

## Discrimination of Shades of Gray for Different Intervals of Time.

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In an early number of the *Phil. Stud.* (Vol. V) Alfred Lehmann gives some curiously neglected results of experiments on what has been commonly called Sensory Memory. Lehmann is working with the simplest form of recognition in order to decide between the rival claims of the Similarity and Contiguity theories of Association, and to this end he devises experiments to show that recognition often takes place only by means of contiguous association. He shows, for example that so long as the number of shades in a series of grays does not exceed the number of commonly used terms for the shades, viz: black, white, dark gray, light gray and gray, the recognition of any given shade takes place with great accuracy. When the number of shades is raised from five to six, the accuracy of recognition falls off over 25%, and when the series is increased to nine, the recognition amounts to hardly more than guessing. When, however, an observer had learned to associate a name with each of the nine shades of gray, the number of correct ›recognitions‹ rose from 46% to 75%.

Further, argues Lehmann, if the perception of a likeness or difference between two shades of gray exposed in succession, amounts to classifying each shade in a scale — to naming it — then recognition of this kind should be practically independent of the time interval between the exposure of the two shades. If the reagent thinks ›light‹ to himself, and classifies the second as ›dark‹ or ›medium‹, the interval of time between the two exposures will make no difference to the accuracy of the judgments. There is no question

here of a fading memory image but simply of the selection of a term. Experimental results confirmed Lehmann's anticipations. Using two shades of gray, he found the judgments of two observers as correct for 90 and 120 sec. as for 15 and 30 sec.

Some years ago the present writer was struck by the discrepancy existing between the results obtained from a large beginners' class, experimenting on so-called Sensory Memory, and the then current memory image theory. On the average the class seemed to show as good a memory for lines and tones for 60 sec. as for 2 sec. And the amount of distraction in the time interval seemed to have but little influence on the accuracy of judgment. Finding, moreover, from a review of »memory« work a great many contradictory results, the writer took up a long series of experiments on clang discrimination for different intervals of time, and found in brief: — 1. that there was no falling off in accuracy of judgment for small differences of stimuli with increasing time intervals up to 60 sec.: — 2. that there was a falling off in accuracy with increase in time interval for objectively light tones, both of these results agreeing roughly with Wolfe's experiments; 3. that various kinds of distraction used for the purpose of affecting or destroying a possible memory image had but little effect on the accuracy of judgment. 4. that some of the judgments were of the kind termed »free« — i. e. judgments delivered with a considerable feeling of security, but seemingly without the presence in consciousness of any standard of comparison.

Before generalizing from the results of these this work it seemed best to carry out similar experiments with other kinds of sensations, — more especially with light sensations. Compared with tones or clangs shades of gray are at a disadvantage as involving after-image and contrast complications; on the other hand, visual impressions are commonly more accessible to introspection.

Accordingly, in the summer semester of 1899 the writer was able, through the kindness of Prof. Külpe, to take up an investigation on the discrimination of shades of gray for different intervals of time in the Psychological Institute at Würzburg. The stimuli were given by a Marbe color-mixer which faced a large window about ten feet distant. Over this window were hung several layers of white muslin, partly for the purpose of exposing the revolving disc to a diffused

white light, and partly, through varying the number of thicknesses of muslin to prevent too great changes in intensity of light from day to day, or even parts of the same experimental hour. The time intervals were measured by a metronome, and the exposures given by raising and dropping a black cotton-flannel curtain which hung in front of the color-mixer. The experiments took place under three different conditions. (A) Eyes closed during interval between norm (*N*) and comparison (*V*) whilst an effort was made to hold fast a visual image of the disc. (a) Eyes open with relaxed attention during the time interval. (D) Distraction experiments in which a simultaneous discrimination of two grays of about the shade of the successive stimuli, was introduced into the middle of the time interval. An attempt to use one disc as a distraction failed through the tendency of the reagents to use the disc as a mediate term of comparison between the two main stimuli. When, however, the reagents had to pass judgment on a pair of >distraction< discs, simultaneously exposed, the tendency to form mediate judgments disappeared.

The norm in all cases was 180 degrees of white plus 180 degrees of black; there was, however, no danger of the formation of an >absolute memory< of the norm partly on account of variations of atmospheric brightness, and partly on account of variations in the reagents subjective estimates of the norm. The method used was the mixed method of right and wrong cases and of minimal changes, and to this end the norm was compared with itself and 4 other brightnesses: — viz. 200, 190, 170, 160 deg. of black. The order of exposure was in the first instance determined by chance, and then this order, and its reverse were carried through the entire series of intervals for both time orders, after which a second arrangement was determined by chance. The time of work was in the late afternoon between five and six thirty — a disadvantageous period, as it sometimes happened that the sun went down behind the university buildings during the last series. The reagents were Prof. Külpe (Ke) and Privat Dozent of Philosophy W. Kinkel (Kl) of Giessen, a member of the Würzburg Institute, but at that time a beginner in experimental work.

As regards introspection, the reagents were asked to note such mental imagery as seemed relevant to the work — especially verbal and visual imagery. From time to time they were questioned in

regard to the exact meaning of the notes. In experiments of this kind with more or less long and monotonous intervals, the writer feels that one cannot be too careful in the matter of suggestion. The immediate object of the experiment is the greatest possible accuracy in discrimination under certain experimental conditions, and the mediate and final object, the determination of the factors entering into such discriminating judgments. When, however, the reagents feel that mediately and immediately the introspective data are the main object of experimentation, then one is apt to become aware of a throng of subjective processes which may well be absent in the normal and usual discriminative judgments. It is only in this way that the writer can explain the great number and variety of introspective details recorded, in late work on memory images for clangs sounds and colors. In the careful investigation of G. R. Whipple on the Memory Image for Clangs, for example (*Amer. Journ. of Psych.* XII, No. 4), there was set up before the reagents a placard indicating no less than 11 categories of introspection — some of them with several sub-heads — as a constant »memento introspicere« during the course of experimentation. In the present investigation, though especial stress was laid on introspection, the introspective results, even with so trained and careful an observer as Ke are meagre when compared with those of the above research.

The time of exposure of the norm was at first, 3 sec., but as the reagents found that the disc changed perceptibly in shade during this period, the exposure time was shortened to 2 sec.

Combining all the judgments of both time orders for each reagent with reference to the conditions of *A* and *a*, we get the figures of table I. Owing to unforeseen interruptions the work was not carried out to the extent originally planned. The 15 second interval with forced attention was omitted altogether, and the number of judgments for each interval was hardly enough to justify a comparison of them with regard to time order. Under *u* (undecided) have been placed not only genuinely doubtful but »double« judgments, as for example, a judgment darker followed by like.



Table I.

Actual number of lighter ( $>$ ), darker ( $<$ ), and like (|||), exposures of comparison disc ( $n$ ) and percentage of right ( $r$ ), and undecided ( $u$ ) judgments on the same for the given time intervals for reagents Ke and Kl. A: eyes closed, forced attention; a: eyes open, free attention. (Time order, not wholly balanced for each interval.)

		A											
		5 sec.			15 sec.			30 sec.			60 sec.		
		$n$	% $r$	% $u$	$n$	% $r$	% $u$	$n$	% $r$	% $u$	$n$	% $r$	% $u$
Ke	$>$	23	52	9				32	34	12	19	37	20
	$<$	23	35	26				28	29	18	20	45	20
		25	52	32				28	36	21	20	50	25
	total	71	46	22				88	33	17	59	44	22
Kl	$>$	16	37	—				26	23	12	19	53	—
	$<$	15	27	—				26	31	8	18	78	—
		14	50	—				26	50	4	20	60	5
	total	45	38	0				78	35	8	57	64	2
		a											
		5 sec.			15 sec.			30 sec.			60 sec.		
		$n$	% $r$	% $u$	$n$	% $r$	% $u$	$n$	% $r$	% $u$	$n$	% $r$	% $u$
Ke	$>$	20	50	5	15	53	—	36	33	31	16	62	12
	$<$	21	43	14	14	64	7	30	53	13	16	50	12
		19	37	2	19	26	42	33	36	21	17	35	6
	total	60	43	7	48	47	16	99	41	22	49	49	10
Kl	$>$	24	41	—	12	58	9	12	42	—	14	29	—
	$<$	24	58	—	11	66	9	10	10	—	14	71	—
		25	54	—	11	73	9	12	50	—	17	35	12
	total	73	51	—	34	65	9	34	34	—	45	45	4

The table indicates that the accuracy of judgment is practically independent of the time interval employed. Thus with both fixed and free attention we get the following percentage of correct judgments:

		5 sec.	15 sec.	30 sec.	60 sec.
a	{ Ke . . .	43	47	41	49
	{ Kl . . .	51	65	34	45
A	{ Ke . . .	46		33	44
	{ Kl . . .	38		35	64

The figures indicating *a* judgments do not show any increase in difficulty of judging with increase in the time interval. Nor, do we find, any marked differences corresponding to the different conditions in *A* and *a* — assuredly nothing corresponding to the great difference in mental effort. Taking five, thirty, and sixty sec. with *A*, Ke has an average of 41% correct judgments, and with *a* 44%; Kl has 46% with *A*. and 43% with *a*. That is, Ke seems to judge slightly better with open eyes and Kl with closed eyes and forced attention. Ke, however, says it is slightly easier for him to judge with closed eyes, and Kl found it very much harder, as was evident from the action of his facial muscles during the time interval.

The results of the distraction experiments are given in the following table:

Table II.  
Judgments with Distraction.

	15 sec.		30 sec.		60 sec.	
	<i>n</i>	% <i>r</i>	<i>n</i>	% <i>r</i>	<i>n</i>	% <i>r</i>
Ke . . .	47	49	59	36	24	33
Kl . . .	33	52	52	56	23	43

This table is in one respect somewhat misleading; there are in it more cases from the second time order (*V*—*N*) than from the first. The probable effect of this is to increase Ke's right judgments considerably and decrease slightly those of Kl. The average for all the time intervals with distraction is for reagent Ke 39%; without distraction, 43%. With Kl, the corresponding figures are 50% with, and 47% without distraction. A more equal distribution of the time order would probably have made these pairs of figures more nearly

equal. So far as the figures go, however, it would appear that Ke is hindered and Kl helped by distraction. The number of judgments marked »Sicher« is too small both in distraction and undivided attention to help decide this question, and the same holds true with regard to the relation of *A* to *a*.

The next question that arises is, — How far do the notes in the protocol books explain these figures? In the case of reagent Ke the writer anticipated a great deal of visual imagery; as reagent in the method of mean gradations he had constructed a sort of visual ladder up and down which the variable moved, and several years later Ament notes (Phil. Stud. XVI, p. 173) another visual scheme which Ke had constructed in the method of minimal changes. While in the earlier stages of the work with the larger intervals, Ke notes the presence of visual images of the disc which serve as means of comparison, the number of these is insignificant as compared with the references to verbal reproduction, and in the latter part of the work references to visual reproduction cease altogether. On the other hand, notices of verbal associations are exceedingly frequent: »Bei Reiz 1 dunkel«, »Bei Reiz 1 recht hell«, »Auf Grund der wörtlichen Bezeichnung«, is by far the most frequent type of remarks. Ke is of the opinion that the verbal images assist in the comparison, though he also notices that their presence may contribute nothing to the act of comparison, and he finds that, in the course of a series, there is a very considerable falling off in the energy of reproduction. He notes almost at the start a tendency to name the shades through »inability to hold fast the picture«. In the course of the experimentation Ke elaborated the following scale: — hell, ziemlich hell, ziemlich bis recht hell, recht hell und ganz hell; dunkel, ziemlich dunkel, mittel dunkel, recht dunkel — all used to designate the first disc of the comparison. Nor was this scale long in forming; on the third day of experimentation Ke notes that »absolute« judgments play an important part, that there is rarely a real comparison and that when the first disc appears, he says »hell« or »dunkel«. Besides verbal and visual imagery Ke notes sensations of tension in the eyes and forehead — the latter probably coming from attempting to serve as reagent when fatigued. These tension sensations are however rarely noted, and the amount they served with this reagent as a vehicle of comparison is a matter

of doubt. Ke stated on the third day of experimentation (5 sec.) that he tried to reproduce the first impression or effect »which is hardly an idea of the image«. This, together with a remark (4th day 5 sec.) that movements of the eyes during the interval destroyed the visual image, may mean that these tension sensations served as a basis of comparison. This, however, is noted only for short periods.

With reagent K1, reproduction is confined almost wholly to verbal imagery. At the beginning he notes an indistinct image which »does not assist in the comparison.« After a months experimentation he remarks that the words »hell« and »dunkel« call up an image of the disc. »No visual image but by means of a word«, »Always by means of words 'ziemlich hell'«. If he forgets the term used at the exposure of the first disc, he cannot make the comparison. His notes indicate a scale of but three values — »ziemlich hell«, »hell«, »dunkel«. It is, however, to be remarked that for many reagents verbal terms are by no means the only marks which may be carried over from the norm. to the comparison; in marking the first disc the quickness or briskness or even degree of ease or satisfaction with which it is recognized as light or dark, may all serve as marks for carrying over the first impression to the second.

The protocol notes indicate therefore that most of Ke's judgments and about all of K1's are based on contiguous association, more especially on verbal reproduction. If this is the case, the numerical results of the experiments are easily explained. For judgments of this kind it is obvious that the time intervals used would make no great difference. After an impression has been classified as bright either verbally or through the rapidity and ease with which it is apprehended as »light«, it is evident that the comparison can be classified with respect to the norm so long as the »reading«, so to speak, of the norm remains in mind. For such judgments too it is obvious that closed or open eyes — fixed or free attention, or artificial distraction would make no essential difference. Some accidental variation might well arise through the confusing or changing of the memory of the reading, but in the main the results would be about what we have found in these experiments. This explanation too is in accordance with Lehmann's results referred to at the beginning of this paper. Lehmann also introduced a distraction judgment

into the 120 sec. intervals, and found that the recognition of one of two shades of gray for 120 seconds with distraction was as accurate as for 30 sec. without distraction. Accordingly, he argues as the writer has urged in case of clangs (*Amer. Journ. Psych.* XII, 69) that such judgments cannot be based on memory images of the same kind as the stimuli.

Two other factors remain to be considered in this connection — the formation of free judgments and the results arising from objectively like stimuli. These topics will come up for discussion in the second part of this paper.

### Experiments of the second part.

In the spring and summer of 1901 the above experiments were repeated at Stanford University to see if the results of the Würzburg experiments would be confirmed by other reagents and under better experimental conditions. The Marbe color-mixer was mounted on a weighted box insulated from the experiment table by spongy rubber. The mixer was driven by a smoothly running Edison motor also mounted on an insulated box, whilst the experiment table was separated from the floor by several folds of cloth. In this way with the bearings of the apparatus carefully oiled and adjusted there was no metallic rattle or resonance from table or floor perceptible. The disc of the color-mixer was about 8 feet distant from broad double windows covered, as in the previous experiment, with several layers of white muslin. Experiments were carried on in a room built for the purpose of black paper and open on the side toward the window. The exposure curtain was about 75 cm wide and mounted on a spring roller. Back of the curtain, black cotton-flannel was so hung that nothing save the disc and its black back-ground were visible when the curtain was raised. The conditions as regards colorless light were so good that the reagents complained of colored after-images arising from a tinge of color in the paper of the note books, so that it became necessary to cover the note-book pages with black cardboard through which slits were cut for making notes. In addition the reagents rested their eyes on the note-books as little as possible.

The reagents were Alvin Borgquist (Bt), a mature student with

about two years experience in psychological work, and the writer (Al). Bt was formerly a student of philosophy and has acquired the tendency to think and speak in abstract terms; on the other hand, he has a marked habit of making clear to himself scientific theories and propositions by means of visual schemes. Al is of the ordinary motor acoustic type with perhaps an originally strong tendency towards visualization. At the time Al was acting as reagent he had not worked up the results of the Würzburg experiment. He had, however, read all the introspections save some written by Ke in shorthand, and he had »guessed« that the judgments were based in great part on verbal associations. Al's introspective data therefore may have been influenced by this knowledge, though of course he is not conscious that any data recorded by him are colored by such influences. The experimenter was Mr. F. Thompson, who had served long enough in experiments of this kind to carry out the experimentation with judgment. The procedure was wholly without knowledge. Reagent Al presumed that the experiments would follow the general line of the Würzburg work, but of the value of the norms — whether or not the norms were changed from time to time — of the values and arrangement of the scale of comparisons — of all this he had as little knowledge as Bt.

In as much as Bt was naturally much inclined to introspection, he was simply instructed to note what he thought relevant with special reference to the visual image. Both reagents were to underscore judgments which they felt sure were correct. The time of exposure of the discs was 1,5 sec. In Table III the figures of these experiments are given for both reagents, both time orders, with and without the distraction of the simultaneous comparison of two discs. The signs are not in all respects like those of the preceding tables. The brightnesses are given in degrees of white instead of black. The calculation of results is also somewhat different. The double judgments, e. g. »darker — like« have been split and each component assigned with a value 0,5 to its proper category<sup>1</sup>).

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1) The averages were calculated by Mr. Thompson for a paper of his own. The absolute values have been somewhat changed without greatly affecting their relations.



A glance at the columns giving the averages of correct judgments for differences of norm and comparison amounting to  $10^\circ$  or  $20^\circ$  of white as well as the general average of these two  $\left(\frac{r_1 + r_2}{2}\right)$ , show that so far as discriminations of differences are concerned, the correctness of judgment is practically independent of the time intervals. The figures for the D'n experiments indicate neither influence of D'n nor of flight of time for objective differences of the stimuli. On the other hand, the number of correct judgments for  $N = V$  falls off irregularly with the time, the drop from 5 sec. being very marked. In all these respects the experiments agree more or less closely with similar experiments on clangs. (Angell and Harwood, *Discrimination of clangs etc.*, Amer. Journ. of Psych. XI, 67.)

Examining the protocol books to see in how far their records agree or disagree with those of Ke and Kl, we find the same tendency towards the formation of a scale of brightness as a basis for comparison. Bt indeed notes a great deal of visual imagery, usually of the disc or details immediately connected with it. Sometimes this is a simple image of the norm, called up when the signal for the comparison is given, sometimes it is a persistent image of the disc waxing and waning in brightness, and sometimes it is a photism, as when he had a bright image of »pale freckled face formed out of the image of the norm«, lasting the entire time interval (60 sec.). In this connection it may be said that during the first half of the work, Bt complained of a play of after-images. Sensations of tension also enter largely into Bt's consciousness during the time interval, especially those coming from the trunk, respiratory muscles and eyes. He tries as far as possible, to keep these sensations constant. On the other hand, Bt notes early in the course of the work the tendency to judge through classification of  $N$  and  $V$ . Later on he notes »I seem to place the norm in a series; i. e. when I see a norm I seem to recognize it as a member of a certain class, or as having seen it frequently before.«

In the case of Al there was a large amount of visual reproduction during the 30 sec. and 60 sec. intervals, but for the smaller intervals reproduction was rarely noted. This reproduction was usually at once verbal and visual, and it was often impossible to say which

Table IIIa.

General table of judgments for reagents Al and Bt, for both time orders with and without distraction ( $D'n$ ) for the several values of the comparison.  $n$  = no. of judgments,  $\succ l \ll$  lighter and  $\succ || \ll$  like judgments.  $r_1, r_2, r_a$  correct judgments.

Degrees of White	160°			170°			180°			190°			200°			$\Delta_1$	$\Delta_2$	$\frac{r_1+r_2}{2}$
	$n$	% $r$	% $  $	$n$	% $r$	% $  $	$n$	% $l$	% $  $	$n$	% $r$	% $  $	$n$	% $r$	% $  $	$\pm 10$	$\pm 20$	% $r_a$
Time Order I	5"	38	76.2	13.1	41	48.8	21.9	32.9	24.4	35	47.0	19.9	35	71.4	12.8	47.9	73.8	60.8
	15"	43	68.5	12.7	45	41.1	22.2	41.1	11.1	40	43.7	17.5	41	65.8	15.8	42.4	67.1	54.7
	30"	34	72.0	10.0	36	36.1	13.9	39.9	12.8	32	71.9	4.6	32	65.6	10.9	54.0	68.8	61.4
	60"	32	70.2	7.7	33	27.2	15.1	54.5	15.1	31	66.0	11.5	30	88.3	0.0	46.6	79.2	62.9
	Av.		71.8	10.9		38.3	18.3	42.1	15.9		57.1	13.9		72.8	9.9			59.9
Time Order II	5"	30	88.3	3.3	31	37.1	29.0	53.3	25.0	28	60.6	7.1	29	74.2	10.3	48.8	81.2	65.0
	15"	30	63.3	10.0	32	51.5	14.0	53.2	8.0	28	57.1	16.1	28	85.7	0.0	54.3	74.5	64.4
	30"	20	55.0	20.0	21	50.0	19.0	28.5	14.2	18	55.5	25.0	19	86.7	2.6	52.7	70.8	61.7
	60"		68.8	11.1		46.2	20.6	45.0	15.7		57.7	16.1		82.2	4.3			63.7
	Av.																	
Time Order I	5"	55	74.5	13.6	55	54.5	26.3	29.1	42.7	56	58.0	17.8	56	68.7	16.9	56.2	71.6	63.9
	15"	38	73.6	6.5	37	58.1	12.1	39.4	18.4	38	36.8	17.0	38	68.4	11.8	47.4	71.0	59.2
	30"	30	65.0	1.6	30	66.6	13.3	48.3	10.0	28	35.7	16.0	30	41.7	16.6	51.1	53.3	52.2
	60"	19	84.1	5.1	20	50.0	22.5	52.6	15.8	20	30.0	25.0	20	62.5	17.5	40.0	73.3	56.6
	Av.		74.3	6.7		57.3	18.5	42.3	21.7		40.1	18.9		60.3	15.7			57.9
Time Order II	15"	28	67.8	10.7	27	42.5	22.3	29.6	24.1	28	42.8	14.2	28	60.7	17.8	42.6	64.2	53.4
	30"	26	71.1	3.8	25	64.0	2.0	40.4	7.7	26	50.0	15.4	26	53.8	21.2	57.0	62.4	59.7
	60"	26	65.4	11.5	26	61.5	15.4	44.2	15.4	26	38.5	0.0	26	55.7	15.4	50.0	60.5	55.2
	Av.		68.1	8.7		56.0	13.2	38.1	15.7		43.7	9.9		56.1	18.1			56.1

Reagent Al.

Table IIIb.

Degrees of White	160°			170°			180°			190°			200°			$\frac{r_1+r_2}{2}$ % $r_a$	
	<i>n</i>	% <i>r</i>	% III	<i>n</i>	% <i>r</i>	% III	<i>n</i>	% <i>l</i>	% III	<i>n</i>	% <i>r</i>	% III	<i>n</i>	% <i>r</i>	% III		
Time Order I <i>D<sub>n</sub></i>	5'	37	68,8	13,5	41	65,8	20,7	41	12,2	31,7	34	29,4	32,3	35	48,5	25,7	53,1
	15'	40	90,0	2,5	42	58,3	10,7	42	17,8	16,6	38	31,5	18,4	38	68,4	13,1	62,0
	30'	32	90,6	3,1	33	48,5	9,1	34	36,8	10,3	30	48,3	10,0	30	65,0	10,0	63,1
	60'	29	63,7	6,9	30	45,0	18,3	30	48,3	3,3	29	51,7	5,1	29	74,1	6,9	58,6
	Av.		80,8	6,5		54,4	14,7		28,8	12,7		40,2	16,4		64,0	13,9	59,2
Time Order II <i>D<sub>n</sub></i>	15'	29	82,7	3,4	31	58,0	14,5	31	25,7	16,1	29	44,8	5,1	29	77,6	5,1	65,7
	30'	27	88,8	0,0	29	48,2	6,9	30	25,0	6,6	25	52,0	6,0	24	77,0	6,2	66,5
	60'	18	83,3	8,3	18	55,5	11,1	19	26,3	7,8	17	58,8	23,5	17	61,7	11,7	64,8
	Av.		84,9	5,8		53,9	10,8		25,7	10,2		51,9	11,5		72,1	7,7	65,7
	Time Order II <i>D<sub>n</sub></i>	5'	61	81,1	9,0	61	54,8	10,6	59	22,9	30,4	62	64,5	10,5	62	71,8	9,7
15'		42	45,2	14,3	42	47,6	5,9	42	25,0	16,7	42	57,1	13,1	42	77,4	8,3	56,8
30'		32	70,3	3,1	32	39,1	17,2	32	31,3	15,6	32	53,1	12,5	32	68,7	6,2	57,8
60'		22	77,3	6,8	22	59,1	13,6	22	36,4	20,4	22	47,7	11,4	22	63,6	4,5	61,9
Av.			68,5	8,3		50,0	11,8		29,1	20,8		55,6	11,9		70,4	7,2	61,1
Time Order II <i>D<sub>n</sub></i>	15'	30	60,0	6,6	30	50,0	16,6	29	43,1	6,9	29	58,6	3,4	30	63,3	0,0	57,9
	30'	29	62,0	12,0	29	44,8	10,3	29	32,7	10,3	30	58,3	5,0	30	71,6	8,3	59,1
	60'	28	55,3	10,7	27	38,9	9,3	28	35,7	3,6	27	55,5	5,6	28	60,7	5,4	54,6
	Av.		59,1	9,8		44,6	12,1		37,2	6,9		57,5	4,7		65,1	6,8	57,2
	Reagent Bt																

was the antecedent — the term or the visual image. The visual images often included the disc, the button on the disc, the motion of the disc and the black back-ground. When the image was of the disc alone it seemed to wax and wane in its brightness whilst its circular form changed to irregular shapes. For the 5 sec. and 15 sec. intervals, tension sensations in the eyes, oral and respiratory muscles were most marked — resulting from an attempt to keep bodily conditions unchanged until the second stimulus appeared. For the longer intervals these sensations were not present. The visual image appeared most frequently immediately after the word »ready« before the comparison. Rarely an act of comparison seemed to take place directly between the visual image and the second stimulus.

The formation of judgments through verbal association was first noted in the fourth series. The words »that was light« arose after viewing the norm. The terms »light«, »bright«, »very light«, »exceedingly bright«, »dark«, »darker« (this last as compared with preceding norm.) were noted. At the same time the brightness of the disc did not seem to vary equally in both directions around a standard as the terms would seem to imply. At the end of the last period of experimentation, the experimenter exposed, in irregular order, the stimuli that he had been using as comparisons and asked each reagent to designate each shade as it was exposed. The result was as follows.

		160°	170°	180°	190°	200° White
Al	1.	dark medium	light medium	light medium	light	very light
	2.	» »	dark	» »	»	» »
Bt	1.	dark	dark	dark	medium dark	light
	2.	med. dark	med. dark	light	» »	medium

The tendencies shown in the above scales are reflected in the table III, where Bt. has more correct judgments on the dark, and Al. more on the light side. Often the disc seemed to vary in such a way that the reagent surmised the experimenter was using several norms. The brightness seemed to vary not only from day to day but from series to series and even during the course of a series.

Almost at the beginning Al, and somewhat later, Bt, noticed the formation of free judgments — i. e. judgments in which the reagent

could not recall that the norm. was present in the act of passing judgment. Bt notes »I think I judge this in a negative way, not by a conscious comparison but because  $V$  seems striking, I did not remember having seen anything so bright before. I have observed several of this kind, and this seems to be common. It struck me with a feeling of surprise«. Throughout the experimentation Al notes the uttering of free judgments.

According to Martin and Müller's analysis of this class of judgments<sup>1)</sup> we should expect more correct cases in the time order  $N-V$  than in the order  $V-N$ . Taking the general averages in table III ( $r_a$ ), we find the proportion of right judgments in the two time orders for Bt is  $\frac{\text{time order 1}}{\text{time order 2}} = \frac{61,9}{59,4}$ , and for Al,  $\frac{67,5}{57,1}$ .

But beside these free judgments, both reagents noted cases where they could deliver no judgment because the norm was »forgotten«. In these cases no lack of attention was noted; the reagents were simply unable to pass judgment because impression of the norm had passed away; it was too undecided or too weak to last during the time interval. According to theory there should be proportionately more free judgments in time order 1 than in time order 2. Taking all the judgments up to the beginning of the chronometric experiments (to be discussed later) we get the following table.

Table IV.

Per cent of free judgments and of »failures«.

	Time Order 1			Time Order 2		
	<i>n</i>	% free	% fail.	<i>n</i>	% free	% fail.
Bt. . . . .	848	4,3	2,0	1051	1,1	3,0
Al. . . . .	852	4,1	0,8	846	2,0	1,0

The above table gives only the percentage of cases where a distinct effort was made to recall the norm.; it is probably complete as regards the failures, but it does not include a great number of cases where the judgment was uttered quickly but without a trace of comparison.

1) Zur Analyse der Unterschiedsempfindlichkeit. S. 25 u. 45.

It therefore seems probable that running along with and playing into the contiguous associations before noted the factor of free judgments helps to make these discriminations independent of the time interval.

### Chronometric Experiments and Like Cases.

Everyone who has served as reagent or experimenter has noticed the marked difference in the quickness of delivering discriminative judgments. It has been commonly noted that »sure« judgments were the shortest and doubtful judgments the longest. The place taken by like judgments has not been commonly known, though in making up averages they have been often classed with doubtful judgments. At any rate, the writer thought that a knowledge of the time relations of the several kinds of judgment might throw some light on the processes of formation.

Accordingly an apparatus was arranged for recording the time of judgments. Around a pair of horizontal drums, placed about 1,5 m apart, there ran a belt of 3,5 m of the ordinary glazed kymograph paper. This belt could be conveniently smoked by a broad wick flat-iron lamp placed beneath the lower layer of paper. Motion was given by clock-work connected with one drum. The recording apparatus consisted of a triple time marker connected with telegraph keys screwed to the reagents' chairs, and with the roller curtain in front of the disc. Time was marked by an electrically driven spring rod marking  $\frac{1}{15}$  sec. When the lower edge of the swiftly rising curtain reached the upper edge of the disc it tripped a lever connected with a Pfeil time-marker, and the reagents then registered »judgment reaction time« by pressing the key. Of course this took place only with the comparison disc. It must be said that this arrangement made no small demand on the dexterity of the experimenter: — to let up and pull down the curtain, to set the reading of the color-mixer, adjust the second disc of the D'n experiment, to raise and lower the curtain for the simultaneous judgment, to re — set the color-mixer for the main comparison, to turn down the lever and set the vibrating spring and drums in motion, and finally to raise and lower the curtain — all done quietly and without interruption at stated intervals given by metronome beats, calls for no



small amount of ready skill in manipulation for which the writer is exceedingly indebted to Mr. Frank Thompson, Assistant in the Department of Pedagogy.

It was not supposed that absolute values of these judgment times would be of any great moment; the processes are too complex and the number of variables too great to give these averages an unambiguous value. There is formed e. g. a tendency in these experiments towards anticipatory judgment; the norm strikes one as being very bright and the judgment »darker« is anticipated. If the judgment is »darker«, a very quick or even anticipatory judgment may take place. But if the judgment is »lighter«, a period of adaptation and feeling of surprise come into play which may greatly retard the judgment, even when it may be recorded as »sure«. In addition the readings were taken only to tenths of a second.

The immediate effect of these reactions was to serve as a spur for attention: — the reagents were much more on the alert than before, especially in the longer time intervals. A further effect was either to increase the sharpness of introspection or the tendency towards classifying the norm. At any rate, the tendency to fix the value of the norm by a term became much more apparent. Bt notes: »Verbal association — ,White but not glaringly white'. I notice the tendency to characterize the judgment in some such way. I hear myself saying something about the character of the norm during the interval, and feel an incipient motion in my vocal organs as if trying to utter it. I notice when the signal ,ready' is given that the characterization comes, and the visual image, if at all, comes later«.

The figures of the time measurements fulfilled only in part the writers expectations. In the case of Bt practice had not gone far enough to make his reactions automatic and the fluctuations in the first half of the work are large. Excluding therefore the first half of Bt's reactions altogether and omitting those which he marked as faulty, we find that the averages of the reaction times for 15 sec., 30 sec., and 60 sec. are 0,63, 0,62, and 0,55 respectively. Maximum, 1,2 sec.: minimum, 0,4 sec. It would thus appear that Bt has no more hesitation — perhaps less — in judging longer intervals than shorter. As regards different categories of judgment his unqualified

judgments average 0,57 sec. as against 0,63 for the qualified (e. g. »lighter doubtful«).

As reagent A1 used less categories of judgment than Bt, his results are less scattered. His fluctuations are also less.

The results of A1's time measurements are given in table V. Two places of decimals is of course, the result of averaging. Times of double judgments are not included, as such judgments were infrequent. The main object in separating the distracted comparisons from the undistracted, is merely to show that the latter have the same trend as the former, — quickest for the »sure« judgments, and slowest for the »like«. Otherwise, on account of the small number of cases it would be better to lump both conditions of attention together.

The mean variations of the several categories of judgment with each time interval range from 10 to 13 per cent.

Table V.

Averages of reaction times ( $t$ ) for the several time intervals and for the several categories of judgment under each interval with ( $D'n$ ) and without distraction (no  $D'n$ ). Number of reaction =  $n$ . Reagent: A1. Times given in hundredths of a sec.

Character of judgment	5 sec.		15 sec.				30 sec.				60 sec.			
	$n$	$\frac{no}{D'n}$ $t$	$n$	$\frac{no}{D'n}$ $t$	$n$	$\frac{D'n}{t}$	$n$	$\frac{no}{D'n}$ $t$	$n$	$\frac{D'n}{t}$	$n$	$\frac{no}{D'n}$ $t$	$n$	$\frac{D'n}{t}$
Sure . . . . .	9	0,74	17	0,69	8	0,67	14	0,63	8	0,75	29	0,63	9	0,68
Fairly sure . .	25	0,80	16	0,73	23	0,71	29	0,75	22	0,77	30	0,71	32	0,75
Like . . . . .	6	0,90	6	0,83	2	0,85	7	0,85	6	0,80	6	0,77	8	0,87
Doubtful . . .	5	0,72	5	0,82	6	0,80	4	0,90	6	0,80	13	0,87	9	0,75

The indications from this table are that the »sure« judgments are the quickest and the »like« judgments the slowest, with the »fairly sure« holding an intermediate position. Comparing the time intervals without distraction, we find as far as the figures go, that the 5 sec. interval takes more time in judging than any other interval for every category except »doubtful«. As however the figures do not go very far for the separate divisions of the 5 sec. judgments it is better to get the general average from all the reaction times for each interval without distraction. This gives for 5 sec. — 0,77,

for 15 sec. — 0,74, for 30 sec. — 0,74, for 60 sec. — 0,71. It is probable therefore that for this reagent, at any rate, the longest intervals are judged most quickly and the shortest intervals most slowly. The difference would be greater if the highly ambiguous class of doubtful judgments were omitted.

The results of the time measurements are in accord with the explanation of these judgment processes. The reaction time for 60 sec. is shorter than for any other time interval; it is the interval also in which one would rely most on the formation of a scale of brightnesses and on free judgments.

As regards the reactions for 5 sec., it has been observed that the demeanor of reagents for the shorter intervals is commonly, not invariably, different from what it is in the longer. In the 30 and 60 sec. intervals, the reagent is apt, soon after the exposure of the norm, to relax the trunk muscles, settle himself into an easy attitude, to breathe easily and to move the eyes from time to time over the background. During the shorter periods as has already been observed, the reagents usually try to maintain uniform sensory conditions for both norm and comparison: the tension sensations from the trunk, respiration and eye muscles are kept constant, in order apparently, to make the conditions of comparison as much alike as possible. Accordingly we have, for most reagents, a much larger mass or background of sensation entering into the comparisons of the shorter intervals, and in all probability more genuine acts of comparison. This position is strengthened by the longer reaction time for 5 sec., — so far as it is permissible to draw conclusions from a few experiments.

As has been remarked the percentage of right cases for  $N = V$  decreases with the time interval and the law of forgetting for sensory impressions has been drawn from the like cases<sup>1)</sup>. The judgments of »like« differ from those »unlike« in being in great part negative. They are, so to speak, a function of the »unlike« judgments. The greater the difference between  $N$  and  $V$ , and the easier it is to mark differences, the easier it is to judge »like« when  $N = V$ . Accordingly, judgments of »like« result, in great part, from failure

1) Wolfe, in Philos. Studien, III, p. 552.

to perceive a difference. In accordance with this we find that reaction-times of A1 for »like« are slower for all time intervals, both with and without D'n. When a series of comparisons is made up of stimuli, differing in part but a little, and in part not at all, from the norm stimulus, the judgments of »like« may be attended by a conviction of likeness which is very often due to a feeling, mood or tension sensation, or even to accidental circumstance. The judgment »like« which A1 delivered with the strongest feeling of conviction, came from a faint pink tinge, on both norm and comparison, resulting from a trace of blue in the page of the note-book. If then mental processes, not necessarily integral parts of the visual image of the disc, but present both at the exposure of the norm and the comparison, may determine judgments of »like«, then we should expect the greatest frequency of these judgments where such common factors most frequently occur, viz. in the shorter time intervals. Turning to the averages of the undistracted intervals of table III, we find that the average number of »like« judgments of the 5 sec. intervals for A1 is 21,2 %; for the other three intervals 11,4 %. For Bt the corresponding figures are: 5 sec. —19,4 %; other intervals — 10,4 %.

This last fact helps to explain the greater proportion of right judgments of »like« in the shorter intervals. Granting, as is highly probable, that more direct and accurate acts of visual comparison take place in the shorter intervals, we have also the additional factor of the relatively greater number of these judgments in the shorter intervals.

It is obvious that the tendency towards incorrect judgments will be greater for like than for unlike values of  $N$  and  $V$  for the longer time intervals. For  $N$  and  $V$  in these judgments are medium shades and less apt to call out free judgments than the extreme brightnesses used as comparisons. But the effect on judgments depending on contiguous association would probably be still more pronounced: for in the first place, a medium shade of gray might be classed at one time as light and another time as dark, but neither with any great degree of conviction so that in the time order  $N—V$  especially the associated member whether verbal or otherwise, might easily be confused or lost. This is shown clearly in the case of Bt who makes

not infrequent use of the note ›forgot‹, i. e. he cannot deliver a judgment because the norm has passed out of mind. He has 69 of these ›forgot‹ distributed as follows:

	$V=160^\circ$	$170^\circ$	$180^\circ$	$190^\circ$	$200^\circ$ White
Order $N-V$ . . .	5	12	15	5	6
› $V-N$ . . .	4	4	9	7	2
total ›forgot‹	9	16	24	12	8

His forgotten norms follow accordingly the inverse order of the physical brightnesses, and as is to be expected, are more numerous in the t. o.  $N-V$ .

With reagents who maintained practically fairly like conditions of relaxation or tension for all time intervals, we should expect different results, so far as the ›like‹ cases are concerned. But in general, the writer would explain the results obtained in the above and in similar experiments:

1. from the presence of contiguous reproduction, usually verbal, coming from the formation of a scale of values;
2. from the presence of free judgments resulting also from the formation of a scale of values;
3. from the relatively large number of judgments of ›like‹ for the shorter intervals resulting from the maintenance of common conditions during the periods of exposure of norm and comparison.

In conclusion the writer desires to express his thanks to Prof. Külpe, Dr. Kinkel and Mr. Borgquist for their patient and valuable services as reagents, and to Mr. Thompson for his skillful manipulation of the apparatus.