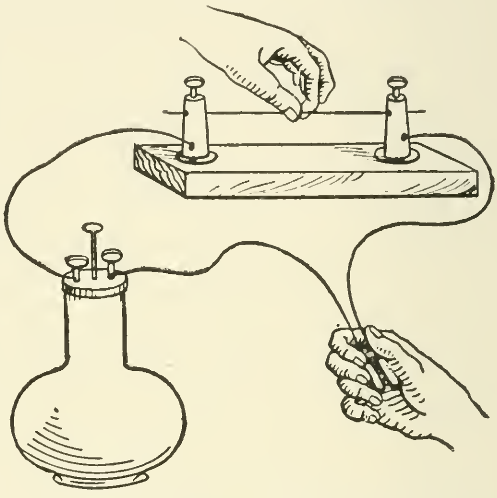


FIG. 178.—Producing a Hallucination of Warmth.

This method has been extended to include lights, tones, and actual objects. Thus a person was to press a key as soon as he could hear a faint tone in a telephone, which would be produced a moment after he had received a signal to be ready. The faint tone was actually produced a few times, but after that it was sufficient to give the signal only; he would regularly hear the tone again purely as a matter of suggestion. In another set of experiments a small blue bead was placed inside of the white circle shown through the door in Fig. 16. A tape measure was stretched from the door to a distant point. The person experimented upon was told to start at a distant point and walk toward the door until he could first distinguish the bead; he was then to read off on the tape measure just how far he was from the door. This he continued to do a number of times, the distance being noted each time. After the first few times the bead was slipped out of sight unknown to him; this made no difference, and he continued to see it and read off the distance as before. These two experiments were tried on a large number of persons and never failed.

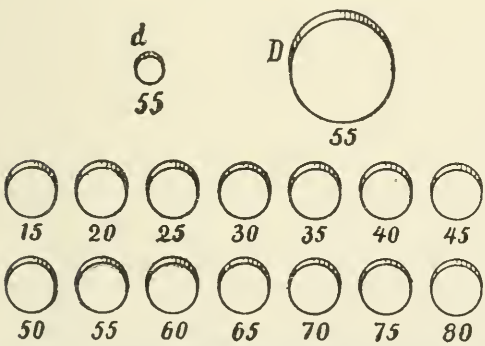


Fig. 179.—Blocks for Measuring the Effect of a Suggestion of Size.

Experiments in measuring the effects of suggestion of size can be made by a series of round blocks painted black; in appearance they are all just alike, but in weight they are different. The block *D* is a very big block ; you are to pick out that one of the series which appears of the same weight as the big one, when lifted between thumb and finger. You know nothing about the blocks except that, to the best of your belief, the big one is of the same weight as the medium-sized one picked out. You put them on the scales ; down goes the big one ; you judged it to be much lighter than it was. You try it over again as often as you please ; always the same result. By means of the scales you find the medium one that weighs exactly the same as the large one. Then you compare them by lifting ; nothing but the incontestable evidence of the scales will make you believe they are the same. After being familiar with the experiment for many years I still find the effect almost as strong as at first.

But how much? It is not sufficient to show that there is a suggestive effect, you must measure it. The difference in weight between the two blocks supposed to be equal gives the effect of suggestion in just so many ounces or grams.

In a set of experiments carried out on school children the medium-sized blocks were graded in weight from 15 grams to 80 grams. A large block *D* and a small block *d*, each of 55 grams, were successively compared with the set of graded blocks. The difference between the weight picked out for the larger one, *e. g.*, 20 grams, and that for the smaller one, *e. g.*, 70 grams, would give the effect of the difference in size between the two blocks. The difference in weight in this example would be 50 grams, which would be the result of the difference of six centimetres in the diameter of the blocks.

The effect of the suggestion depends upon the age. The results for the New Haven school children are indicated in Fig. 180. The figures at the bottom indicate the ages; those at the left the number of grams in the effect of suggestion.

About 100 children of each age from 6 to 17 were taken. The average effect of the suggestion was as follows: 6 years, 42 grams; 7 years, 45 grams; 8 years, 48 grams; 9 years, 50 grams; 10 years, 44 grams; 11 and 12 years, 40 grams; 13 years, 38 grams; 14 to 16 years, 35 grams; 17 years, 27 grams. For all ages

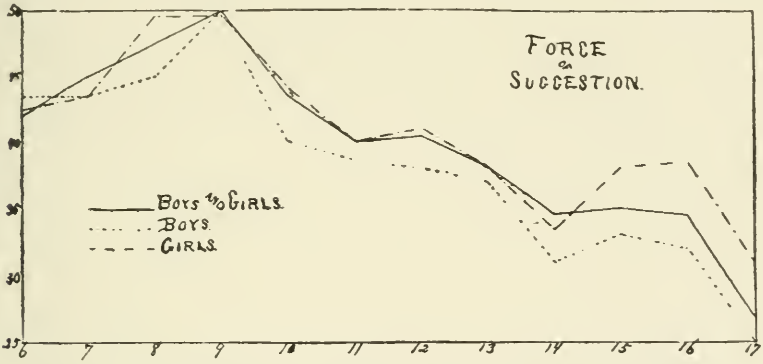


FIG. 180.—Dependence of the Effect of Suggestion on Age and Sex.

the average was above twenty-five grams. The suggestibility slowly increased from six years to nine years; after nine years it steadily decreased as the children grow older. The results, when separately calculated for boys and girls, showed that at all ages the girls were more susceptible to suggestion than the boys, with the exception of the age nine, where both were extremely susceptible.

These are the average results for large numbers of children. Many young people, however, were so susceptible that the set of middle-sized blocks did not range far enough to suit them. At the age of seven years 37 per cent. of the children declared that the large block was lighter than the lightest block, and that the small block was heavier than the heaviest. The actual difference between them was 65 grams; thus the effect of suggestion was more than the weight of the suggesting blocks *D* and *d*.

The factors that produce such a deception of judgment seem to consist in a suggestion—or, rather, a disappointed suggestion—of weight. Big things are, of course, heavier than little things of exactly the same kind. When we find two things of the same appearance but differing in size, the big thing *must* be heavier. This reasoning is all done without our suspecting it, and we unconsciously allow our judgment of weight to be influenced by the size as seen. When the eyes are closed and the blocks are lifted by strings, of course there is no illusion.

Which is the heavier, a pound of lead or a pound of feathers? A pound of lead, says the unsuspecting person, and then you guy him for his stupidity. But this poor fellow, who has been laughed at for centuries, is right. A pound is n't a pound all the world over; it all depends how the pound looks. A pound of lead *is* heavier than a pound of feathers. Try it with a pillow and a piece of lead pipe. No matter if the scales do say that they weigh just the same, the pound of lead is much the heavier as long as you look at it.

In the preceding case we have had a suggestion from sight alone. Similar effects are produced by differences in the span of the fingers. Suppose we have all our blocks of exactly the same diameter. We have one set just alike in size but differing in weight, and other blocks of just the same diameter and weight but differing in length, one being very long and the other very short. The experiments are made in the same way as before except that the eyes are closed. The suggestion arises from the difference in span of the fingers for a long block and a short one. By looking at the blocks with the eyes open, a sight-suggestion is added to the muscular suggestion.[1]

In the preceding cases it has been noticed how a suggestion causes a change in judgment; there is another field in which suggestion is very active, namely, the suggestion of movement. While a person is exerting his whole power on a dynamometer (page 69), let him observe contracting movements of your hand. He soon feels irresistible twitchings in his own hand and actually exerts still more force.

The suggestion of movement may even take effect against the will of the person concerned. A child in school with the Vitus dance will sometimes be involuntarily imitated by the others. A contagion of this kind that occurs in every-day life is the effect of gaping.

The orator and the actor make use of facial expressions and gestures intended to arouse similar impulses in their hearers and consequently to make their ideas more effective.

On the other hand, if you wish to get the thoughts of the person with whom you are speaking, you should

[1] Further researches on the size-weight illusion are described in my *New Psychology*, Ch. XIX.

look steadily at his face. His expression cannot help changing, and these changes tend to produce similar changes in your own face, thereby awakening various emotions of doubt, confidence, anxiety, etc. The readiness of women to read characters in this way may be due to their greater susceptibility to suggestion.

Every idea of a movement brings an impulse to movement. This is especially prominent in the many individuals who cannot keep a secret. The very reading and thinking about crimes and scandalous action produce a tendency to commit them. In some persons this influence is quite irresistible. As soon as one bomb-thrower attacks a rich banker, everybody knows that in a week half a dozen others will do the same. No sooner does one person commit suicide in such a way that it is strikingly described in the newspapers, than a dozen others go and do likewise.

A runner, prepared to start, can often cause the starter to fire his pistol unintentionally by starting to run. This runner is ahead of the starter by the amount of the starter's reaction-time, while the other runners are behind the starter by the amounts of their own reaction-times. As the reaction-time may readily amount to one-third of a second, the runner who relied on the suggestion may gain by a large fraction of a second.

The full significance of suggestibility is apparent when we remember that teaching, preaching, acting, public speaking, and pleading are forms of suggesting. The freaks of hypnotism are performed by suggestion. The faith-cures and the miraculous effects of the Grotto of Lourdes are benevolent suggestions. The ceremonials of our churches are suggestions bringing us into a religious frame of mind. The manipulations of the spiritualists and the monotonous blackness of a funeral are all forms of suggestion. How shall we develop the children so as to produce in them minds well-balanced in respect to suggestion? Is this not as important a task as learning to do percentage or to parse a sentence? The problem is still unsolved.

In expecting an event we have some thought in mind; this thought often acts as a suggestion.

The time of reaction depends on its expectedness; unexpected events require in general more time and produce very irregular results. It is customary to give a warning click about two seconds before an experiment. Experiments on one person gave an average reaction-time of 31Σ without warning and 19Σ with warning (see Chapter III).

It also makes a difference if the attention is directed to the stimulus expected or to the movement to be executed. In general the latter method is quicker, but with some persons the reverse is the case. Experiments made on one subject give as reaction-time to sound the result 22Σ when the attention was directed toward the expected sound, and 13Σ when it was directed toward the finger to be moved.

The expectation that a star will pass one of the hair-lines in a telescope produces differences in regard to the record of the time of its passage as actually recorded. This phenomenon, which led to the discovery of mental times, is more complicated than the simple cases of reaction-time and thinking-time that we have considered in Chapters III and IV.

Let me illustrate by a simple case how this happens. Suppose that we have to determine the time of the passage of a star at some distance from the pole across the meridian. We may employ an old astronomical method which is still sometimes used for time-determinations, and which is called the "eye and ear method." A little before the time of the expected passage, the astronomer sets his telescope, in the eye-piece of which there have been fixed a number of clearly visible vertical threads, in such a way that the middle thread exactly coincides with the meridian of the part of the sky under observation. Before looking through the instrument, he notes the time by the astronomical clock at his side, and then goes on counting the pendulum-beats while he follows the movement of the star.

Now, the time-determination would be very simple if a pendulum-beat came at the precise moment at which the star crosses the middle thread. But that, of course, happens only occasionally and by chance; as a rule, the passage occurs in the interval between two beats. To ascertain the exact time of the passage, therefore, it is necessary to determine how much time has elapsed between the last beat before the passage and the passage itself, and to add this time—some fraction of a second—to the time of the last beat. The observer notes, therefore, the position of the star at the beat directly before its passage across the middle thread, and also its position at the beat which comes immediately after the passage, and then divides the time according to the length of space traversed.

If *f* (Fig. 181) is the middle thread of the telescope, *a* the position of the star at the first beat, and *b* at the second, and if *af* is twice as long as *fb*, then $\frac{2}{3}$ of a

Fig. 181.—Actual Positions of the Star at the Pendulum-beats.

second must be added to the last counted second.

It has already been told (page 27) how astronomers disagree in their records although the star had exactly the same position for all. A constant and regular difference, such as this actually is, can be explained on the assumption that the objective times of the actual events and the times of their notice by the observer are not identical, and that these times show further differences from one another according to the individual observer. Now, attention will obviously exercise a decisive influence upon the direction and magnitude of such individual variations. Suppose that one observer is attending more closely to the visual impression of the star. A relatively longer time will

Fig. 182.—Supposed Positions with Visual Attention.

elapse before he notices the sound of the pendulum-beat. If, therefore, the real position of the star is *a* at the first beat and *b* at the second (Fig. 182) the sound will possibly not be noticed till *c* and *d*, so that these appear to be the two positions of the star. If *ac* and *bd* are each of them $\frac{1}{3}$ of a second, the passage of the star is plainly put $\frac{1}{3}$ of a second later than it really should be.

On the other hand, if the attention is concentrated principally on the pendulum-beats, it will be fully ready and properly adjusted for these, coming as they do in regular succession, before they actually enter consciousness.

Hence it may happen that the beat of the pendulum is associated with some point of time earlier than the exact moment of the star's passage across the meridian.

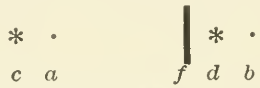


FIG. 183.—Supposed Positions with Auditory Attention.

In this case you hear too early, so to speak, just as in the other case you heard too late. The positions *c* and *d* (Fig. 183) are now inversely related to *a* and *b*. If *ca* and *db* are, say, $\frac{2}{9}$ of a second, the passage is put $\frac{2}{9}$ of a second earlier than it really occurs. If we imagine that one of two astronomers observes on the scheme of Fig. 182, the other on that of Fig. 183—in other words, that the attention of the one is predominantly visual, that of the other predominantly auditory—there will be a constant personal difference between them of $\frac{1}{3} + \frac{2}{9} = \frac{5}{9}$ of a second. You can also see that smaller differences will appear where the manner of observing is the same in both cases but with differences in the degree of the strain of the attention; while larger differences must point to differences like those just described, in the direction of the attention.

CHAPTER XX

GENERAL PROBLEMS

HAVING become familiar with some of the methods and results of psychological work, we are now in a position to discuss some of the more general problems of the science. This is exactly the opposite of the procedure of the psychologist of the old school, who in the quiet of his library began and ended with "looking into his own mind," describing what he saw there and speculating on its fundamental laws and the nature of the soul. This "arm-chair" psychology—as I have ventured to term it—was the only psychology possible before the new methods were devised; its representatives included some of the greatest thinkers the world has seen—Aristotle, Locke, Hume, Hamilton, etc. But the very same method led other more or less clever men to views of the mind that to-day seem either silly or insane. I need only mention the doctrine of Schelling, that the contents of dreams are truer than our waking experiences; or the statements of an American college professor that through Mrs. Piper, a hysterical woman, he was able to communicate with the spirit of his uncle and thus find out when his little brother had had the measles; or the delusion of "thought transference," whose existence was stoutly maintained by an English professor in spite of the fact that the first case turned out to be a swindle by two clever little girls, and also of the fact that no "thought transference" could ever be verified by a laboratory experiment.

All this rubbish we can—and must—throw overboard, as the other sciences have done, one after the other, ever since Galilei introduced experimental methods to replace vague speculation. We must begin with the careful collection of facts by modern methods. These methods include in the first place unaided observation of normal persons; its results are always so contaminated by error (pp. 2—8) that we can rely on it only for general outlines of the facts and for suggestions for further work. To improve observations we make experiments (p. 11), and are thus able to get uncontrovertible records. Nearly every portion of mind has now been opened up to experimental methods; even the feelings have at last yielded (Chapter XVI). Just so far as experiment goes do we have knowledge that can be relied on; where it has not only yet gone—as in the study of the emotions—we have guesswork, and that is worse than nothing. When measurements are introduced into observations with and without experiments, we have definite results of the most reliable kind.

Clinical observation of defects of sensation, emotion, and will, and of mental diseases is another method of the highest importance; it is often aided by experiment and measurement. The introduction of this method into psychological work is quite new; at each advance it has produced revolutionary results. The whole doctrine of colour sensation (p. 126) rests upon the study of defects of colour vision. Entirely new laws of attention and memory are now being worked out by experiments on mentally unsound persons. Pathological cases are, indeed, striking experiments performed by nature which call our attention to unsuspected facts. At present we have no inkling of the methods to be employed in investigating the emotions and moods, but a study of their abnormalities among the nervous and the insane would soon give the clues.

We have to begin, then, all studies of mental life by the most careful collection of facts, arranging experiments, measurements, and records at each step, and doubting every result till it is proven. Along with this collection of facts we begin to formulate general laws, such as the law of practice, the law of fatigue, etc. On the basis of such general laws we can speculate, if we wish, concerning such general questions as the "nature of mind," "the immortality of the soul," etc. Yet these problems can be answered only by belief; psychology—that is, mental science in the newer meaning—has not furnished and cannot furnish any facts that bear upon them.

What is the material of psychological investigations? It consists in the first place of my own sensations, feelings, and volitions. At the present moment, for example, I am aware of a room in which I sit, of a desk, chairs, books, etc., of persons in the room, and so on. All these things appear to me as patches of colour, and as forms of various kinds at various distances. I see that my hand touches these patches of colour and I feel that they have consistency, etc. Some of these patches of colour move independently of me, such as the clock, or the tuning fork, or the drum when once set in motion; these I use as registering apparatus to indicate when a colour appears to me and when I make a responsive movement. In this way I get records of my reaction-time (p. 13) and thinking-time (p. 37), and deduce the laws of my thinking, feeling, and willing as far as concerns time. In similar ways I arrange other apparatus—which I see as patches of colour, feel as heavy, cold, etc., but which I can prove to act independently of me—to experiment on my various sensations, feelings, and emotions (Chapters II to XVI). Thus one portion of the material of psychological investigation consists of my own mental experience. The investigation of this material has been called the "introspective method"; we had better speak of the "introspective material" of psychology.

Among the patches of colour I see about me there are some that I consider human beings like myself. I also believe that they have sensations, feelings, and volitions which are in the main like my own. I apply my apparatus to them and find both agreement and disagreement in the results. As far as they agree, I assume that these people have the same sensations, feelings, and volitions as myself; where they disagree, I deduce differences. For example, in sorting wools in the test for colour-blindness I find that most persons sort as I do; I therefore conclude that we see the colours alike. About four per cent., however, sort differently; half of them confuse light greens with greys, and half confuse dark greens with greys. They also make characteristic confusions of greens with reds, etc. I assume that they see colours, not as I do, but quite differently; and that they fall into two groups (p. 151). Finer experiments and measurements cause me to distinguish still other persons who see colours differently. Still finer measurements show that, whereas the majority of people agree with my results, yet each one of them has small peculiarities. In this way I proceed through all the experiments of psychology and draw conclusions concerning the resemblance of each person's sensations, feelings, and volitions to my own.

This material may be termed the "objective" as contrasted to the "introspective," or "subjective," material.

I never see another person's feeling of pleasure or his sensation of colour. Indeed, I can never hope to do so; for all anatomical dissections of and operations on persons reveal only inorganic materials such as water, salt, etc., and organic forms composed of cells. Yet I find so many resemblances between the responses of a living person to those I make myself that I feel justified in assuming that he has a mind as like my own as the experiments point out. This same reasoning applies not only to human beings but to animals. There can be no doubt that the dog who performs reactions (p. 46) in certain experiments just as I would, has the mental experiences that I know as perception, discrimination, choice, and volition. We can thus build up the mental life of a dog with its colours, sounds, volitions, love, anger, fatigue, etc., as nearly like our own as the experiments justify us in assuming.

The attempt has been made to specify some special part of the body as the place where the person's (or animal's) mental life is located. In past centuries speculation has asserted the liver, or the heart, etc., to be such an "organ of mind." At the present day we have evidence that the brain is the organ most intimately connected with our mental life. This evidence consists mainly of cases of brain disease, where injury to the brain is found to have accompanied mental disturbance. We know, for example, that softening of one part of the brain is accompanied by "mental blindness," whereby the person can see everything perfectly but can not recognise it; he sees the candle flame but may call it a hat or may try to eat it if told that it is an apple. Such localisations of the mental faculties are very valuable in medical work but the study of them is hardly in place in an elementary work on psychology.

From the beginning psychologists have attempted to classify the contents of mind. Such items as colours, sounds, tastes, smells, touches, hot and cold impressions, joint-, muscle- and tendon-experiences, and the pains have been lumped together as "sensations"; it is quite convenient to keep the term in this sense to denote merely experiences of a certain kind. Experiences of another kind (p. 178) we term the "feelings"; those of still another kind we term "volitions" or acts of will. Combinations of the sensations produce "perceptions"; we perceive the orange as having colour, taste, smell, resistance, form, etc. Combinations of perceptions with the traces of past experience we call "apperceptions."

All these experiences we regard as being in the present; from them we distinguish others, called "memories," which carry with them the indications that they were sensations, feelings, and volitions at some past time. We also distinguish the "imaginations" from the rest by the fact that we regard them as unreal. "Hallucinations" are experiences that appear to be real but that can be proven to be unreal. By "ideas" we generally mean summarised abstracts of our memories concerning things or events; sometimes the term is applied to groups of perceptions.

"Sensations" have sometimes been defined as the elements of mental life. In such a sense there are only three sensations of colour, namely, elementary red, green, and blue; all the hues, shades, tints, and greys are compounds. The six feelings and the various impulses would also be sensations according to this classification. Sensations have also been defined as the mental experiences due to external stimulation. Thus, colours are due to light falling upon the eye, tones to air-vibrations coming to the ear, etc. In like manner we would speak of the sensations from the lining of the abdominal cavity—the peritoneum—which become painful in colic, or sensations from the duct of the gall-bladder which arise during the passage of gall-stones, and so on, although the external stimulation is within the body.

Our mental life is governed partly by the impressions from the world about us. A certain sound makes us think of the door bell; this starts us to go to the door. A different sound arouses the thought of dinner and we go to the dining-room. Still another sound sets us thinking of the opera; scene after scene, aria after aria "passes through our mind." Such experiences we describe by saying that an external stimulus arouses us to a response or starts associations of ideas.

The response to a stimulus may be "impulsive" like the jump when a fire-cracker goes off. It is "deliberate" when we take our time about it. The reaction in the first case is a simple one including perception and volition (p. 30), in the other a complex one including discrimination and choice (p. 40).

For most purposes we may assume that the association of ideas (p. 41) proceeds according to the rule of coincidence; an idea is followed by one that has something in common with it. This common factor may be some component; *e. g.*, the word "street" may be followed by the thought of the word "strong," both beginning with the same letters "str." Or the common factor may be the larger idea of which both ideas are part; *e. g.* "street" may be followed by "car," because both have occurred as parts of the idea "street car."

This rule does not explain why on one occasion "strong" is associated and on another occasion "car." My explanation of the association of ideas is as follows:

Every idea in the mind fades away at first rapidly, then more and more slowly (see the memory curve p. 209); although it soon becomes so faint that we no longer notice it, it never entirely disappears; its intensity approaches zero asymptotically, as the mathematicians say. Whenever the same idea enters the mind again, it is strengthened by what remains of the first one. This may occur any number of times, the idea gaining each time. It is a familiar experience with all of us that the oftener we see a thing the more often it comes into the mind at other times.

This law holds good of each element of the ideas; like elements fuse although they may be in different ideas. For example, the elements "s-t-r" fuse together when such a series of words as "struggle, strive, strict, straw, strong," etc, is repeated. Now let a new idea enter, say "street"; the elements "str" fuse with the same ones of the series of words and this makes them so strong that they determine the association. This is why "strong" is associated and not "car." We can carry the same principle further and explain why "strong" and not "strive" was associated. These principles the reader can investigate for himself. He can have a person read over many times a long list of words; then on calling out to him some word, he will be able to notice the influence of the list on the associations.

There are thus three fundamental laws of association of ideas: 1, each element of an idea persists in an intensity that steadily decreases toward but never reaches zero; 2, every element of an idea adds its intensity to the residual intensity of every preceding element of the same kind; 3, an element adds to the intensity of any other element with which it was previously connected.

During our waking hours our associations of ideas are continually started anew by impressions from the world about us; the persons talking to us, the sights we see, the sounds we hear, all force us to think along certain lines. In revery we are left more to ourselves and our thoughts have freer play. In sleep the impressions from outside are few and weak; we dream long continued stories which, freed from outside influences, may appear quite absurd when we awake. Yet, although our thoughts are freest in dreams, they are still influenced by impressions from the skin, intestines, etc.

"Is mind governed by law?" By "law" we mean an established sequence of events. If we let go of a box, it falls to the ground; this we say is an illustration of the law of gravitation. If the box does not fall, we may do one of two things. We may say: "Here is a case that does not conform to law; therefore we must admit the existence of mysterious forces concerning which we are at liberty to believe anything we please." Such reasoning produces the "mystics," whose fundamental principle is, that, since there are things we cannot explain by laws, therefore belief is at liberty to set up any laws it pleases. This is the basis of clairvoyance, spiritualism, thought-transference, telepathy, palmistry, and similar delusions.

When the box does not fall, the common-sense man says: "The case apparently does not conform to law, but let us inquire if some unseen or undiscovered force is not counteracting gravitation. Even if I myself cannot find it, yet I believe only in the action of forces according to laws and I will search for the hidden one or leave more able men to do so." On investigating the box he finds an unnoticed string that holds it up, or some similar arrangement that had escaped him. Men of this kind—whether trained or not—are men of scientific habits of thought. The advance of science is one continuous battle of the scientists against the mystics.

Applying the principles of science to mental life, we establish the laws of reaction, of habit, etc. Where these laws do not suffice, we simply say so and wait for further information; we absolutely reject all mystic explanations. Mind, therefore, we assume to be governed by law even to its finest details.

CHAPTER XXI

MATERIALISM AND SPIRITUALISM IN PSYCHOLOGY

IN the good old days, now happily gone forever, when psychology was a matter of doctrine, we used to hear of materialistic psychology, spiritualistic psychology, the psychology of Hamilton, the psychology of Hegel, English psychology, German psychology, etc., etc.

Nowadays it is just as absurd to speak of anybody's system of psychology as to speak of anybody's system of chemistry. There is one science of chemistry to which all scientific chemists are contributors; there is one science of psychology which all scientific psychologists make their humble efforts to develop. How this has come about I am going to tell by translating a few pages from Wundt's *Vorlesungen über Menschen und Thierseele.*

"The earliest psychology is materialism. The soul is air or fire or an ether; it remains, however, material nothwithstanding the efforts to lighten and thereby to spiritualise the matter. Among the Greeks it was Plato who first freed the soul from the body, whereby he made it the ruling principle of the latter. He thus opened the path for the one-sided dualism which regarded sensory existence as the contamination and degradation of a purely mental being. Aristotle, who united a wonderful sharpness of observation to his gift of speculation, sought to soften this contrast by infusing the soul into matter as the vivifying and constructive principle. In the animals, in the expression of the human form in repose and motion, even in nourishment and growth, he saw direct effects of mental forces, and he drew the general conclusion that the soul brings forth all organic form just as the artist forms the block of marble. Life and soul were for him the same ; even the plant had a soul. Yet, Aristotle, like no one before him, had studied into the depths of his own consciousness. In his work on the soul, the first book treating psychology as an independent science, we find the fundamental processes carefully distinguished and—as far as possible in his time—explained as to their relations.

"The Aristotelian psychology, and especially its fundamental doctrine that the soul is the principle of life, governed the whole of the Middle Ages. At the beginning of modern times here, as in other subjects, a return to the Platonic views began to weaken its power. Soon a new influence was associated : the revival of the modern natural sciences and the mechanical views of the world which they spread abroad. The result of the conflict was the birth of two fundamental views in psychology, which down to the present day have fought each other in the field of science : spiritualism and materialism. Strange to say, the very same man was of primary importance for the development of both. Descartes, no less great as mathematician than as philosopher, defined, in opposition to the Aristotelian psychology, the soul exclusively as a thinking being ; and, following the Platonic views, he ascribed to it an existence, originally apart from the body, whence it derived as permanent property all those ideas which go beyond sensory experience. Itself occupying no space, this soul was connected with the body at one point of the brain, in order to receive the influences from the outer world and in its turn to exercise its influence on the body."

The later spiritualism advanced but little beyond this theory of Descartes. Its last great representative was Herbart. He developed in thoroughly logical manner the idea of a simple soul substance, according to Descartes. Herbart was of very great service to the new psychology in a certain way, and we shall say something about his work later, but his spiritualistic psychology was a total failure. His attempts at deducing the facts of mental life from the idea of a simple soul and its relations to other beings proved fruitless. His efforts showed more clearly than anything else could do that this pathway was an impossible one for psychology. The idea of a simple soul substance had not been derived from actual observations of mental life, but had been arbitrarily and unreasonably asserted; the facts were to be forced to fit.

Descartes contributed to the development of modern materialism in two ways, by his strictly mechanical view of nature in general and by his treatment of animals as automats. Man alone had a mind; animals were machines. But if the many evidences of thinking, feeling, and willing among animals can be explained physiologically, why cannot the same explanation be used for man? This was the starting point for the materialism of the seventeenth century.

"For materialism all facts of thinking, feeling, and doing are products of certain organs in the nervous system. Any observation of the facts of mind is valueless until such facts can be explained by chemical and physical processes. Thinking is a production of the brain. Since this process stops when the circulation of the blood stops and life ceases, therefore thought is nothing but an accompaniment of the materials of which the brain is composed."

Down to the present day modern materialism has not gotten beyond this point—mental life is a product of the brain; psychology is merely physiology of the brain.

"Our feelings, thoughts, and acts of will, however, cannot be observed as all phenomena of nature have been observed. We can hear the word that expresses a thought, we can see the man who formed it, we can dissect the brain that thought it; but the word, the man, the brain—these were not the thought."

A feeling of anger is accompanied by an increase of blood in the brain; but no matter how minute our knowledge of the chemical processes between the blood and the brain substance may be, we know that we can never discover the chemistry of anger.

But, says materialism, these material processes may not be the thoughts, yet they produce them. Just as the liver produces bile, just as the contraction of muscle causes motion, so are our ideas and emotions produced by blood and brain, by heat and electricity. Yet a very important difference has been overlooked. We can show how the bile is produced by chemical process in the liver; we can show how the movement is the result of chemical processes in the muscle; but brain processes give us no information of the way thoughts are produced. We can understand how one bodily movement produces another movement, how one emotion or sensation changes to another motion or sensation; but how a motion of molecules or a chemical process can produce thought is what no system of mechanics can make clear.

These vagaries of materialism have called attention to the study of the relations between mind and brain, and we have had "mental physiologies," even from those who are not materialists. The study of what happens in the brain or in any part of the body when we are angry, or when we think of an apple, is of course an immensely valuable thing. The absurdity arises when it is asserted that every mental fact is merely an appendix to some brain process; that, for example, we do not feel merry at the thought of a joke, but that certain chemical processes in the brain produced the thought of the joke and at the same time set going other chemical processes that produced the merry feeling. There are many volumes of so-called "psychology" in which each mental process is translated into some imaginary (for we have no facts on the subject) movement of brain molecules, which in some imaginary fashion sets up another imaginary movement, which is translated into a second mental process that really followed the first one according to a simple psychological law.

But the strife between spiritualism and materialism is almost passed.

"It has left no contribution to science, and no one who carefully examines the subject of the strife can wonder at such a result. For what was the central point of the battle of opinions? About nothing else than the questions concerning the soul, its seat, its connection with the body. Materialism here fell into the same fault as spiritualism. Instead of beginning upon the facts that were observed and investigating their relations, it busied itself with metaphysical questions for which answers can be found only—if ever—through a completely unprejudiced—*i. e.*, at the start free from every metaphysical supposition—investigation of the facts of experience."

Starting from entirely different points of view, both spiritualism and materialism have landed in utterly fruitless suppositions. The reason lay in the methods which they employed. To suppose that anything could be gained by vague speculation on mental life was folly equalled only by the belief that dissecting brains would lead to a knowledge of mind. Both parties forgot one point—namely, to examine the facts of mind itself.

It is this forgotten duty that led to the new psychology—a psychology of fact. This psychology of mental life, this science of direct investigation of our thinking, feeling, and doing, is neither spiritualism nor materialism; it has no speculations of either kind to offer. It confines itself strictly to the domain of fact. As long as they can set themselves in harmony with the facts, the Hegelian philosopher and the Feuerbachian materialist have equal rights. When they go beyond the facts, they may settle the question between them; the new psychology is very thankful that it has nothing to do with either.

CHAPTER XXII

THE NEW PSYCHOLOGY

THE facts we have been considering in this book have been facts of mind, not of the physical world. The beautiful colours we see are—the physicists tell us—only vibrations of ether; the physical world has no colour, the colours exist only when we are present. Physical vibrations of the air are to us tones. Certain mechanical movements are to us pressures. Feelings and will-impulses may betray themselves by movements or otherwise; in themselves they are mental facts. In short, we may say that all the facts, as we know them, are mental facts. The science of these facts is psychology.

But what is the *new* psychology? The new psychology is entitled to its special adjective because it employs a method new in the history of psychology, although not new in the history of science.

The old psychologist, like Locke, Hamilton, and many of the present day, sits at his desk and writes volumes of vague observation, endless speculation, and flimsy guesswork. The psychologist of the new dispensation must see every statement proven by experiment and measurement before he will commit himself in regard to it.

The difference between the old and the new is not one of material; the subject is the same for both, namely, the facts of mind. The difference lies in the carefulness with which the information in regard to these phenomena is obtained. Instead of careless observation and guesswork the utmost care and self-sacrificing labour are expended in the laboratory in order to obtain single facts. This method of careful, scientific work is unintelligible to the men of the old school. The method of experiment "taxes patience to the utmost" and "could hardly have arisen in a country whose natives could be *bored*."

Who are the men to whom we owe the regeneration? Of course, the psychological awakening is only a part of the great movement by which many of the sciences have successively emerged from the scholasticism of the Middle Ages. Mathematics, physics, chemistry, biology, and others are now free and fruitful sciences; psychology has just joined the group.

Sir William Hamilton is the one to whom we must look back as having vindicated the right to build psychology upon observations and not to deduce it from philosophical prejudices.

In Germany the natural revolt from the dull scholasticism of the psychology of Wolff and the mad speculation of Schelling was led by Herbart. The philosopher, psychologist, and educator, Herbart, was born in 1776. He became professor of philosophy at Göttingen; later he succeeded Kant as professor of philosophy in Königsberg, where he died in 1841. He is best known for his works on education; these, being founded on his psychology, have led educational people to adopt the Herbartian psychology with the Herbartian pedagogy. The Herbartian pedagogy, with the improvements of its followers is, to-day perhaps the best system and guide that we have.

To Herbart as a psychologist we also owe a debt. The old faculty-psychology, with its groundless and endless speculation, aroused his ire; he set about producing a new psychology. In the first place, he determined to start from the facts as he observed them in his own mind; this was in itself a great step. You have probably heard of the mediæval student, who at the time when the discovery of spots on the sun began to be talked about, called the attention of his old instructor to them. The reply was: "There can be no spots on the sun, for I have read Aristotle's works from beginning to end and he says the sun is incorruptible. Clean your lenses, and if the spots are not in the telescope, they must be in your eye."

Fig. 184.—Johann Friedrich Herbart.

This debt we owe to Herbart is a great one; the other debt we owe him is for a different reason. Mathematics, we all know, is the fostering mother of the sciences. What was more natural than to place a discredited psychology in her care? This is what Herbart attempted. On the basis of his observations he proceeded to build up his mathematics of ideas. His results are very curious; for example, if you have an idea in your mind and another one wishes to get in, there occurs a strife between them and they press against each other with a force proportional to $\frac{a}{\sqrt{a+b}}$. Of course, the whole thing was ahead of time. Mathematics makes use of symbols for *quantities;* when you speak of a distance t, you mean *just so many* inches or centimeters or miles; t represents a number. But when Herbart speaks of an idea with the intensity a, there is no method of giving any quantitative indication of how great this intensity is; he knows of no measure of intensity, and his use of symbols is absolutely meaningless. No mathematician would ever dream of such folly. Herbart revolted against metaphysical speculation, but fell into a kind of mathematical speculation that was no less futile.

But if all that was lacking was merely the quantitative expression for psychological facts, why not get to work and measure them, just as in astronomy and physics? But how? How can we measure the intensity of a pain, or the time of thought, or the extent of touch? The matter seemed to Herbart really incomprehensible.

One of the surest ways of being put in the wrong is to say that something can never be done. Comte, the philosopher, once said that it would be forever impossible to tell the composition of the stars; forty-three years later the use of the spectroscope enabled astronomers to analyse each one. Herbart declared that "psychology must not experiment with man; and instruments thereto do not exist"; in another place he asserts that "psychological quantities are not presented in such a way that they can be measured; they allow only an incomplete estimate." Nineteen years later Fechner published his great work on psychophysics, in which he showed how to experiment on mental processes and measure psychological facts.

Other influences had been tending toward the development of psychology, and, although Fechner was the first really to start the new psychology, he is only the logical outcome of the progress of thought in other lines.

Fig. 185.—Gustav Theodor Fechner.

Both the physicist and the physiologist frequently come to problems where mental life is involved. Physicists still amuse themselves by the so-called optical illusions and the beautiful phenomena of contrast, although there is not a particle of physics in any way connected with the subject. Physiologists have always been forced to consider questions of sensation, emotion, and volition, in order to draw conclusions in regard to bodily processes. Many names might be mentioned in this connection, but one is of special importance, that of Ernst Heinrich Weber. This distinguished physiologist and physicist wrote a semi-psychological treatise on "Sensations of Touch and the Internal Feelings," which not only induced later physiologists to continue the work, but was also the direct stimulus for Fechner. This influence we may call the physiological one; it has done its main psychological service in outlining the sensations in a qualitative manner. Fechner may be considered as the builder of psychology representing the final passage from the qualitative to the quantitative.

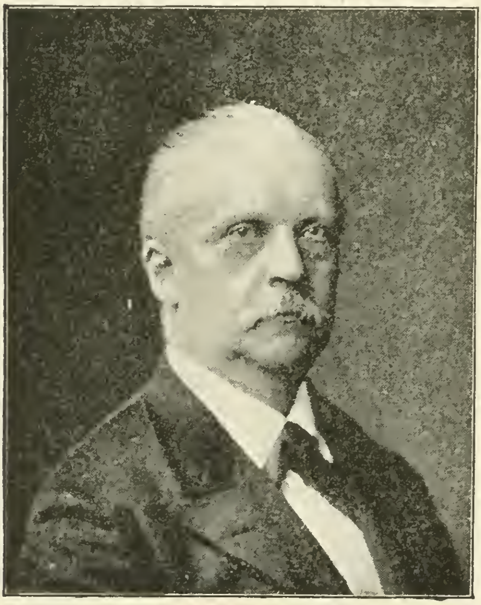


FIG. 186.—Hermann von Helmholtz.

Fechner (1801–1887) was the founder of experimental psychology. While professor of physics at the University of Leipzig he invented and worked out the methods which we have used in finding the threshold (see Index). His greatest works were, *Elemente* *der Psychophysik* and *Revision der Hauptunkte der Psychophysik.* So much of Fechner is embodied in all our psychological work that it is useless to attempt more than to indicate his main services. I will sum them up as: (1) the invention of new methods of measuring the intensity of sensations; (2) the introduction of new methods of calculating results; (3) the development of laws concerning the relation of intensities of sensations; (4) the foundation of experimental æsthetics; and (5) numerous smaller investigations and observations.

A greater than Fechner was to come. Mathematician, physicist, physiologist, psychologist, and technologist, Hermann von Helmholtz has given to the psychology of sight and hearing the best his sciences had to give. We cannot claim him as a psychologist, his genius was too great for a science still so limited. Nevertheless there are few to whom psychology owes more.

We must turn back to the last century for a second current of thought that was to develop psychology. This time it was an astronomer puzzled by mistakes of his own method The story has been told in chapters III and XIX. The time measurements of mental phenomena were afterwards taken up and developed by Wundt, in whose laboratory they are still continually pushed further.

Wilhelm Wundt, born at Neckerau in Baden in 1832, was a student of medicine at Tübingen, Heidelberg, and Berlin. His academical career began with a place as instructor in physiology at Heidelberg, where in 1863 he published his *Lectures on Human and Animal Psychology.* In 1864 he was made assistant professor of physiology. In 1866 he published *The Physical Axioms and their Relations to the Principles of Causality.* In 1874 he published the *Outlines of Physiological Psychology.* In the same year he was called to Zürich as professor of philosophy, in 1875 to Leipzig. His later works have covered most sections of philosophy: *Logic, Essays, Ethics, System of Philosophy.* His latest achievement is his *Folk Psychology.* The institute at Leipzig has taken up not only the time measurements and the work begun by Fechner, but also nearly every portion of psychology accessible to experiment.

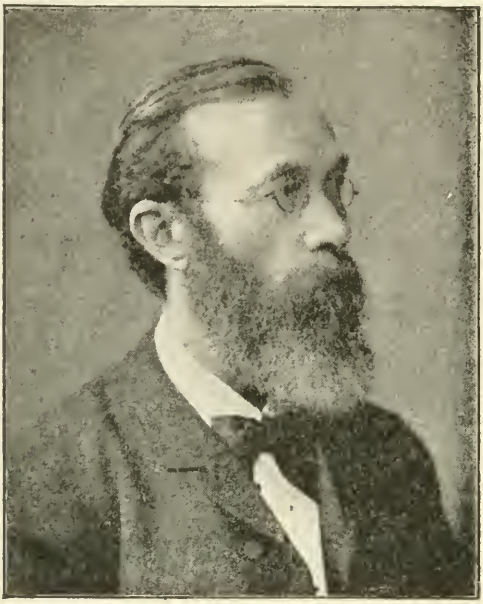


FIG. 187.—Wilhelm Wundt.

These men are merely the most prominent figures in the army of investigators that has created the new psychology. The others are no less deserving of credit but it is impossible to mention them singly on account of their multitude.

INDEX

A Selection from the Catalogue of

G. P. PUTNAM'S SONS

7.—A Book of Whales. By F. E. BEDDARD, M.A., F.R.S. Illustrated. 8°. $2.00.

"Mr. Beddard has done well to devote a whole volume to whales. They are worthy of the biographer who has now well grouped and described these creatures. The general reader will not find the volume too technical, nor has the author failed in his attempt to produce a book that shall be acceptable to the zoölogist and the naturalist."—*N. Y. Times.*

8.—Comparative Physiology of the Brain and Comparative Psychology. With special reference to the Invertebrates. By JACQUES LOEB, M.D., Professor of Physiology in the University of Chicago. Illustrated. 8°. $1.75.

"No student of this most interesting phase of the problems of life can afford to remain in ignorance of the wide range of facts and the suggestive series of interpretations which Professor Loeb has brought together in this volume."—JOSEPH JASTROW, in the *Chicago Dial.*

9.—The Stars. By Professor SIMON NEWCOMB, U.S.N., Nautical Almanac Office, and Johns Hopkins University. 8°. Illustrated. Net. $2.00. (By mail, $2.00.)

"The work is a thoroughly scientific treatise on stars. The name of the author is sufficient guarantee of scholarly and accurate work."—*Scientific American.*

10.—The Basis of Social Relations. A Study in Ethnic Psychology. By DANIEL G. BRINTON, A.M., M.D., LL.D., Sc.D., Late Professor of American Archæology and Linguistics in the University of Pennsylvania; Author of "History of Primitive Religions," "Races and Peoples," "The American Race," etc. Edited by LIVINGSTON FARRAND, Columbia University. 8°. Net, $1.50 (By mail, $1.60.)

"Professor Brinton his shown in this volume an intimate and appreciative knowledge of all the important anthropological theories. No one seems to have been better acquainted with the very great body of facts represented by these sciences."—*Am. Journal of Sociology.*

11.—Experiments on Animals. By STEPHEN PAGET. With an Introduction by Lord Lister. Illustrated. 8°. Net, $2.00. (By mail, $2.20.)

"To a large class of readers this presentation will be attractive, since it gives to them in a nut-shell the meat of a hundred scientific dissertations in current periodical literature. The volume has the authoritative sanction of Lord Lister."—*Boston Transcript.*

12.—Infection and Immunity. With Special Reference to the Prevention of Infectious Diseases. By GEORGE M. STERNBERG, M.D., LL.D., Surgeon-General U. S. Army (Retired). Illustrated. 8°. Net, $1.75. (By mail, $1.90.)

"A distinct public service by an eminent authority. This admirable little work should be a part of the prescribed reading of the head of every institution in which children or youths are gathered. Conspicuously useful."—*N. Y. Times.*

13.—Fatigue. By A. MOSSO, Professor of Physiology in the University of Turin. Translated by MARGARET DRUMMOND, M.A., and W. B. DRUMMOND, M.B., C.M., F.R.C.P.E., extra Physician, Royal Hospital for Sick Children, Edinburgh; Author of "The Child, His Nature and Nurture." Illustrated. 8°. Net, $1.50.

"A book for the student and for the instructor, full of interest, also for the intelligent general reader. The subject constitutes one of the most fascinating chapters in the history of medical science and of philosophical research."—*Yorkshire Post.*

14.—**Earthquakes.** In the Light of the New Seismology. By CLARENCE E. DUTTON, Major U. S. A. Illustrated. 8°. Net, $2.00. (By mail, $2.20.)

"The book summarizes the results of the men who have accomplished the great things in their pursuit of seismological knowledge. It is abundantly illustrated and it fills a place unique in the literature of modern science."—*Chicago Tribune.*

15.—**The Nature of Man.** Studies in Optimistic Philosophy. By ÉLIE METCHNIKOFF, Professor at the Pasteur Institute. Translation and introduction by P. CHAMBERS MITCHELL, M.A., D.Sc. Oxon. Illustrated. 8°. Net, $2.00.

"A book to be set side by side with Huxley's Essays, whose spirit it carries a step further on the long road towards its goal."—*Mail and Express.*

The following volumes are in preparation :

Meteors and Comets. By Professor C. A. YOUNG, Princeton University.

The Measurement of the Earth. By Professor C. T. MENDENHALL, Worcester Polytechnic Institute, formerly Superintendent of the U. S. Coast and Geodetic Survey.

The History of Science. C. S. PIERCE.

Recent Theories of Evolution. By J. MARK BALDWIN, Princeton University.

The Reproduction of Living Beings. By Professor MARCUS HARTOG, Queen's College, Cork.

Man and the Higher Apes. By D.. \. KEITH, F.R.C.S.

Heredity. By J. ARTHUR THOMPSON, School of Medicine, Edinburgh.

Life Areas of North America: A Study in the Distribution of Animals and Plants. By Dr. C. HART MERRIAM, Chief of the Biological Survey, U. S. Department of Agriculture.

Age, Growth, Sex, and Death. By Professor CHARLES S. MINOT, Harvard Medical School.

History of Botany. By Professor A. H. GREEN.

Planetary Motion. By G. W. HILL.