Apparent movement in tridimensional space*

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The space-time relationships satisfying Korte's third law of apparent movement were studied in three experiments. The results generally confirm and extend Corbin's conclusion that apparent movement is not a projection-level phenomenon, but one involving spatial constancy, i.e., some representation of tridimensional space. Between situations in which the stimuli were retinally matched, the time interval necessary for apparent movement varied with their phenomenal separation, whether the latter was determined by the distance of stimuli from the O, deviation of stimuli from the frontal plane, or illusory slant of the stimulus plane produced by a perspective gradient.

According to Korte's (1915) third law of apparent movement, an increase in the spatial separation between two successive stimuli must be accompanied by an increase in their temporal separation for an optimal appearance of movement to occur. This principle has been repeatedly verified, usually for stimuli in the frontal plane. Some years ago, however, Corbin (1942) raised an interesting question: Is the spatial separation to which Korte's law applies a matter of retinal distance or of distance in perceived space? He dissociated proximal from distal separation by varying the slant at which his Ss viewed the screen on which stimuli appeared. Shrinking retinal separation in this manner, while holding physical separation constant, seemed to have no effect whatever on the temporal threshold for optimal movement, whereas variation in physical separation (either in the frontal plane or in depth) yielded a typical Korte's law relationship.

If Corbin's results can be taken at face value, they strongly support the view that an approximately isotropic tridimensional model of physical space is constructed internally (see Attneave, 1972), and that apparent movement is based on events within this analog model. We have repeatedly encountered psychologists who are reluctant to accept this conclusion, and who suppose that Corbin's experiment must have contained some catch or loophole that would allow a peripheral explanation of the results. It may be noted, for example, that Corbin's stimuli appeared on a well-defined rectangular screen which was horizontally contracted on the retina when viewed at a slant; therefore, the important variable might have been retinal separation relative to retinal frame width [cf. the experiments of J. F. Brown (1931) on frame of reference and perceived velocity]. If this were the case, the results would still be interesting, but would not necessarily require the assumption that perceived objects are mapped into a tridimensional analog space. A similar and perhaps more

serious criticism is that the stimuli themselves (bright horizontal lines) were likewise contracted retinally under the slant conditions, and it is known otherwise that decreasing stimulus size in a constant frontal plane, like decreasing brightness, increases the time interval required for apparent movement (see Koffka, 1935, pp. 289-298).

Considering that the issue here is of basic importance for a theory of spatial representation, we were led to do the following studies. They are essentially similar to Corbin's, but also entail our best efforts to eliminate possibilities for attributing positive results to peripheral mechanisms.

EXPERIMENT I

Method

Subjects

Six paid student volunteers from the University of Oregon served as Ss. In both this and the subsequent experiments, a preliminary screening session was held for each prospective S. About half of those screened were rejected, either because their judgments were excessively variable or (what was usually the same thing) because their time thresholds for apparent movement showed no clear separation between different distances in the frontal plane. Screening sessions never included any of the critical conditions involving depth manipulations.

Apparatus and Experimental Conditions

The two stimulus lights were mounted at eye level, 6 ft (1.82 m) in front of the seated S on separate movable posts which stood on a table. Each consisted of a neon bulb enclosed in a small black pillbox lined with reflective foil. In the front cover of the box, a .2 x 1 cm horizontal slit was cut; behind this was a diffusing surface of tracing paper.

The luminance of these stimulus lines was about 5.5 cd/m². The experimental room was illuminated by a single 7½-W red-coated incandescent bulb behind the S and outside his field of view, which produced an average luminance of the order of .015 cd/m² in the S's field. This level of illumination was not great enough to suppress apparent movement between the stimuli, but was sufficient to allow their spatial locations to be clearly perceived.

The stimuli were positioned at either a 4-in. (10.16-cm) or an 8-in. (20.32-cm) separation in the frontal plane or, in the critical

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Fig. 1. The three stimulus arrangements of Experiment I are superimposed in this diagram to show how the 8-in. separation of the diagonal stimuli subtended the same visual angle as the 4-in. frontal separation. The S is located outside the drawing, at the intersection of the dashed lines.

condition, at an 8-in. separation on a diagonal such that the visual angle between them was equated to that of the 4-in. separation in the frontal plane (3 deg 11 min). The three conditions are shown superimposed in Fig. 1. Although the plane of movement was rotated by about 60 deg in the diagonal condition, the light boxes were not themselves rotated; thus the S still viewed the stimulus apertures orthogonally. In the diagonal condition, different box covers were used, with apertures altered slightly in size to compensate for the changes in distance from the O; however, these corrections were so minute that they could hardly have made any difference. Six inches behind the (frontal plane) stimuli was the black wall of the experimental room, on which a small luminous fixation point was located 2 in. below the bisector of the angle formed by the stimuli.

Stimulus durations and intervals were controlled by Hunter decade timers.

Procedure

On each presentation, the two stimuli, of 50 msec duration, were separated by an interval that varied from trial to trial. Three such presentations, 2 sec apart, made up a trial; thus, the S saw a light line that moved three times in a particular direction, provided the variable interval was great enough to permit apparent movement. The use of several presentations per trial seemed to contribute to the stability of results.

The interval or asynchrony between stimuli, which will be described throughout this article in onset-to-onset terms, was varied by an ascending method of limits. On the first trial of an ascending series, the interval was set 10, 20, or 30 msec (randomly decided) below the value at which the S had reported movement on the immediately preceding series (except at the beginning of a block, in which case a safely low starting point was used); from this level, the interval was increased by either 5- or 10-msec steps (randomly decided) until movement was again reported.

The first day was a screening session for all prospective Ss and served further as a practice session for those who were continued. The S was first reminded of the commonly seen signs and advertising displays in which discrete lights produce apparent movement, and was told in general terms that our object was to study the conditions under which such movement occurs. He was shown examples of movement at optimal time intervals in the experimental situation and was told to adopt as

stable a criterion as he could for what constituted "good" or "believable" movement. It was explained that he might see movement on the first trial of a series, but that more typically he would have to wait for some irregular number of trials before movement appeared. Thereafter, he was run for as many threshold determinations in the 4- and 8-in. frontal plane conditions as the hour session permitted.

In each of the two subsequent experimental sessions, the S was initially adapted for 10 min to the room illumination. Thresholds for movement were then obtained under all three conditions—4-in. frontal, 8-in. frontal, and 8-in. diagonal—which were counterbalanced over 12 blocks per session. Since 5 thresholds were determined in each block, a total of 40 thresholds per condition per S were obtained in all.

The spatial locations of the stimuli were reasonably obvious under the experimental conditions. All the Ss reported that they saw the movement in depth in the diagonal condition.

Results

If the threshold for the 8-in. diagonal condition were equal to that for the 4-in. frontal condition, we would conclude that it depended entirely on proximal separation, whereas if it were equal to that for the 8-in. frontal condition, we would conclude that it depended entirely on distal separation. If values of zero and unity, respectively, are assigned to these unequivocal extremes, any result obtained can be expressed in comparable terms, i.e., as a Brunswik ratio with an immediately obvious interpretation.

Results are shown for individual Ss in Table 1. With one exception (a case of "over-constancy"), the Brunswik ratios have values between zero and one, their mean being .77 with a standard error of .12. This differs from zero (no constancy) by a $t(5) = 6.50$, $p < .005$, and from unity (perfect constancy) by a $t(5) = 1.97$, which is not significant at the .05 level but is large enough to make us doubt the null hypothesis. On the latter point, our results are not quite as unequivocal as Corbin's, which showed practically no deviation from perfect constancy. On the major issue, however, the conclusion is clear enough: apparent movement depends on perceived separation, even with retinal separation, retinal size, and retinal frame of reference held constant.

Table 1
Stimulus Onset Asynchrony (in Milliseconds) at Threshold for Apparent Movement: Experiment I

S	Stimulus Arrangement		
	4-in. Frontal	8-in. Diagonal	8-in. Frontal
1	95	102 (.76)*	104
2	113	119 (.124)	117
3	154	172 (.78)	177
4	173	195 (.64)	207
5	123	128 (.82)	130
6	106	112 (.35)	122
Means	128	138 (.77)	143

*Each parenthetical value is a "Brunswik Ratio" = $\frac{t(8\text{-in. diagonal}) - t(4\text{-in. frontal})}{t(8\text{-in. frontal}) - t(4\text{-in. frontal})}$

Control

Experimental

Fig. 2. The two pictorial displays used in Experiment II. The 4-cm separation is shown by open circles; the 8-cm separation is shown by closed circles.

EXPERIMENT II

This experiment was designed to determine whether the manipulation of apparent separation by purely pictorial means could likewise affect the time interval required for apparent movement. Since the preceding experiment (like Corbin's) was carried out with binocular viewing, in the diagonal condition the two stimuli differed in retinal disparity. It might be argued that the increase in temporal threshold was *directly* due to this disparity difference and had nothing to do with phenomenal separation, particularly in view of the Barlow, Blakemore, and Pettigrew (1967) finding that there are disparity-specific units in the primary visual cortex. On the other hand, if phenomenal separation is the important variable, it should not matter how the separation came to be so represented.

Method

Subjects

Six new Ss were employed; they were screened as in Experiment I.

Apparatus

The stimuli were viewed monocularly in an enclosed display box. Under *all* conditions, they were located in the frontal plane, 47 cm from S's eye, but in the critical conditions, a perspective

drawing was used to make them appear to lie in an oblique plane. This is shown, together with the control drawing which did not produce an appearance of depth, in Fig. 2. These two patterns were equal in length (19 cm), in average width (15.8 cm), and in number of lines or textural elements on each dimension, as well as in the number of textural elements separating lights 4 cm apart. They were drawn, on a black ground, with fluorescent threads which glowed red (approximately the same hue as the neon stimulus lights) under ultraviolet illumination. The stimuli between which movement appeared were 2-mm apertures illuminated by neon lamps at an intensity of about 225 cd/m², located either 4 or 8 cm apart in a central alley unobstructed by lines, as shown in Fig. 2.

Procedure

Preliminaries of screening, instruction, adaptation, and practice were essentially as in Experiment I.

Each trial consisted of a 2-sec period during which the two stimulus lights regularly alternated. Stimulus duration was always 50 msec; interstimulus intervals, which were the same in both directions, varied from trial to trial. When this interval was adequate, the light appeared to oscillate rapidly back and forth (rather than to move repeatedly in the same direction as in Experiment I). At shorter intervals, both lights appeared to stay on, with some flicker, throughout the trial. Thresholds for movement were found by the ascending method of limits used in Experiment I, with this minor modification: the starting point of each ascending series was tied to the lower of the two preceding threshold determinations, not always to the one immediately preceding as before.

Again, there were two control conditions and one experimental condition: the stimuli were separated by either 4 or 8 cm in the control display, or by 4 cm in the experimental

Table 2
Thresholds for Apparent Movement Compared with Apparent Stimulus Separations: Experiment II

S	Threshold for Apparent Movement (Onset Asynchrony in Msec) by Condition				Judged Separation (Cm)		γ^{**}	Judged Slant (Deg)	$\lambda^\dagger$
	C4	E4	C8	β^*	C4	E4		E4	
1	174	193	220	.41	3.3	3.7	.12	49	.52
2	97	110	146	.25	3.3	3.8	.15	36	.24
3	86	95	130	.22	2.9	3.9	.35	31	.17
4	115	136	206	.23	3.5	4.5	.29	33	.19
5	146	170	213	.37	3.6	5.7	.31	41	.33
6	131	144	221	.14	3.3	3.7	.12	34	.21
Mean	125	141	189.3	.27	3.32	4.05	.22	37	.28

$$\beta^* = \frac{t(E4) - t(C4)}{t(C8) - t(C4)}$$

$$^{**}\gamma = \frac{\text{Judged Separation (E4)}}{\text{Judged Separation (C4)}} - 1$$

$$^\dagger\lambda = \text{Secant Judged Slant (E4)} - 1$$

display. The parallel between this and the design of Experiment I is not as exact as it may appear at first glance. Whereas the S could be expected to perceive depth relationships more or less veridically before, in Experiment II depth was entirely illusory and the magnitude of the illusion was not known in advance. In theory, the experimental display was a projection of a rectangular grid rotated approximately 70 deg from the frontal plane. If the plane had been perceived at this angle, extents along the central alley would presumably have appeared about three times as great as retinally equivalent extents in the control display. It was evident from the beginning that the perceived depth effect would really be much weaker than the hypothetical; hence, the two control separations were varied by a factor of two instead of three. Note that the separation of 8 cm was chosen quite arbitrarily to provide a second anchor point for the Korte's law relationship in the apparent frontal plane and was not supposed to be equated on any basis to the experimental condition.

The major question asked by the experiment was simply whether the 4-cm experimental condition would require significantly longer time intervals for apparent movement than the 4-cm control condition. However, to have any expectations about the magnitude of such a difference, we needed to know, at least roughly, how much the phenomenal separation between the lights was increased by the perspective gradient. Therefore, we spent a few minutes at the end of each session having the S make judgments of the depth effect. He judged the separation between the lights (simultaneously on) in both the 4-cm conditions by (a) drawing lines of appropriate length on paper, in the first two sessions, and subsequently (b) marking off the perceived distance with a slider on a dowel. He also (c) judged the slant of the apparent plane in the experimental display by setting a binocularly viewed stick orthogonal to it; see Attneave and Frost (1969) and Attneave (1972) for details of this method.

The three conditions were counterbalanced over 12 blocks within each of four sessions, essentially as in Experiment I except that each block included six instead of five threshold determinations. In the first and third sessions, the displays were oriented horizontally, as in Fig. 2, whereas in the second and fourth they were oriented vertically, so that the experimental display looked somewhat like a floor or ground surface. Two fixation regions were provided, equidistant from the two lights and 2 cm to either side of the path between them. The S alternated between these two fixation regions from one ascending series to the next, to minimize local adaptation effects. (This was also the reason for using fixation regions, bounded by four points, rather than single fixation points.) These procedural variables were of some incidental interest in their own right, since the horizontal movement was presumably interhemispheric, whereas the vertical movement was

presumably represented in either the left or the right hemisphere, depending on the fixation region. However, a careful inspection of the data yielded no hint that either of these variables (inter- vs intrahemisphere or left vs right hemisphere) make any difference; therefore, they will not be considered further.

Results

In the data summarized in Table 2, it may first be noted that every one of the Ss required longer intervals to see movement in the 4-cm experimental condition (E4) than in the 4-cm control condition (C4). To make Ss more comparable, we calculated for each a pseudo-Brunswik ratio, β , which tells where the experimental threshold fell as a proportion of the way between the thresholds for the two control conditions. It is not a real Brunswik ratio, since a hypothetical value of unity would in no way signify veridical perception. However, a hypothetical value of zero would mean that thresholds were identical for the C4 and E4 conditions. The obtained distribution of β values differs from zero by a $t(5)$ of 6.97, $p < .001$. This comparison establishes firmly the major point that when *phenomenal* separation is varied by pictorial context, the time interval required for apparent movement varies with it, even though *physical* separation and *retinal* separation are both held constant.

Let us now look at the magnitude of the effect. The average value of β is .27, which means that the experimental threshold is 27% of the way between the 4- and 8-cm control thresholds, about what we would expect (by linear interpolation) from a separation of slightly more than 5 cm in the apparent frontal plane, or (incidentally, owing to the particular separations used) from a 4-cm separation that was overestimated by 27% because of the depth illusion. According to the somewhat crude judgments of separation in the C4 and E4 conditions, the latter was overestimated (relative to the former, which showed a strong constant error that is of no great interest to us) by about 22% on the average; this proportional overestimation is called " γ " in Table 2.

The mean β value of .27, then, is just a little greater than we would expect from the judged separations. An additional, indirect measure of overestimation in the experimental display is given by the slant judgments. The stimulus plane was judged to deviate from the frontal plane by an average of 37 deg—considerably less than the 70 deg or so that the perspective gradient was drawn to depict. A small extent on such an apparently slanting plane (taken in a direction orthogonal to the apparent axis of rotation) should appear greater than a frontal plane extent subtending the same visual angle by a factor approximately equal to the secant of the slant. The proportional overestimation of the experimental separation inferred on this basis, designated " λ " in Table 2, has a mean value of .28, which is almost exactly equal to the mean value of .27 for β .

These correspondences between means are as close as anyone could reasonably expect, but we can further ask whether those Ss whose thresholds for apparent movement were most modified by the perspective display were the ones who got the strongest illusions of depth from it. Individual values of β do not covary with the obtained judgments of separation: $r_{\gamma\beta} = -.04$. Judged slant, however, is a remarkably good predictor: $r_{\lambda\beta} = .89$. Even with the very small N of 6 ($df = 4$), this relationship is significant at the .02 level. It appears that the slant judgments were simply a great deal more reliable than the separation judgments.

EXPERIMENT III

For the sake of generality, we wished to untie retinal from phenomenal separation by another, quite obvious operation, i.e., by varying the viewing distance of stimuli in the frontal plane. This was done under conditions roughly similar to those of Experiment I.

Method

Subjects

Six new Ss were selected, as before.

Apparatus

The stimuli were viewed binocularly in a room illuminated dimly with red light, as in Experiment I. Again, the stimulus lights were mounted in pillboxes on posts above a table. They were circular apertures of either $\frac{1}{4}$ in. (.64 cm) or $\frac{1}{2}$ in. (1.27 cm) illuminated at an intensity of about 5.5 cd/m². These were located at eye level, always in the frontal plane, and were horizontally separated by either 4 in. (10.16 cm) or 8 in. (20.32 cm). A small luminous fixation point was located in the same plane, either 1 in. (2.54 cm) or 2 in. (3.08 cm) below the midpoint of the two lights. The S viewed the stimuli from a distance of either 4 ft (1.22 m) or 8 ft (2.44 m).

Procedure

Screening, practice, etc., were essentially as in the two previous experiments. Only the two control conditions were employed in the preliminary session.

Table 3
Stimulus Onset Asynchrony (in Milliseconds) at Threshold for Apparent Movement: Experiment III

S	Condition			
	C4S	F8L	F8S	C8S
1	90	96 (.27)*	103 (.54)	115
2	119	135 (.27)	161 (.68)	181
3	120	132 (.33)	139 (.52)	156
4	98	107 (.27)	115 (.53)	131
5	110	123 (.39)	132 (.63)	144
6	116	133 (.34)	148 (.64)	166
Mean	109	121 (.31)	133 (.59)	149

*Parenthetical values are Brunswik ratios; cf. Table 1.

Each trial consisted of a 4-sec period during which the two stimuli, each of 50 msec duration, were regularly alternated (as in Experiment II, except for the length of the period). An ascending method of limits was used as before, except that interstimulus interval was increased always in 10-msec steps and that each ascending series was started 10, 20, 30, or 40 msec (randomly decided) below the lower of the last two thresholds determined under the same conditions.

At the closer (4-ft) viewing distance, the smaller stimuli ($\frac{1}{4}$ -in. diam) were separated by either 4 or 8 in., with fixation 1 in. below their midpoint. These two conditions, designated C4S and C8S, may conveniently be thought of as control conditions, establishing the frame of reference for the others. In Condition F8L, the S sat at the farther viewing distance (8 ft) and was shown the larger stimuli ($\frac{1}{2}$ -in. diam) at a separation of 8 in., fixating 2 in. below their midpoint. Thus, F8L was equivalent, in terms of the *proximal* configuration provided by the stimulus lights, to C4S, since in both conditions the two stimuli were separated by the same visual angle (4 deg 56 min) and individually subtended the same visual angle (18 min); in other words, extents in C4S were doubled in F8L to compensate for the doubling of viewing distance. Condition F8L was physically equivalent to C8S in stimulus separation, but not in stimulus size; note that the size variable prevents us from setting up two control conditions of which one is retinally identical and the other physically identical to an experimental condition at a different viewing distance. Therefore, a fourth condition, F8S, was added; this was the same as F8L except that it used the smaller ($\frac{1}{4}$ -in.) stimuli. It was, therefore, *physically* identical, in both size and separation of stimuli, to C8S. Comparing results from F8S and F8L will show the effect of doubling stimulus diameter (i.e., quadrupling area) with separation and viewing distance constant.

These four conditions were counterbalanced over 16 blocks (a block being five threshold determinations) in each of four sessions.

Results

Doubling the separation of the lights at the closer viewing distance caused the mean threshold for movement to increase from 109 to 149 msec, as Table 3 shows. These values (or, rather, their counterparts for individual Ss) provide the zero and unity points, respectively, for "Brunswik ratios" describing the results of the other two conditions. For F8L, the condition of retinal equivalence at the farther distance, the mean ratio is .31. Though rather small, this is quite significantly different from zero [$t(5) = 15.7$, $p < .001$]:

therefore, we can again conclude that Korte's third law involves some degree of extent constancy, in this case over variation in viewing distance. For Condition F8S, in which proximal stimulus size was allowed to vary normally with viewing distance, the mean ratio increases significantly [$t(4) = 9.4$, $p < .001$] to .59; this difference between F8S and F8L shows the effect of doubling stimulus diameter with separation and viewing distance constant. Condition F8S also differs quite significantly from C8S (i.e., the mean ratio of .59 is reliably different from unity: $t(5) = 15.2$, $p < .001$). This difference, with *physical* size and separation equated, shows that constancy was considerably less than perfect for the extents pertaining to Korte's third law.

GENERAL DISCUSSION

These three experiments unequivocally support Corbin's major thesis: apparent movement occurs at a postconstancy level of the perceptual system. The only discrepancies between our results and Corbin's, or between the results of one and another of our own studies, have to do with the amount or degree of constancy that is involved.

Corbin found essentially perfect constancy for the separations pertaining to Korte's law. So did Kahneman, in an ingenious study that has not been published in detail.¹ He displayed stimuli for apparent movement at the front of a large room, and Ss seated at various distances and viewing angles rated the goodness of the movement. Ratings varied systematically with the physical spacing and timing of the stimuli, but *not* with the S's location in the room. Since neither Corbin nor Kahneman compared conditions that were strictly matched with respect to proximal stimulation, they left open the possibility (never a very plausible one) that peripheral factors of some sort might account for the effects. The present studies rather thoroughly rule out this possibility and show that the representation of distances in tridimensional space is antecedent to the occurrence of apparent movement. Once having firmly established this conclusion, however, we may admit and even emphasize that the manipulations to which we resorted were not as natural, or as representative of real-life situations, as those of Corbin or Kahneman: e.g., outside the laboratory retinal size does *not* stay constant as distance changes.

We cannot be sure that perfect constancy (with respect to the Korte's law relationship) did or did not obtain in Experiment I, since the mean Brunswik ratio was less than unity, but not significantly so. In Experiment III, however, the results were clear: with retinal stimulus size controlled, the degree of constancy (.31), though highly significant, was very far from perfect. When retinal size varied "naturally" with distance, constancy was considerably greater (.59), but still by no means perfect.

The concept of constancy does not apply literally to Experiment II, in which the true physical separations were beside the point. However, that experiment showed an exceedingly close agreement between the temporal thresholds for movement and the picture-based *phenomenal* separations between stimuli in space, particularly when the latter were inferred from slant judgments. This suggests that we were remiss in not likewise obtaining judgments of spatial separation in Experiments I and III. We did not do so because it seemed clear, from casual observation, that any such judgments would have been practically veridical. However, phenomenal extent can be quite an elusive variable to pin down experimentally—as many investigators of the size-distance invariance hypothesis, for example, have discovered. It is entirely possible for an O to judge, correctly, that a pair of large circles and a pair of small circles are each separated by about 8 in., and nevertheless to perceive the larger ones as closer together. Likewise, large objects appear to move more slowly than small ones. It seems likely (since peripheral explanations of apparent movement have been otherwise disconfirmed) that the effect of stimulus size on apparent movement, as between Conditions F8L and F8S of Experiment III, is not a direct effect, but one mediated by phenomenal separation; cf. Koffka's (1935, pp. 286-298) discussion of Korte's laws in relationship to the work of J. F. Brown and others. Why constancy was at best so imperfect in Experiment III remains somewhat puzzling. It is possible that in the course of a long session during which the S's attention is restricted to a relatively small segment of his surroundings, the phenomenal distance that he assigns to the focal objects may regress toward some preferred or normal value, like the "specific distance" at which the Ss of Gogel (1969) locate objects under conditions of reduction.

Although it is not essential to the purpose of these studies, we should like to understand more clearly than we do the mechanism that underlies Korte's third law in any case. Why, in either a tridimensional medium or otherwise, do greater spatial separations require greater time intervals for apparent movement? The superficially obvious answer is that the velocity of movement through the representational space is limited, so that an object needs more time to traverse a long distance than a short one. This explanation has serious difficulties, however. It assumes (or seems to assume) that the movement starts at the time of the first stimulus and ends at the time of the second. But how is the perceptual system to "know" in what direction (or at what velocity) to move the object until *after* the second stimulus has occurred? It might be supposed that anticipation, based on repeated trials, enables the system to get the movement under way at once; in that case, Korte's third law would depend upon the predictability of the events. In fact, it does not: our colleague, Professor Jacob Beck, has unpublished data that show clearly the Korte's law relationship under conditions in which the S could

anticipate neither the direction nor the distance of the second stimulus from the first. The only remaining possibility that we can see for explaining Korte's law in terms of a moving process (such as an image of the object that moves continuously through the representational space from the initial to the terminal locus) would involve the postulation of a peripheral memory store in which both temporal and spatial information are accumulated over a brief time-span before being mapped (matched?) in the representational system.

The study of Shepard and Metzler (1971) on mental rotation and subsequent unpublished studies by Shepard and his collaborators show beyond any reasonable doubt that when a mental image is rotated, either in the frontal plane or tridimensionally, it *moves continuously* through intermediate positions in going from one aspect to another. Our results, along with those of Corbin and Kahneman, show clearly that apparent movement occurs between loci in a tridimensional phenomenal space. This may very well be the same medium as that in which mental images are rotated. We cannot be at all certain, however, that the apparent movement itself is represented in an analog manner, by a process that moves through the medium. One of several alternatives is that there are higher-level "movement detectors" that are stimulated by changes of locus in the representational medium; some velocity-tuning of such detectors might account for Korte's third law. Whether apparent movement is *modeled* or *described* (or modeled before it is described) is an interesting issue, which we hope to clarify in further investigation.

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NOTE

1. Personal communication from Daniel Kahneman. The study is described briefly in a paper, "On Masking and Motion," that Kahneman presented at the International Psychological Conference, London, 1969.

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