

THE RELATION OF PERCEPTIVE AND REVIVED MENTAL MATERIAL AS SHOWN BY THE SUBJECTIVE CONTROL OF VISUAL AFTER-IMAGES.

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I.

The existence of mental content of these two sorts, is not in question here. Indeed, the fact of relation between them is not in question. There are mental processes which arise primarily by a stimulus coming to us from the environment, — stimuli impinging upon our sense organs, be they inner or outer, — and there are mental processes which seem to arise within the nervous system itself. In every act of perception also, no matter how simple it is, we seem to have involved, on the one hand an objective factor, and on the other what Professor James has called the ‘ideational excitement.’ There seems to be an interworking of these in every case of conscious mental acquisition. Herbart set forth the fact of this relation in his classic exposition of the apperceptive process. He showed the fact of their existence, but by his mechanical treatment of psychology he was unable to show how they coöperated in the production of new content. Professor James, in his discussion of ‘The Intimate Nature of the Attention Process,’¹ gives the whole matter a very much more lucid description. ‘Attentive’ is in general applied to one who is experiencing, or perceiving, or cognizing, in a higher and more vivid fashion than ordinarily. Attention may therefore be assumed to exaggerate and bring into clear light the important factors in all cognition.

There are, even at the present time, recrudescences of Condillac’s theory of attention. In fact the purposes of explanation are always served best where that which appears to be com-

¹ *The Principles of Psychology*, Vol. 1, pp. 434 ff.

plex, can be shown to be simple. Could one see the essence of attention as a simple inpouring of new mental material aroused by the inpouring of stimuli, — as nothing more than the exclusive and excessive use of a given avenue of sense at a given time, this indeed would be in the service of science. Ribot and Lange, in placing the emphasis they do upon the motor adaptation, as constituting the essence of the attention process, emphasize the facilitation of the incoming stimulus, and make the so-called inner factor to consist wholly in a bodily preparation. But the inner factor is more than this. It is something independent of and separate from the adaptation of the sense organ. Lange¹ maintains that the anticipatory preparation, from within, of the ideational centers, is the result, simply and solely of the motor adjustment. He would go even so far as to maintain that all imagination depends upon motor adjustment. And thus all so-called centrally-aroused mental processes are nothing more than sensations from motor organs, and the resultant feelings. This may be a too liberal interpretation of the author, but it flows from his view. It is an aim in the right direction, as it seeks simplicity; but it goes far beyond, and even contrary to, the facts. That imagination and all centrally aroused mental processes are not solely the product of motor adaptation, can be asserted unqualifiedly. That some of them are so aroused we will grant. For some mental types it may be that all are so aroused; but this is certainly not true for others. It is a hasty generalization to claim that they are. We may have motor adjustment without attention. But it may still be urged that the inner adjustment is a resultant of the motor adjustment; that it is lacking in these cases simply because the outer adjustment process fails to proceed to its natural development. But where this is a fact it already indicates that the two are less nearly the same process than they were claimed to be. And this relation is no longer thinkable when we realize the reverse fact, that we may have the ideational preparation of attention, or the revival of content without the innervation of any muscles. At least, in many persons of other than the muscular type, it seems not only possible, but the normal process, to be attentive to intellec-

¹ *Philosophische Studien*, 4 : 413 ff.

tual processes without any muscular contractions, and consequently without any directly aroused kinæsthetic sensations. We think it highly probable however that there are revived kinæsthetic sensations present.

It is also highly probable that these and all revived mental processes bear a much closer relation to the physical basis of the original processes of which they are the revival, than is commonly supposed. It may even be that the peripheral sensory neurons are involved, — that the difference between this revived process and the original is really one of accompanying processes. If this is true, it is at once evident that the contentions of both sides in the attention debate are right. There may be cases of subjective attention where the objective factor is wholly represented by incipient motor processes which however fail to become anything more than tendencies to action, and so they pass for cases of attention without motor adjustment. And there may be cases of attention where the motor processes are the cue for the centrally aroused processes. The whole matter of the relation of the peripherally aroused and the centrally aroused or revived mental processes is in a very unsatisfactory state. The voluntary control of after-images offers a means of studying the relation between a centrally initiated and a peripherally aroused process.

There are four distinct lines of observation bearing on this line of work, as follows :

1. Vivid visualization of memory images.
2. Control of the color and form of idio-retinal light.
3. After-images of memory images of color, or of subjectively induced color.
4. Control of the color of visual after-images.

1. There are many classic instances of vivid visualization of color, and discussions of their relations to the so-called spectral illusions, to visual hallucinations, and to dreams proper. Notable amongst these is the account of his own experience given by Sir Isaac Newton in a letter to John Locke. This account has contained so much of suggestion for the present investigation that we shall quote it in part. Newton looked upon the image of the sun in a mirror, for a very short time, with his

right eye, and then turned his eyes toward a dark corner to observe the decay of the after-images. He says: "This I repeated a second and third time. At the third time, when the phantasm of light and colors about it were almost vanished, intending my fancy upon them to see their last appearance, I found, to my amazement that *they began to return, and by little and little, to become as lively and vivid as when I had newly looked upon the sun*; but when I ceased to intend my fancy upon them, they vanished again. . After this, I found that as often as I went into the dark, and intended my mind upon them, as when a man looks earnestly to anything which is difficult to be seen, *I could make the phantasm return*, without looking any more upon the sun, and, *the oftener I made it return, the more easily I could make it return again*. And at length, by repeating this, without looking any more upon the sun, I made such an impression upon my eye, that if I looked upon the clouds, or a book, or any bright object, I saw upon it a round bright spot of light, like the sun, and, which is still stranger, *though I looked upon the sun with my right eye only, and not with my left, yet my fancy began to make an impression on my left eye*, as well as upon my right: for if I shut my right eye, and looked upon a book or the clouds with my left eye, I could see the spectrum of the sun almost as plain as with my right eye, if I did but intend my fancy a little while upon it. * * * And now, in a few hours' time, I had brought my eyes to such a pass that I could look upon no bright object with either eye, but that I saw the sun before me, so that I durst neither write nor read, but to recover the use of my eyes, shut myself up in my chamber, made dark, for three days together, and used all means to divert my imagination from the sun." By this means he began to recover the use of his eyes in three or four days. "But for some months," he says, "the spectrum of the sun began to return as often as I began to mediate upon the phenomena, even though I lay in bed at midnight with my curtains drawn."¹

¹This letter is given in full in King's *Life of Locke*, 1830, Vol. I., p. 40; also quoted by Sir David Brewster, *Quarterly Review*, July, 1831, 45: 341-358.

We have to do here with a strong after-image and also a very vivid memory image. It is an after-image in the early stages. It comes back involuntarily when the retinal illumination is changed, as when he looks at a cloud or a book. After-images may also be shifted from one eye to the other. This though is not a means of identifying an after-image. This behavior of after-images may really be a point of close connection between them and memory images. It is certainly a matter of the voluntary control of the after-image. Revived processes play a part in the phenomenon. Newton's description is also clearly of a memory image. His phrase 'intending my fancy upon it' is very aptly descriptive of the process of voluntary revival and intellectual attention. This 'intention of the fancy,' or direction of the attention, upon a strong retinal impression (this includes the after-image) greatly increases the vividness of the latter — brings it into great prominence in the life of the mind, and makes it far more liable to recall.

Goethe's experience of the constantly unfolding rosette, which he saw every time he closed his eyes and bent his head forward, is a case of a habitual connection between a position and a memory image. The position was the cue to set it going. It would constantly throw out new petals of different colors, but mostly red, as long as he cared to watch it. A Mrs. Haweis, one of Mr. Galton's correspondents, as a child, when it was dark, saw a flight of pink roses floating in a mass from left to right, which presently changed to a flight of sparks or gold speckles.¹ These are both cases of automatized memory images. They have started in some more or less accidental way, which the person no longer knows about. Children have many more of these vagrant images than do adults. Of the specifically willed images, those of the Bushmen drawing animals are in point.² They carefully place several dots, and then rapidly fill in the sketch. They evidently have a mental picture before the mind's eye.

Strong visualizers can project their mental pictures, and it sometimes becomes difficult for them to distinguish this vivid

¹ *Human Faculty*, p. 159.

² Galton, *Human Faculty*, p. 103.

mental imagery from the real world. More frequently though the mental image, projected, seems transparent like the reflected image from plain glass, and the real is seen through it, as the transmitted is through the reflected image. It is as if the mental image were seen in a lustrous surface through which the landscape was visible. Like the illusion of movement in Fleischl's waterfall experiment, in a way it is there, and in another way it is not there. In a way it seems real, and in a way it does not seem real. In so far as we distinguish it from the real, it is merely mental imagery; and in so far as it seems real it is hallucination.

This power of visualizing the form and color of objects, real or imagined, is one capable of cultivation. It increases rapidly when attention is directed toward it. A little systematic effort will convince anyone of the truth of this statement.¹

2. As a more restricted field, but at the same time a part of the group of phenomena considered, we are especially interested in what Professor Ladd has called the "voluntary control of the 'Eigenlicht.'" ² Professor Ladd, finding that the light of the retina assumed various and peculiar forms, in his case, without effort on his part, set about trying what he could do voluntarily to modify the form and the color. "This power grew rapidly, with continued practice; that is to say I was soon able, by attentively willing (compare Newton's 'intending his fancy'), for perhaps some three to five minutes, to cause a cross or a circle, or two concentric circles or some other simple figure, to appear in the retinal field." The method was simply to close the eyes, wait till all after-images had died away, and then persistently and attentively *to will* that the color mass caused by the 'Eigenlicht' should take on some particular form or should change in color. A number of students who took up the experiment at Professor Ladd's suggestion had very good success in both of these lines. It seems that any one can get some power of calling up colors and forms at will, by persistently trying to do so.

¹ See Galton, *Human Faculty*, pp. 109 and 106. See also James, *Principles of Psy.*, II., p. 66; F. Meakin, *Harvard Psy. Studies*, I., pp. 235-275; and C. S. Moore, *Harvard Psy. Studies*, I., pp. 277-306.

² *Direct Control of the Retinal Field*, G. T. Ladd, *PSYCH. REV.*, 1: 51-355.

3. There are several records of visual after-images (negative and complementary) of forms and colors, which themselves have been induced voluntarily and without external stimuli, as in the cases just cited. The color, having been induced by subjective control, and then being allowed to take free course, runs into a complementary stage. G. H. Meyer¹ says that most of his subjectively induced colors, when bright, left after-images behind them when the eyes were quickly opened during their presence. Some of Ladd's students observed the same phenomenon. Binet and Féré² find that the persistent idea of a color develops into its complementary.

Complementary after-images of hallucinatory color impressions, induced in the hypnotic state, have been reported frequently. It is claimed that an hallucination of a red star, for example, is followed by a green after-image of the same form, and that this follows without any suggestion whatever from the hypnotizer. But this relation must, as yet, be regarded as decidedly doubtful. It is of less weight than that furnished by normal subjects. If, in either case, there is any hint of the probability of the complementary color succeeding the induced color, this would be induced as certainly and as easily as the first color. Both alike would be subjective, meaning by that non-retinal, in origin. The hypnotic subject is more liable to this than the normal because of his abnormal suggestibility. He may take a suggestion without either himself or the hypnotizer suspecting it.³ Even Charcot was led to suppose that some of the fulfillments of his own expectations were a part of the natural process, to the extent of falling into error in description and classification of hypnotic phenomena.

If however the complementary color impression arises independently of either suggestion or volition, it at once constitutes a close connection between the memory image or induced subjective color impression, on the one hand, and the sensory source of the original experience of which this is a revival, on the other hand. For the after-image is proved to be an affair

¹Quoted in James' *Principles*, II., p. 67.

²*Animal Magnetism*, p. 254.

³See *Animal Magnetism*, Binet and Féré, p. 253.

of the sense-organ — of the peripheral visual apparatus. If, then, the so-called after-image of the subjective memory image (imagination product) is really a physiological consequent of the subjective memory image (or rather of the physiological processes which lead up to it), as the regular visual after-image is the physiological consequent of the visual processes which lead up to the visual sensation, of which it is an after-image; then the subjective memory image would seem to involve retinal processes as part of the neural apparatus for its production. Anything which will prove or disprove the non-volitional character of this so-called after-image of the memory image, is then of decided importance in the question of the relation of sensational and revival processes.

It was for the purpose of meeting this situation that Miss Downey worked with her *naïve* subject. This subject had excellent power for visualizing color, could control the images well, and could project them. She was entirely ignorant of the complementary relations of colors of sensations and colors of after-images. She was also entirely in the dark as to the purpose of the experiments. In eighty per cent. (80 per cent.) of her trials the after color was the complementary of the induced color which it had succeeded.¹

4. Miss Downey says that her subject did not believe she could change the course of an after-image voluntarily, and that she herself has never been able to do so. This is however improbable, as a consequence of her own experiment. We do not impugn her good faith in making the statement. But if one can create vivid color impressions and experience after-images of these, which bear the same relation to them that the ordinary visual after-image bears to the sense impression, it seems highly probable, as urged above, that the same retinal processes are involved in both the ordinary after-image and the subjectively aroused or memory process. If this is the case they ought to interfere with each other when it is attempted to carry them on simultaneously. It ought to be possible to interrupt and change the course of an after-image by voluntarily arousing subjective

¹ 'An Experience in Getting an After-image from a Mental Image,' *PSYCH. REV.*, 8: 42.

colors. In other words it ought to be possible, if the above reasoning from the observed facts is correct, to *control* the course of the visual after-image, that is, to alter, voluntarily, its natural course.

Miss Washburn¹ found quite a considerable modification of the normal 'flight of colors' was produced by an effort persistently to see a given color through the course of an after-image. It was not possible to wholly submerge the regular colors of the after-image, but the color 'tried for' prevailed much more than when no effort was made. The subjects were practised until they obtained a fairly uniform course of color at each successive trial. They were then told to try hard to drown out the other colors by thinking persistently of a given color. With three of the subjects the traces of the color striven for were intensified and were held longer than in the normal after-image, and they also came sooner. With the other subject, who was an exceptionally good visualizer, the color striven for was held almost without interruption throughout the time of the after-image course.

II.

In view of the doubt that seems to prevail as to whether the course of the after-image can be altered or interfered with by mental imagery, it is worth while to look for further evidence on the question. And especially, in view of our ignorance as to the nature of the interference, if there is such, did it seem worth while to make further experiments along lines similar to some already reported. Our special desideratum was knowledge of the processes of the memory image, on the one hand, and of the after-image, on the other hand, that we might see the relations between them. In other words, we wanted to know how the 'ideational preparation' of the attention impinges upon and modifies the sensory process. In the case of the after-image we have a unique process. The peripheral apparatus keeps on sending in nervous disturbances, which arouse sensations, long after the external stimulus has been withdrawn, so that the possibilities of an even division of the attention between the memory image, which is called up voluntarily, and the peripherally

¹ 'Subjective Colors and the After-image,' *Mind*, N. S. (1899), 8: 25-34.

aroused process, is very much easier than it is in the case where the peripherally aroused process is caused directly and immediately by an external stimulus. This is for the simple reason that we have to attend to the after-image in very much the same way that we attend to the memory image, whereas the sensation proper makes a much more forcible entrance into the focal region of consciousness. It is more compelling in its power over attention.

After the first preliminary work, which was directed to ascertaining whether there was a fair degree of constancy in the course of the after-image, we proceeded on the following plan: Each day we gave (1) a series of two to six normal after-images, usually with a twenty-second exposure, then (2) about two memory images, or subjective controls for a given color, beginning when no after-image effects were present, and then (3) two or more subjective controls, for a given color, of the after-image, this after-image being aroused in precisely the same way as the normal after-image. We found it necessary to have all these three kinds of experiment performed each day, in order to have a valid ground of comparison, for the different light conditions on different days led to very different color courses and lengths of courses in the after-image. This plan of procedure enables us to see, side by side (1) the simple after-image effect, (2) the simple memory image (imagination product) and then (3) these two combined.

The work was done in a dark room. The stimulus for the after-images was daylight admitted through a window, measuring 36 x 38 centimeters. This window was high up above the floor of the room so the subject, from his position, saw only the sky or clouds. A sliding shutter, with pulley attachments, made it possible to regulate the time of exposure very accurately. Some bars crossed the window, making it easier to follow the course of the after-image. The subject sat facing the window about six meters distant. The experimenter sat directly under the window, with his back to the subject. He worked by a small hand electric lamp, closely shielded in a box. The subject usually turned his head to another part of the room and closed his eyes, when observing an after-image. We do not

think our results were impaired by the small amount of light present, but of course absolute darkness would be preferable, as that would remove all doubt. Telephonic connections or an automatic recording apparatus would remove all necessity for light in the room where the observations were being made. An automatic recorder would be of further use in that it would make possible a more accurate transcription of the actual color changes. The subject himself finds it impossible to speak of all the changes, those he does speak of are already past when they are mentioned, and the experimenter may get them recorded for a still later time. Two reaction times enter into the error. Of course these hold alike of all records, and so their comparative value is not impaired. And they are used only comparatively here. An automatic recorder with receiving apparatus furnished with pressure taps for four or six colors, arranged in spectral order, would greatly facilitate work in this field.

The exposures were mostly of twenty seconds. In order to avoid fatigue, we usually changed off, experimenter becoming subject and vice versa, every fifteen minutes. And ample time was allowed in every case between experiments for the complete disappearance of the effects of the previous after-image.

Neither of us are exceptional visualizers. H. has always depended about equally upon the visual sense and the vocal muscular sense for the verification of spelling. When, a few years ago, as a beginner in psychology, his attention was first drawn to the work of Francis Galton on mental types, he found great difficulty in recalling the face of a near friend. The result of efforts at visualization were very disappointing. It seemed that objects of such worth must of necessity occupy a more prominent place in the visual imagination than that which this test revealed them to hold. As the visual attention was turned upon these thought objects, they seemed to vanish as do faces seen in clouds, or cliffs, or the moon, when they are closely scrutinized. But this power steadily improved, and H. can now visualize faces with ease, and can get a fair wealth of detail.

W. has always had a fair visual memory, being able to

remember dates, definitions, etc., best by having a visual image of a page or list of names. He had little difficulty in calling up the faces of friends. The visual image of a person was usually called up by the name of the person and was always connected with familiar circumstances. But these recalls were always very literal reproductions of the original experience. For example, he had seen Mr. Moody preaching and could easily see him in that position; but if he tried to see him in his study or at a hotel, it was no longer Mr. Moody. The image was very indefinite and unlike the original. When W. was about fifteen years of age, he often saw as he lay in bed, in the dark, 'flights of color.' These always had the same elliptical shape (about three inches by two) with an irregular, colorless spot occupying the center. This figure and these colors appeared about eighteen to twenty inches distant from his eyes. The phenomenon was of accidental origin, so far as W. is aware, and would appear and disappear of its own accord. But he was soon able to start it at will. When once set going, though, it went through its usual course. After a few months, this experience was lost sight of. It was recalled since he began working with after-images. But he cannot reproduce the figure, as he then had it.

This experience indicates a natural facility in W. for visual imagery. But since beginning this work, he has noticed a marked increase in this facility. His images are now more life-like, and he has no difficulty in calling up images of any familiar experience, such as a person or a landscape. Further he now has control of this imagery, so that he can see a familiar person in a situation very foreign to the person in question, such as the President of the university firing an engine or ascending in a balloon, things which he has never known him to do.

The charts presented herewith are reproductions of the courses of after-images, normal and controlled, and of controlled memory images. The principal object in view in presenting those on Chart I. is to show samples of the very early after-images. V., VI., VII., VIII., and IX. show a close similarity. These of February 24 show a marked increase in regularity over those of February 10; though even these earlier ones are

by no means without similarity. The improvement is probably an improvement in the power of observing this species of phenomena. Chart II. shows, side by side, the normal after-image, the controlled after-image, and the controlled memory image or the voluntary revival and retention of color sensation, one series being by H. and one by W. In making up these charts as well as in making up the tables of averages it was necessary to adopt some arbitrary way of treating such colors as violet and orange, both for the purpose of simplifying the work of reproduction in the charts and in order to bring the summary statement of the results into a reasonable compass. The following compositions were adopted: Purple = two thirds red and one third blue, violet = two thirds blue and one third red, blue green = one half blue and one half green, orange = one half red and one half yellow, green yellow = one-half green and one half yellow.

The chief objection to this is that there is no means of distinguishing when these colors appear separately in different parts of the image and when they represent colors the same all over the field. But two simultaneous colors were comparatively infrequent. Spaces left without color indicate times when the image was colorless or had vanished from the field, temporarily or finally. The numbers at the left side of the charts represent seconds from the time of the beginning of the image.

TABLE I.

Name of Observer	W.	H
Total Number of normal after-images observed	91	92
Average total time of the course of the normal after-image.....	171 ¹	213
Average total time of <i>yellow</i> in the normal after-image.....	13	18
Average total time of <i>red</i> in the normal after-image.....	7.5	31.7
Average total time of <i>green</i> in the normal after-image.....	22	30
Average total time of <i>blue</i> in the normal after-image.....	42	75
Total number of controlled after-images.....	47	46
Average total time of the course of a controlled after-image.....	226	317
Number of after-images controlled for <i>blue</i>	19	23
Average total time of <i>yellow</i> in after-images controlled for <i>blue</i> ...	13	12
Average total time of <i>red</i> in after-images controlled for <i>blue</i>	6	28.6
Average total time of <i>green</i> in after-images controlled for <i>blue</i>	21	24.5
Average total time of <i>blue</i> in after-images controlled for <i>blue</i>	108	190
Number of after-images controlled for <i>green</i>	7	5

¹ Time is always given in seconds.

TABLE I.—Continued.

Name of Observer	W.	H
Average total time of <i>yellow</i> in after-images controlled for <i>green</i> ..	20	20
Average total time of <i>red</i> in after-images controlled for <i>green</i>	16	27.6
Average total time of <i>green</i> in after-images controlled for <i>green</i> ...	133	168
Average total time of <i>blue</i> in after-images controlled for <i>green</i>	21	66
Number of after-images controlled for <i>red</i>	6	7
Average total time of <i>yellow</i> in after-images controlled for <i>red</i>	7.4	28
Average total time of <i>red</i> in after-images controlled for <i>red</i>	147	212
Average total time of <i>green</i> in after-images controlled for <i>red</i>	57	23
Average total time of <i>blue</i> in after-images controlled for <i>red</i>	25	90
Number of after-images controlled for <i>yellow</i>	15	11
Average total time of <i>yellow</i> in after-images controlled for <i>yellow</i>	45	102
Average total time of <i>red</i> in after-images controlled for <i>yellow</i>	10 6	22.6
Average total time of <i>green</i> in after-images controlled for <i>yellow</i>	36	18.5
Average total of <i>blue</i> in after-images controlled for <i>yellow</i>	30	53 6
Number of memory images controlled for <i>blue</i>	3	3
Average total time of <i>yellow</i> in memory images controlled for <i>blue</i>	14.5	16.6
Average total time of <i>red</i> in memory images controlled for <i>blue</i> ...	5.6	24.6
Average total time of <i>green</i> in memory images controlled for <i>blue</i>	0	24.8
Average total time of <i>blue</i> in memory images controlled for <i>blue</i> ..	123	228
Number of memory images controlled for <i>green</i>	4	4
Average total time of <i>yellow</i> in memory images controlled for <i>green</i>	5.5	15.6
Average total time of <i>red</i> in memory images controlled for <i>green</i> ..	16	20
Average total time of <i>green</i> in memory images controlled for <i>green</i>	62	134
Average total time of <i>blue</i> in memory images controlled for <i>green</i>	10.5	60
Number of memory images controlled for <i>red</i>	6	6
Average total time of <i>yellow</i> in memory images controlled for <i>red</i>	5.-	16
Average total time of <i>red</i> in memory images controlled for <i>red</i> ...	99	172
Average total time of <i>green</i> in memory images controlled for <i>red</i> ..	79	16
Average total time of <i>blue</i> in memory images controlled for <i>red</i> ...	31	29
Number of memory images controlled for <i>yellow</i>	6	4
Average total time of <i>yellow</i> in memory images controlled for <i>yellow</i>	93	161
Average total time of <i>red</i> in memory images controlled for <i>yellow</i>	27	23
Average total time of <i>green</i> in memory images controlled for <i>yellow</i>	18.6	38
Average total time of <i>blue</i> in memory images controlled for <i>yellow</i>	33	16.5

TABLE II.

	Blue.		Green.		Red		Yellow.	
	W.	H.	W.	H.	W.	H.	W.	H.
Total time of color in normal after-image.	42	75	22	30	7.5	31.7	13	18
Total time of color in after-image controlled for <i>blue</i> .	108	190	21	24.5	6	28.6	13	12
Total time of color in memory image controlled for <i>blue</i> .	123	228	0	24.8	5.6	24.6	14.5	16.6

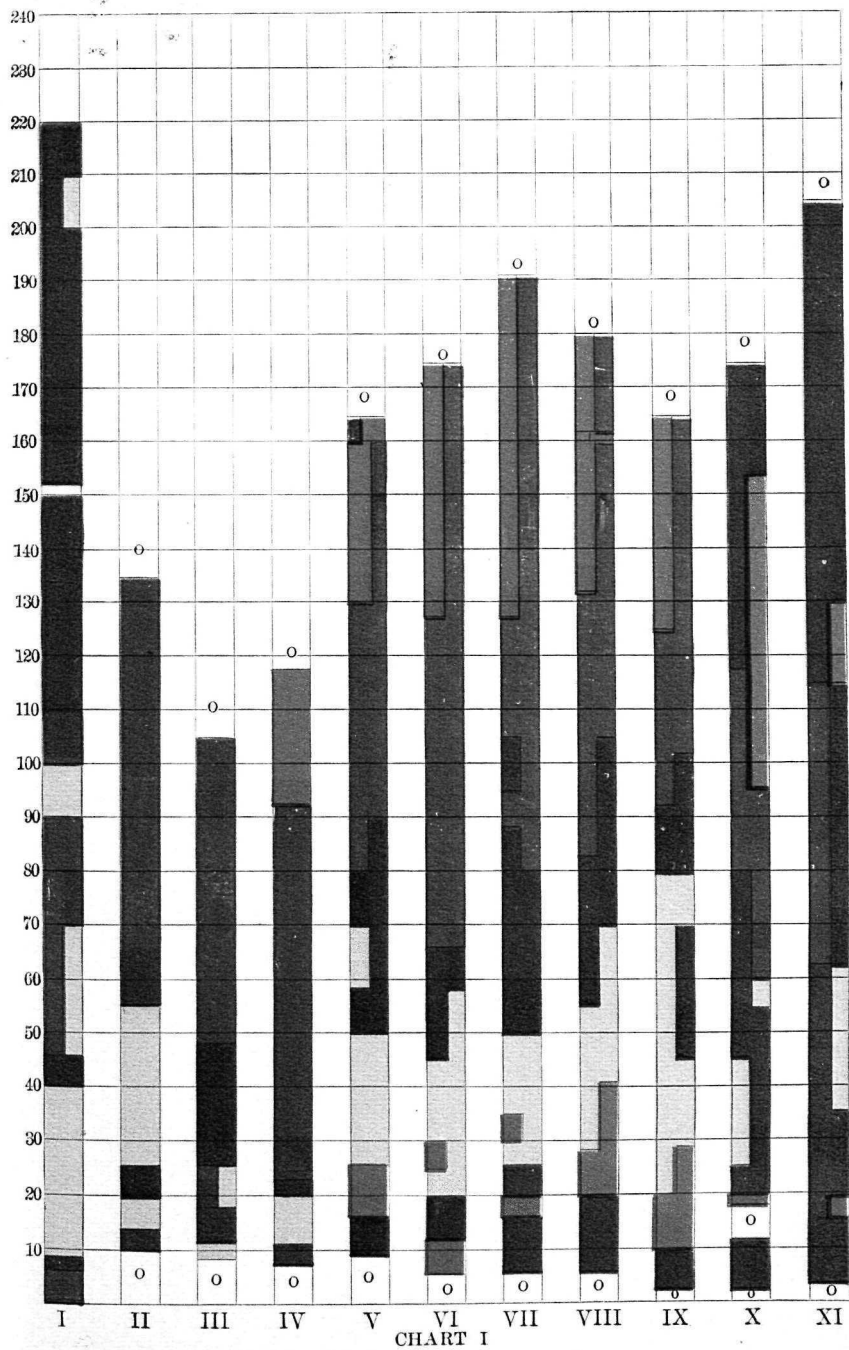
TABLE II. — *Continued.*

	Blue.		Green.		Red		Yellow.	
	W.	H.	W.	H.	W.	H.	W.	H.
Total time of color in after-image controlled for <i>green</i> .	21	66	133	168	16	27.6	20	20
Total time of color in memory image controlled for <i>green</i> .	10.5	60	61	134	16	20	5.5	15.6
Total time of color in after-image controlled for <i>red</i> .	25	90	57	23	147	212	7.4	28
Total time of color in memory image controlled for <i>red</i> .	31	29	79	16	99	172	5.5	16
Total time of color in after-image controlled for <i>yellow</i> .	30	53.6	36	18.5	10.6	22.6	45	102
Total time of color in memory image controlled for <i>yellow</i> .	33	16.5	18.6	38	27	23	93	161

A summary of the work of H. and W. is presented in Table I. This is the result of a very careful and complete analysis and averaging of 183 normal after-images, 93 controlled after-images, and 36 controlled memory images. One of the first things that strikes one as he looks at our scores of charts, or at this table, is the considerable increase of the total time of the controlled after-image over the normal. The latter increase the time about 70 per cent. in each subject. This longer time of the controlled image may be in part due to the engrossing of the attention in the work of distinguishing and holding the desired color, so that the time of the disappearance of the after-image is not noticed. In fact H. often reported, in the case of the normal after-image, that he no longer had an after-image,—that he now knew it was not present because he could move his eyes without affecting the image, but he did not know when it left. Its departure was not signalized by any observable change, but now that his arrested attention was turned to it he knew that it was not an after-image. If this was possible where the attention was directed wholly upon the after-image, it would be much more likely to happen when the attention was divided between the observation of the after-image and the revival of a color. W., however, never had this difficulty. He knew very clearly when the after-image proper was at an end. The lengthened time in his case then shows the effect of attention upon the after-image. It lengthens its life. We both feel

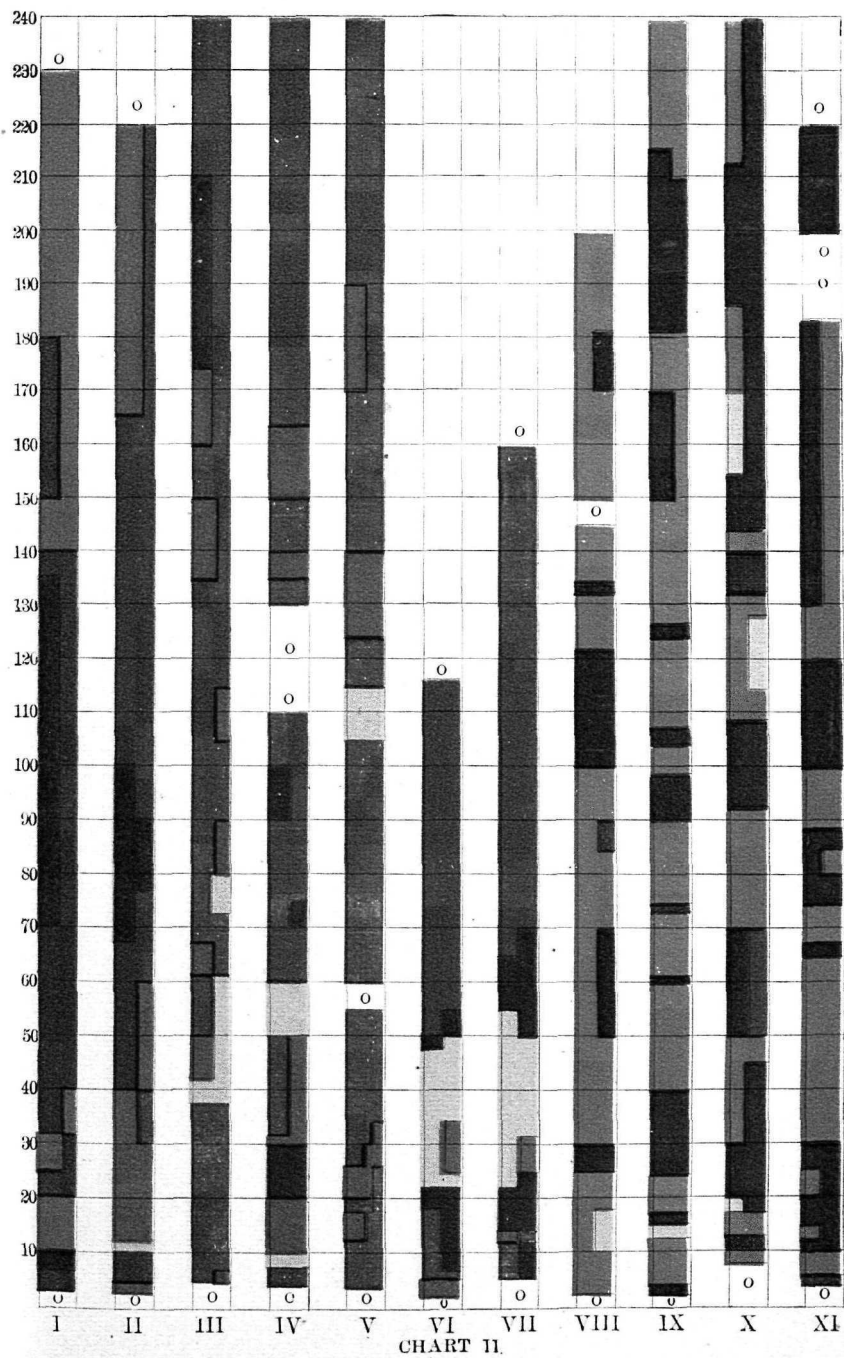
EXPLANATION OF CHART I.

I. W., February 10, normal after-image, 20 seconds exposure. II. W., February 10, normal after-image, 20 seconds exposure. III. W., February 10, normal after-image, 20 seconds exposure. IV. W., February 10, normal after-image, 20 seconds exposure. V. W., February 24, normal after-image, 20 seconds exposure. VI. W., February 24, normal after-image, 20 seconds exposure. VII. W., February 24, normal after-image, 20 seconds exposure. VIII. W., February 24, normal after-image, 20 seconds exposure. IX. W., February 24, normal after-image, 20 seconds exposure. X. W., February 24, memory image controlled for green. (No exposure.) XI. W., February 24, memory image controlled for green. (No exposure.)



EXPLANATION OF CHART II.

I. H., April 23, normal after-image, 20 seconds exposure. II. H., April 23, normal after-image, 20 seconds exposure. III. H., April 23, memory image controlled for blue. (No exposure.) IV. H., April 23, after-image controlled for blue, 20 seconds exposure. V. H., April 23, after-image controlled for blue, 20 seconds exposure. VI. W. April 28, normal after-image, 20 seconds exposure. VII. W., April 28, normal after-image, 20 seconds exposure. VIII., W., April 28, memory image controlled for red. (No exposure.) IX. W., April 28, memory image controlled for red. (No exposure.) X. W., April 28, after-image controlled for red, 20 seconds exposure. XI. W., April 28, after, image controlled for red, 20 seconds exposure.



that this is the effect of attention directed to the after-image, independently of these objective results and this interpretation of them. Of course the factor that lengthens the after-image for H. by causing him to mistake a memory image for it, is ultimately the same as that attention factor which lengthens it for W. For the memory image which H. projects and mistakes for the after-image, because it is so vivid and his attention is not critical of the source of his experience, is created by this very activity of attention, which is one of the factors in the perception of the after-image. Having the attention more actively aroused, means the prolongation of the after-image, and with a little more arousal still, it seems possible to bring up a vivid substitute which may be mistaken for it. This relation of the after-image and the memory image must be taken up in the final section of the paper; but this much of the way seems to be pointed out in the pursuit of the question immediately raised by the lengthened course of the controlled after-image.

The point at which anyone shall conclude that his after-image has ceased and a memory image begun, is, it seems to us, a matter depending upon that person's experience in the comparison of these two kinds of mental contents. Probably both the subjective and objective factors are operative in all cases of mental activity of any sort. Those in which the subjective factor predominates are called subjective, and those in which the objective factor predominates are called objective. And on the border-land, as in these cases of the controlled after-image, it is a matter which will vary from individual to individual as to which he shall call objective and which subjective. Without some such special experience as afforded by these experiments, these two realms remain comparatively widely separated from each other; and it serves the purposes of life that they do. But such experience as we have had in this work tends to fill in the normal gap between them with a series of experiences, hardly different in themselves, and yet approaching both sides of the gap. In such conditions it is often difficult to know when the limit is reached. In fact in these experiences we find, as we expected to find, a very intimate interworking of the objective and subjective factors; and

this is one reason at least for the lengthening of the after-image when it is controlled.

This greater total time of the controlled image is the reason for the greater total time of a given color, in some cases, in the controlled image, even when another is controlled for, than in the normal after-image. As an extreme case, H. has yellow in the normal after-image only 18 seconds, while in the after-image controlled for red he has yellow for a total of 28 seconds (see Table II.). This increase is about proportional to the increase of the total time of the after-image when controlled. The same factor is operative, of course, in the increase of the time of the color controlled for; but the increase is so much greater in any and all of these cases that there can be no question but that there is another factor at work here. Take *e. g.*, the case of the increase of red in the image controlled for red whose amount of yellow was just now cited, and it is seen that the average amount of red has increased from 31.7 seconds in the normal after-image to 212 seconds in these controlled for red, in the case of H. So it is in the case of any color controlled for. The increase is so significant that there can be no doubt that the voluntary control is a very important element in *bringing in* the color in question.

In looking at the results as they are presented in Table II. (which is simply another form of some of the results shown in Table I., arranged with a view to comparisons of the sort made above) the question arises as to whether the color, complementary to the one controlled for, comes into any greater prominence than the other two. If red is the color controlled for, will green be more prevalent than in the cases where blue, for example, is controlled for? A glance at the table shows us that H. has less of the complementary of the color controlled for in every case, than he has of the same color in the normal after-image, while W. has relatively less of yellow in images controlled for blue and of blue in images controlled for yellow than in the normal after-images. There is an increase of red in images controlled for green and of green in images controlled for red. But there is also an increase of yellow in images controlled for green and of green in images controlled for yellow.

These increases are however not large enough to signify the influence of any special relation of green and yellow. It would seem, too, as though the above hint at a relation is not borne out in other parts of the table.

In comparing the average total times of a given color, in the after-image controlled for that color, and in the memory image controlled for that same color, we find a curious relation brought out. Green and red are each decidedly less in the memory image controlled for those colors respectively than in the after-images controlled for the same colors. In red we find the after-image at 147 and 212 seconds while in the memory image it is 99 and 172 seconds. Just the reverse holds in the cases of yellow and blue. Here the time of the color in the memory image is greater than in the after-image, and about as much greater as red and green are less. It seems more difficult to hold, subjectively, green and red than it is to hold, subjectively, yellow and blue. The interchange of these two colors between themselves, when one of them is being controlled for in the memory image, is more marked than it is with blue or yellow. The predominance of the complementary green in both controlled after-image and controlled memory images is well shown by the last four series on Chart II. (VIII., IX., X., and XI.), in all of which the control is for red.

Table III. presents results obtained from three other subjects, of the same general nature as the results from W. and H., but of a more preliminary nature. They seem worth presenting for the special reason that two of these subjects were especially poor visualizers at the start of their work, and yet present good evidence of a control over their after-images. One of these, M., described the memory image he had of blue as being 'like the fading blue after-image about a minute after the image had gone.' He as well as D., claimed never to have seen color in their memory images. Both of them are of the motor type. These subjects, though, both of them, show a marked increase in the average total time of every one of the four colors in an after-image controlled for the given color over the average total time of the same color in the normal after-image. This clearly indicates a power of subjective control in

TABLE III.

	Observer.	Average Total Time in Normal After-Image	Average Total Time in After-Image Controlled for Blue.	Average Total Time in After-Image Controlled for Green.	Average Total Time in After-Image Controlled for Red	Average Total Time in After-Image Controlled for Yellow.
Blue.	D.	75.2	90			27.5
	M.	42.5	70	32.5	35	40
	Mc.	7.5		20	2.5	0
Green.	D.	14.2	5			19.4
	M.	17.8	25	46.5	10	20
	Mc.	7.5		65	5	0
Red.	D.	35.6	12			10.1
	M.	12.5	15	4	20	15
	Mc.	26		35	92.5	55
Yellow.	D.	20.9	10			50.6
	M.	16.7	0	10	25	20
	Mc.	11		0	12.5	10
Total No.	D.	4	1	0	0	4
	M.	6	1	2	1	1
	Mc.	4	0	1	2	1

cases where there is a minimum of the visual ideational factor in ordinary imagery.

III.

It seems very clear from these various lines of proof that there is an interference of the after-image and the memory image with each other. This also seems very clear to us from our experience with the work. W. felt that his effort to get an effective subjective control of an after-image led to bringing that control color up from *behind* the after-image. It started in a small area and spread out over the area of the after-image. Other colors tend to come in, presumably the colors proper to the normal after-image. There is a continual struggle, as long as the natural course of the after-image, between the color which one is trying to hold in the field and these other colors which are described as 'trying to assert themselves.' The two elements are competing for the same field. This effort to get and keep a given color in the field is a very distinct species of mental work. This is about equally true whether one is controlling an after-image or is trying to hold a given color against chance comers, — memory images. It is as distinctly work as if one should try to lift himself up out of a chair.

With H., the color, which he is trying to have control (suppress) the after-image, often comes as a halo around the after-image, and gradually closes in on it. It closes it out of existence. Other times the color desired comes as a spot of color of very indefinite outlines, off to one side of the after-image. This he may succeed in placing upon the after-image. Or he sometimes was able to change the visual attention from the one field to the other. In many cases the control color "blotted out" the after-image, form and color. Other times the control color came in on the form of the after-image. It is a clear case of competition for both of us.

But with the fact of interference established, the really interesting question first comes prominently into view. This, as already stated, is the question of explanation. What is the nature of this interference? This of course involves a knowledge of the nature of the processes themselves. And a very natural way of approach to this question is to inquire about the physical basis of these processes. This line of inquiry has been pursued very often. Brewster adopted it to explain spectral illusions, and such phenomena as that which Newton describes. He says it is 'a retransmission along the optic nerves to the retina' by which the retinal elements are again excited, and the image is had over again. And he could get a memory image of St. Paul's, of sufficient vividness to blot out the landscape which was before his wide open eyes, simply, as he thought, by this centrally aroused stimulation of the retina. Probably this explanation takes its rise in the feeling, which is very pronounced in such cases of strong and vivid memory images, that the image is a product of one's own willing. From this feeling that one is making it himself, it seems a very easy, and indeed natural, inference that the peripheral process is the result of some energy set free in the retina by an efferent stimulation of some sort.

There are efferent fibers in the optic nerve, known to be such, both from the relative position of axis cylinder and cell body, and from the particular connections in the central nervous system. It is quite possible that these fibers function in such a way as to stimulate the peripheral sensory neurons. And if so we have herein the mechanism of the revival process. The

mechanism, whatever it is, not only serves for the production of spectral illusions, pseudo-hallucinations, and the more vivid species of memory images. For there is only one species of revival. The causes of revival are indeed many. But the mechanism of the process itself must be one and the same. And if this is the *modus operandi* of revivals of this more vivid sort, it is also the way of revivals of every sort. It is highly probable that all revival involves the functioning of the peripheral sensory apparatus, to some extent. It will at once be said that this is certainly not an essential condition of revival. For the blind by accident, who lose their retinae entirely, no more lose the power of visual revival than does the patient who has lost a leg by amputation lose the power of reviving the muscle and joint sensations which he formerly had from that member. To this we simply say that the cases of the blind who have lost their whole peripheral sensory visual apparatus are worthy of very careful psychological investigation. The chances are that some important discoveries with regard to the nature of the revival process await us here. And further that there is undoubtedly a vicariousness in the nervous system by which processes are pared down. Part processes are left out. Nature is always making short-cuts. In this way it may be that the *tendency* to discharge toward the peripheral apparatus, there to set up the revival of the sensory process, is sufficient in itself to engender in the central (cortical) sensory cells a process which stands for the revival of the sensory process. It is a *symbol* of a copy.

From introspection we find that this *symbol* of revived sensory experience is further removed in kind from the genuine revival of a sense image, than is the latter from the sense-image itself. This is what we should expect if our theory of their origin is correct. W. calls them memory images and visual images, respectively. The former (symbols of copies) do not have any color. They are the images most of us have when we are engaged in conversation, and do not have time to get good visual or other sensory images of all the objects mentioned. They are the images which our subjects D. and M. have at their best, when they are trying hardest to get visual

images. They cannot get what W. calls visual images. The after-image, the vivid sensory image, and the ordinary memory image constitute in fact, a series of psychic processes which grade into each other. They differ among themselves in the nature of the interplay of the peripheral and central factors, and the relative importance of each, as suggested above.

The difference between sensational content and revived content, is not merely difference in intensity, as Hume said. It is probably, in part at least, a difference in content itself, as suggested already. It is also well known that memory of an experience is not the mere revival of that experience. If it were merely the experience over again it would not be *recognized* as that former experience. Psychologically considered, the difference between the sensational and revived processes is one of the *organization* of the processes within themselves, rather than of the impetus of the nerve current along any particular channel. Our whole view of the nature of psychical processes has very much changed since Hume. The concept of vividness is a very important aid to the explanation of such a difference as this now under consideration.

Vividness is indeed another name for the organization obtaining in experience. We commonly mean by it that emphasis which a mental process or an experience gets by the direction of attention toward that part of the field of consciousness. The common illustration of the watch ticking and being unnoticed as long as we are occupied with other things, but coming into prominence so soon as we turn our attention to it, is a good one. The loudness of the tick is the same all of the time. But the inner factor changes. That which was 'fringe' now becomes focal in consciousness. More of the energy of attention is directed toward it, and so it occupies a relatively more important place in the field.

The difference between a sensational experience and a memory of it is largely a matter of the changed vividness of many of the part processes involved. As Dr. Sidis¹ expresses it, in characterizing the difference between perception and hallucination, there is a difference in the *nucleus* in the two experiences.

¹ PSYCHOLOGICAL REVIEW, XI., pp. 15-29 and 104-137.

The changed vividness of elements changes the mental center of gravity, placing the emphasis on a new part of the experience. Parts which were focal before, are now in the fringe, and the present focal elements were previously fringe elements. This, at least, is one important species of change which occurs as the sensation becomes memory. Of course there is also the possibility of an actual change of the content, as contemplated above. Some elements may wholly drop out, and other new fringe elements may be brought in. It seems that recognition of the reproduced mental content is largely dependent upon such fringe elements.

The criticism of Hume's psychology inheres in part in all attempts to deal with this problem after the manner of a structural psychology. For this matter of the changing vividness of the various parts of the given organic experience is not in itself the whole of the changes that occur. There is something in the organization as such that escapes us when we analyze the experience. And this something has a very real part in giving its character to the revived process as distinct from the original experience. This, the structuralist says is mere form and so counts for nought in the final estimate of the make-up of the processes. This is an untenable position. We must heed these hints as to significance, which the functional view can give us. This help is especially valuable in this present case. The very essence of the difference between the sensory and the memory process consists in the different meaning attaching to them individually. But, using the functional view as it should be used, as a guide for the analysis of the structural method, the present study serves as an example of the possibility of explaining these significances, in part at least, by the aid of such analyses. The difference between a given sensational experience and the memory of the same experience, which is clearly one of meaning, is largely accounted for in our analysis as content differences. It lies chiefly in the different *start*, or *awakening*, of the peripheral sensory processes and in the different relative parts played by the various factors.¹

¹ The MS. of this article was received July 14, 1904.—ED.