

TACTUAL ILLUSIONS OF MOVEMENT¹

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A. INTRODUCTION

The kinematoscopic illusion in which two similar stationary visual stimuli in quick succession in different places yield an impression of movement has long been familiar. Wertheimer² and Korte³ studied the phenomenon rather exhaustively with variations of intensity, distance, interval, etc. The writer has demonstrated the possibility of such illusions in audition.⁴ Benussi has found similar phenomena in touch and has published two brief accounts,^{5, 6} the latter of which appeared after the present study was in progress. It seemed profitable to determine whether the tactual corresponded to the other sensory fields merely in the existence of the illusion under optimal conditions, or whether there was a correspondence in the more detailed aspects. Accordingly an investigation was made of the rôle of the intensity of the tactual stimuli, the distance between them and other variables much as they were studied by Korte in the visual phenomenon.

The principal facts found by Korte are as follows:

1. If two equal straight lines or other similar visual stimuli a few centimeters apart are presented in quick succession for equal lengths of time certain conditions of intensity, time and distance yield an impression of movement from one

¹ From the Harvard Psychological Laboratory.

² Wertheimer, M., 'Experimentelle Studien über das Sehen von Bewegung,' *Zeitschrift für Psychologie*, 1912, 61, pp. 161-265.

³ Korte, A., 'Kinematoskopische Untersuchungen,' *Zeitschrift für Psychologie*, 1915, 72, pp. 193-296.

⁴ Burtt, H. E., 'Auditory Illusions of Movement,' *J. OF EXP. PSYCHOL.*, 1917, 2, pp. 63-75.

⁵ Benussi, V., 'Kinematohaptische Erscheinungen,' *Archiv für die gesamte Psychologie*, 1913, 29, pp. 385-388.

⁶ Benussi, V., 'Kinematohaptische Scheinbewegung und Auffassungsumformung,' *Bericht VI. Kongres für experimentelle Psychologie*, Göttingen, 1914, pp. 31-35.

stimulus to the other in the direction of the actual temporal succession.

2. The longer the exposure of the stimuli the relatively shorter the interval which gives the optimal impression of movement.

3. The greater the distance between the stimuli the greater the optimal interval.

4. The greater the absolute intensity of the stimuli the shorter the optimal interval.

5. The greater the intensity the greater the optimal distance.

6. If the second stimulus is of greater intensity than the first the direction of the apparent movement is sometimes the reverse of the actual direction of temporal succession.

The above relations were investigated in the present case with tactual stimuli. The effect of varying degrees of difference in intensity between the two stimuli, which occupies a considerable portion of Korte's monograph, was not studied inasmuch as the reversal effect occurred much less frequently in the present case.

B. APPARATUS AND METHOD

An experiment of this sort necessitated some method of giving two similar tactual stimuli at different points of the skin, with control of the time relations, intensity of the stimuli and distance between them. It was also desirable to give as a check some stimulus approximating in its effect a continuous movement on the skin.

Ten brass rods with blunted points 2 cm. apart in a straight line were arranged to stimulate the back of the forearm. With the whole row actuated by solenoids in quick succession the effect was always much like a continuous movement, for any two adjacent points were within a "Weber's circle." This gave the check mentioned above. For most of the work only two solenoids were actuated on a given trial, the distance between stimuli depending on which solenoids were used.

The solenoids were mounted individually on narrow strips

of wood arranged to slide vertically side by side on a large wooden base. A piece of round magnet iron 2.5 cm. long formed the core and was suspended by a spiral spring from an adjusting screw above the solenoid. The lower end of this core contained a hole into which a brass rod of the same diameter as the core was dowelled. The lower end of this brass rod was pointed to give the tactual stimuli. The subject's arm was clamped palm downward in the rest of the Mosso's ergograph with the first and third fingers in the usual tubes to insure rigidity. The base to which were attached the strips of wood carrying the solenoids was mounted longitudinally above the arm. These strips could be moved up and down individually by set screws. The base also could be moved vertically so it was possible to adjust the 10 brass points to any desired distance from the skin. Any hairs in the vicinity of the brass points were of course removed. The iron part of the cores were usually set a few millimeters above center and the brass points adjusted to a distance of about 1 mm. from the skin. Thus the intensity of the stimulus did not vary appreciably with difference in length of time the current passed through the coils although it did vary with the intensity of the current. This latter was controlled by rheostats. The solenoids were actuated by either about 20 volts of storage batteries or by the direct 110-volt laboratory current with a rheostat in series.

A time-controlling mechanism was made from the 'Leipzig time sense apparatus' with a series of closely adjacent marginal contacts and a rather complicated switchboard. It was possible to actuate the 10 solenoids in rapid succession or any two in succession for desired lengths of time with any desired interval between. The space order (up or down the arm) could be reversed at will. The time mechanism was placed in an inner soundproof room. The experimenter and subject sat in an outer room at opposite sides of the table on which were the solenoids, switchboard and rheostats. The subject's arm rested comfortably in the apparatus which was so placed that the upright base was between the subject and the solenoids. Their action was thus invisible

to the subject but could be watched by the experimenter. The action of the solenoids was practically noiseless.

The subjects were not told of the nature of the experiment but merely that it was a study of tactual perception. At the beginning of each hour they were instructed: "When I say ready close your eyes and attend to the forearm and then tell what you felt."

The warning 'ready' was given approximately 1 second before the stimuli. On a given hour trials involving different relations of the given variables were presented in irregular orders. The main interest was in the effect of two successive stimuli, but trials were always intermixed in which a row of adjacent stimuli were given. It could thus be seen how the subject would confuse two discrete stimuli with the close approximation to continuous movement produced by a row.

The experiments were performed in the Harvard Psychological Laboratory in the academic year 1915-16. The subjects were graduate students or undergraduates of considerable psychological experience.

C. RESULTS

I. *The Movement Illusion*

All four subjects who participated in the experiment yielded in many trials the illusion of movement. If the point of a rod was pressed on the skin of the forearm for a definite period and then after a brief interval another rod a few cm. distant pressed on the skin for the same length of time as the first, there was sometimes an impression of movement from the first point to the second, sometimes a single fused sensation and sometimes two discrete impressions. These effects varied with the combination of time, intensity and distance variables employed (*cf. infra*).

The (illusory) movement impression was variously characterized in the introspection of the subjects.

Subject *A* distinguished a *series* in which there appeared to be a number of stimuli in a row 'pretty close but possibly felt as separate,' from a continuous *flow* from one end to the other in which he 'could not tell the separate points.'

There was also at times an *arrow* at the end of the flow as if the movement went on in the air a short distance.

C noted three forms of the illusion: a *line* which was 'as if you pressed down a long object' either all at once or beginning at one end of the object; a *walk* in which there are a number of discrete points in succession; and a *roll* which is 'continuous movement.' He also occasionally reported a *loop*, the motion being in the air above the arm rather than actually upon the skin.

D described the apparent movement as a *snake effect*. He felt a number of intermediate points but also a connection. It suggested black points connected by a line; 'when they were close together the line was thick and when far apart it was thin.' The effect was best when all points appeared equidistant. A frequent report was three points in succession in the order *ABC* or *ACB*. In the latter case, with the middle point felt last, the snake effect appeared less readily.

F reported movement in which they 'skip along like playing four or five notes on a piano in succession.' It often suggested a little boy running along. He also noted frequently a sort of *loop* in the air between the ends. This 'blends into a sensation of movement.' This loop reported by *C* and *F* corresponds to Benussi's 'Bogenbewegung in der Luft.'¹ Benussi found that with a greater time interval the Bogen was greater and the movement worse. This seemed true for the present subject *F*.

II. *Exposure and Interval*

Korte found in his visual studies that the longer the exposure of the stimuli the relatively shorter the interval that yielded the optimal impression of movement. The writer found the same to be true with auditory stimuli.

To test this factor in the present case, intervals between stimuli of 15, 21, and 40 sigma were used with exposures of the same length or multiples thereof. The distance between the stimuli was constant at 12 cm.; the intensity was moderate, that given by a current of 1.5 amps. in the solenoids.

¹ *Op. cit.*, p. 32.

The results are summarized in Table I. The three successive columns represent results obtained with intervals of 15, 21 and 40 sigma respectively. At the left of each column are arranged vertically the exposures (in sigma) which were

TABLE I
EXPOSURE AND INTERVAL
(Distance 12 cm. Intensity 1.5 amps.)

Sub- ject	Expo- sure	Interval 15	Expo- sure	Interval 21	Expo- sure	Interval 40
A			126	Two ends more discrete		
			105	Two ends	200	Two ends rather close together
			84	Series or two	160	Short series then other end
	45	Series or flow	63	<i>Series or flow</i>	120	Series three or four
	30	Two adjacent	42	Slight flow	80	<i>Four in flow or series</i>
	15		21	Single one in middle	40	Three in series
C			147	Two or three at each end		
	90	Ends successive	126	Five rolling with gap	240	<i>Four to six in succession</i>
	75	Ends successive	105	<i>Six or seven in succession (walk)</i>	200	Three or four in succession
	60	Four or five in succession (line) or two ends	84	One end then three rolling at other end	160	Three in succession
	45	<i>Four in succession (line)</i>	63	Three in succession	120	Ends successive but spread
	30	Ends successive	42	Ends successive or simultaneous	80	Ends successive but spread
	15	Ends successive or simultaneous	21	Ends successive or simultaneous	40	Ends successive
D			126	Group at ends		
			105	Two or three in series	200	Several at each end
			84	<i>Three or four with heavy line</i>	160	Three or four in series
			63	Three with thin line	120	Three or four in series
			42	Several simultaneous	80	<i>Four with snake effect</i>
					40	Three or four in series or ends
F	60	Ends	84	Ends		
	45	Ends	63	<i>Three or four</i>		
	30	<i>Three or four</i>	42	Two or three		
	15	Two adjacent	21	Two close together		

combined with the given intervals. In each section is stated briefly the phenomenon that generally occurred with that given combination of exposure and interval for the subject

indicated in the margin at the left. Each statement is based on from 5 to 10 trials and all results in the table were obtained on the same day. The check trials in which an actual series of touches was given by several successive solenoids are omitted. The results in this and subsequent tables are for only those trials in which two stimuli were given for equal lengths of time with an interval between. For instance we note that with the stimuli for 30 sigma each with an interval of 15 sigma between them, subject *A* generally reported two adjacent touches, and with stimuli for 42 sigma each and an interval of 21 sigma he noted usually a 'slight flow.'¹ Following across any horizontal row in the three columns we have exposure and interval in the same ratio. Thus in the example above $30 : 15 :: 42 : 21 :: 80 : 40$. That report in each column which seems to indicate the greatest effect of the illusion is indicated in italics. Thus by noting the distribution of the italicized phrases for the different subjects any individual or general tendencies may be seen. The variables are arranged (in all tables) with the lowest values at the lower left corner so that an array of italics extending obliquely upward to the right indicates a positive relation between the variables and an array extending obliquely downward to the right indicates an inverse relation.

In the table it is evident that two of the subjects show a direct relation and two an inverse relation between the exposure and interval which give the best impression of movement. For instance with subject *A* an interval of 21 sigma is best combined with exposures of 63 sigma, 3 times as great, while a longer interval (40 sigma) is best combined with one only twice as great (80 sigma). That is, the longer the interval the relatively shorter the optimal exposure. *D* shows similar results. *C* and *F* manifest the opposite tendency but the latter's difference is very slight (a matter of 3 *vs.* 4 apparent stimuli) and perhaps negligible. On the whole the difference appears slightly in favor of the inverse relation. The longer the exposure of the stimuli, the relatively shorter the optimal interval. One may note further

¹ For explanation of individual notations, see p. 374-5.

that for a given interval the shorter exposures give an impression of simultaneity or fusion into a single touch, while increase of the exposure produces the movement illusion and still further increase an impression of discrete successiveness, a result in accord with Korte's visual findings.

III. *Distance and Interval*

Table II. summarizes the results with the distance between the points on the skin and the time interval between the stimuli constituting the variables. The exposures were constant at 60 sigma and the intensity at 1.5 amps. through the solenoids. The successive columns give results with the lengths of interval indicated. The rows give the different distances employed. The general tendency for each combination of interval and distance is indicated by a phrase as in Table I., and the report in each row showing the clearest evidence of the illusion is italicized, where such evidence is present. The results for *F* are indicated numerically rather than qualitatively. He usually gave the numbers of the points which he thought touched the skin (having adopted a scheme with No. 1 next the wrist, etc.). From three to six points were reported in each trial. These were simply added and averaged and the figure in the table represents the average number of successive stimuli reported per trial on the given combination when only two stimuli were actually given.

A glance at the italics shows in every instance a tendency toward a distribution obliquely upward to the right. That is, to obtain the optimal impression of movement the longer the interval between the stimuli the greater must be the distance. This result is the same as that found by Korte in vision. We may note further that for a given distance small intervals give a single point or simultaneity, while increase of interval gives movement and later discreteness and succession.

IV. *Absolute Intensity and Interval*

The intensity of the stimuli was varied from 1.8 amps. through the solenoids, which gave a moderate touch to 4.4

TABLE II
DISTANCE AND INTERVAL
(Exposure 60 sigma. Intensity 1.5 amps.)

Subject	Distance	Interval					
		15 Sigma	30 Sigma	45 Sigma	60 Sigma	75 Sigma	105 Sigma
A	16 cm.		Ends or flow at each end	Ends	Ends	Ends	Ends
	12 cm.		1 spread out	2 adjacent with arrow	2 or 3 adjacent	3 in series	
	8 cm.		1 or short flow	1 or short flow	Flow	Flow or series	Series of 3 or 4
A (later)	16 cm.	Ends	Ends	Ends	Ends	Ends	
	12 cm.	Short series or flow	Series or 2 adjacent	Flow or series	Two	Two	
	8 cm.	Flow	Series	Series or 2 adjacent	2 adjacent	2 adjacent	
C	16 cm.	Ends successive or simultaneous	Ends or series	Ends or series simultaneous	Ends each spread	Ends each spread	Ends
	12 cm.	Ends	Ends	2 or 3 successive or simultaneous	4 in succession	4 in succession	Ends spread
	8 cm.	Several in succession or simultaneous	3 in succession	3 or 4 in succession	3 or 4 in succession	3 in succession	3 in succession
D	16 cm.	Ends	Ends	Ends	Slightly snaky	Ends	
	12 cm.	Several simultaneous	Several simultaneous	Snake	Snake	2 or 3 in series	
	8 cm.	One	One	One	One	2 near together	
F	16 cm.	3.2		4.8		4.0	
	12 cm.	7.2		5.8		4.8	
	8 cm.	5.0		4.2		4.4	

(Exposure 120 sigma. Intensity 1.5 amps.)

		40 Sigma	80 Sigma	120 Sigma	160 Sigma
C	16 cm.	Discrete groups	Discrete groups walking or rolling	Ends slightly spread	Ends slightly spread
	12 cm.	5 or 6 rolling	4 or 5 walking or line	Discrete groups	Discrete groups walking
	8 cm.	Several walk	Several walk or roll	Several walk with gap	Several walk

amps., a stimulus so intense as to be startling. In the separate columns of Table III. are the results with different intensities. The rows give the intervals. The exposure was held constant at 60 sigma and the distance at 12 cm. The

TABLE III
INTENSITY AND INTERVAL
(Distance 12 cm. Exposures 60 sigma)

Subject	Interval	1.8 Amps.	2.1 Amps.	2.4 Amps.	3.2 Amps.	4.4 Amps.
<i>A</i>	75 sigma	Two adjacent	Two adjacent	Ends	Ends	Ends
	45 sigma	<i>Two adjacent or flow or arrow</i>	<i>Two adjacent or flow or series</i>	Two or series	Two quite close	Two farther apart
	15 sigma		Series or flow	<i>Flow</i>	Two adjacent	Two farther apart
<i>C</i>	75 sigma		Several in row	<i>Several in row or line</i>	Ends or row with loop	Ends or row with loop
	45 sigma		One or two	<i>Several in row sometimes loop</i>	Several in row	Several in row or ends
	15 sigma		Several in row or one	Several in row	<i>Series with loop or lot of motion</i>	Series or ends
<i>D</i>	75 sigma		2.0	2.2	3.4	3.8
	45 sigma		1.6	2.4	3.0	3.4
	15 sigma		1.6	2.0	2.6	3.8
<i>F</i>	75 sigma		4.2	4.8	3.8	4.4
	45 sigma		4.4	4.6	5.2	5.2
	15 sigma		4.4	6.6	5.6	7.0

general tendency shown on each combination is briefly indicated as in previous tables and the phrase in each row which indicates the optimal illusion italicized. The results for *D* and *F* are recorded numerically as in Table II.—the average number of touches felt per trial.

The italics are distributed with three of the four subjects in a direction obliquely downward toward the right. With *D* the greatest movement occurred always with the greatest intensity. Thus the general tendency of the majority is for a greater intensity to require a lesser interval to produce the movement impression. Further, for the two subjects with qualitative results, with a given interval as the in-

tensity increases the impression passes from that of a single touch, through a row or motion to two discrete touches. Both these facts agree with those found by Korte.

V. *Distance and Intensity*

In Table IV. the distance between the stimuli and the intensity of the stimuli were the variables. The times of exposure and interval were constant, in most cases 60 and 30 sigma respectively. In a few series other times were used, as indicated. The successive columns indicate intensity of the stimuli in terms of the current in the solenoids. The rows for any subject indicate the distance between the stimuli. The most frequent report for each combination of distance and intensity is indicated as previously. In a given row the report which shows the most marked movement illusion is italicized. *F*'s results are given in the form of the previous tables, *i. e.*, the average number of touches felt per trial.

The array of italics for the various subjects shows a rather general tendency toward a distribution extending obliquely upward toward the right, *i. e.*, with a greater distance between stimuli a greater intensity affords a better illusion of movement. This too is in accord with the results of visual experiments. Further, for a given distance, as the intensity varies from weakest to strongest there is somewhat of a tendency for the effect to pass from unity through movement to discreteness, and for a given intensity increase of distance tends to produce increase of discreteness, a result similar to Korte's. In this latter connection we may note Benussi's finding that with distances greater than 16 cm. on the forearm there was an individualizing of the ends following the superficial movement.

VI. *Unequal Intensity*

In all the experiments up to this point the two successive stimuli on a given trial were equal in intensity. This factor was now varied as had been done in the visual and auditory experiments. With exposures of 60 sigma and interval of

TABLE IV
DISTANCE AND INTENSITY
(Exposures 60 sigma. Interval 30 sigma)

Sub- ject	Dis- tance	1.2 Amps.	1.4 Amps.	1.5 Amps.		
A	12 cm. 8 cm.	Ends <i>Flow or series</i>	<i>Flow or series</i> Series	<i>Flow or series</i> Ends or series		
C	12 cm. 8 cm.	One or both ends <i>Three rolling</i>	<i>One end</i> rolling Three rolling or walk	Ends some- times spread Ends some- times spread		
D	12 cm. 8 cm.	Ends One or snake	<i>Ends or several</i> <i>simultaneous</i> <i>Good snake</i>	Ends Two or snake		
F	12 cm. 8 cm.	4.4 4.2	5.0 4.4	3.8 4.4		
		2.1 Amps.	2.3 Amps.	2.8 Amps.	3.6 Amps.	4.4 Amps.
A	16 cm. 12 cm. 8 cm.	Ends close Ends or flow or series <i>Ends or flow</i>		Ends <i>Flow or series</i> Ends		Ends Ends Ends
D	16 cm. 12 cm. 8 cm.	Ends or one One or series One or two		Ends <i>Series</i> <i>Long series</i>		<i>Ends or series</i> <i>Series</i> <i>Series</i>
C	16 cm. 12 cm. 8 cm.	Ends Two adjacent One or two	Ends <i>Two close,</i> <i>with loop</i> <i>3 or 4 succes-</i> <i>sive</i>	Ends Two at one end One or two	<i>Ends with</i> <i>connection</i> Two adjacent One or two	
(Exposures 60 sigma. Interval 45 sigma)						
		2.1 Amps.	2.3 Amps.	2.8 Amps.	3.6 Amps.	
C	16 cm. 12 cm. 8 cm.	Ends or one One or two One	Ends with line on skin One or two <i>One or two</i> <i>with loop</i>	Ends with or without loop <i>2 or 3 with</i> <i>loop</i> One or two	<i>Ends with loop</i> Two connected or with loop One	

30 sigma, with stimuli 8 or 12 cm. apart and with the intensity of the first stimulus 1.5 amps., that of the second was increased from 0.5 to 2 amps. It was varied irregularly through various intensities and trials were intermixed in which both were equal.

Table V. gives the per cent. of trials in which the apparent movement occurred in the direction the reverse from that of the actual temporal succession. The first column gives the per cent. of trials in which the reversal effect occurred when the second stimulus was more intense (including all variations

TABLE V

UNEQUAL INTENSITIES

(Exposures 60 sigma. Interval 30 sigma. Distance 8 or 12 cm. Intensity 1.5 amps.)

Subject	Per Cent. of Trials Yielding Reverse Movement	
	Second Stronger	Equal Intensity
A.....	10.5	0
C.....	21.4	0
D.....	32.0	0
F.....	13.1	0

of intensity); the second column gives the same figures for the trials with equal intensity of the two stimuli. The results were obtained on several days and are based on some 50 trials of each sort for each subject.

It is evident that whereas with equal intensity of the stimuli the reversal effect never occurs, with the second stimulus more intense by various amounts the effect occurs in from 10 to 32 per cent. of the trials with the different subjects, an average of 19 per cent. This per cent. is much less than that found by the writer in the auditory illusions.

No attempt was made to correlate the results with the extent of the intensity difference or to study other aspects of the reversal effect (Korte's delta movement) as was done in the visual studies for the simple reason that the reversal effect occurred so much less frequently. However it is significant that the effect does exist there just as it does in vision and audition.

D. CONCLUSIONS

The above experiments investigated in the tactual illusion of movement the most salient of the factors noted by Korte in the similar visual illusion. The following are the principal results:

1. Two punctate tactual stimuli on the forearm for equal lengths of time separated by a discrete time interval and a

few centimeters apart, yield under certain conditions of time, distance and intensity an impression of movement from one point to the other in the direction of the actual temporal succession.

2. To produce the optimal impression of movement the following relations are required between the different variables under consideration:

(a) The relation between the length of exposure of the two stimuli and the time interval between them is not especially clear cut but on the whole is inverse—the longer the exposure the relatively shorter the interval.

(b) The greater the distance between the stimuli the greater the time interval.

(c) The greater the intensity of the stimuli the less the interval.

(d) The greater the distance between the stimuli the greater the intensity.

3. If the intensity of the second stimulus is greater than that of the first the illusory movement is sometimes produced in the reverse direction.

The above results are quite similar to those found by Korte in the visual illusion of movement. They are also the same as those found by the writer in a preliminary study of auditory illusions as far as that investigation was carried.

It seems a significant fact that the same illusion of movement is found in vision, audition and touch and that the same laws as to the relation between the variables involved hold to a considerable degree in the three fields. This points of course to a central origin. Whether it is due as Wertheimer claims to a physiological 'Kurzschluss' between cortical areas corresponding to the two stimuli at different points in space is an open question. Such a correlation between points of external space and points of the brain is perhaps plausible in vision and touch. The writer has pointed out¹ that such a correlation is highly improbable in audition and that hence a different explanation is necessary, and inasmuch as the three sense departments show the same phenomena it is better to adopt a single theory applicable to all three.

¹ *Op. cit.*, p. 75.

The writer has suggested (*op. cit.*) that the illusion is due to a continuity of motor impulse, and such a theory would be applicable to touch as well as to vision and audition. A tactual stimulus on the forearm produces an impulse to make some motor adjustment to bring that region into the focus of attention, presumably an impulse to turn the head or eyes toward that point. This would have, of course, a biological significance. A second stimulus, farther up the arm for example, gives a second impulse, presumably in the same centers of the motor cortex, to turn the head or eyes still farther. If the interval is of such length that the second impulse supervenes just when the first is about exhausted this continuity of motor impulses gives the movement illusion. When the second follows too quickly the two are not differentiated sufficiently and there is fusion and if the second is too late there is discontinuity and discreteness. Benussi found it impossible to obtain certain of the phenomena when the stimuli were applied to the forehead. This fact is suggestive inasmuch as the usual motor adjustments of the head to bring that region into the focus of attention are impossible.

The various relations between the different variables necessary to produce the optimal illusion are as explicable by such a theory as by the Kurzschluss theory. If we assume that intensity, distance and length of exposure are related positively to the temporal facilitation of the motor impulses and to their consequent sooner subsidence, all the above phenomena can be readily explained. The writer reiterates his suggestion that the action theory can account for the movement illusion which occurs similarly in vision, audition and touch.