The effect of real and imputed distance on judgments of time: Some experiments on the Kappa phenomenon*

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Three experiments are reported which considered an "imputed movement" explanation of the Kappa effect. In Experiment 1, differences in distance had no consistent influence on time judgments when actual, but partial, cues to velocity were present. Experiment 2 showed that with static stimuli, the Kappa effect was stronger when Ss were given instructions enabling them to anticipate the spatial and temporal order of successive stimuli used to delimit time intervals. Experiment 3 showed that when physical distance was held constant apparent distance was important in the Kappa effect. Results are interpreted as suggesting that cues to velocity influence Ss' judgments of time towards veridicality but, when velocity cues are absent, perceived distance assumes undue importance in the phenomenal relationship between time, distance, and velocity. This results in the Kappa effect.

From experiments investigating the interaction of velocity, time, and space in perception, Mashhour (1964) concluded that "...if three stimuli are exposed at equal temporal intervals but unequal spatial intervals, the temporal events undergo a corresponding change in perception. This phenomenon was designated S—effect by Abe (1935) and K (Kappa) effect by Cohen et al (1955).¹ In all these investigations the stimuli were static." The Kappa effect occurs when the apparent duration of a constant time interval between two successive stimuli is lengthened by increasing the distance between the two stimuli.

Recently, Bill & Teft (1969), Parks (1968), and Yoblick & Salvendy (1970) have investigated several parameters of the Kappa effect and its reciprocal, the Tau effect—the interaction of space and time in the perception of visual extent. Explanations of the Kappa effect are, however, somewhat tentative and untested by experiment. As stimuli for the Kappa effect are static, Cohen, Hansel, & Sylvester (1955) and Price-Williams (1954) considered the Kappa effect as a result of “imputed movement.” The imagined moving of the stimulus is allowed for by S in the case of widely separated stimuli. This leads to the relative overestimation of the time interval bounded by the spatially separate stimuli. The present experiments explore some implications of the “imputed movement”

explanation of the Kappa effect and also investigate further parameters of the effect.

EXPERIMENT I

This experiment tested the hypothesis that with partial velocity cues provided for Ss and both velocity and distance varied, Ss' judgments of

duration will be predominantly affected by the distance factor in the hypothetical equation: phenomenal time = phenomenal distance/phenomenal velocity. Ss' task was to reproduce the times taken for a dot on both a large and a small drum to complete a rotation. Physically, rotation times were equal for both drums but, as the movement across the front surface of the large drum (and the assumed passage of the dot around the rear of the large drum) took place over both greater seen and assumed distances than across the small drum, a phenomenon analogous to the Kappa effect was predicted. Time intervals derived from the dot on the large drum should be deemed relatively longer by S, despite the fact that the dot on the large drum had traveled at twice the velocity over twice the distance.

Method

The apparatus used is shown in Fig. 1. S viewed two kymograph drums which projected above a vertical screen hiding E, the kymograph motors, and Venner stoplocks from S. E could set the speed for a rotation of either the large or small drum to take approximately 5 or 7 sec. The exact time for each stimulus rotation

Fig. 1. Drum apparatus. (A) S's viewing position at eye level with kymograph drums. (B) Telegraph key to operate S's timer. (C) Large matt-black kymograph drum, 30.48 cm in diam. (D) Venner stopclock to record S's time judgments. (E) White marker dot on each drum. (F) Small matt-black kymograph drum, 15.24 cm in diam. (G) Venner stopclock to time a rotation of either drum. (H) Table. (I) E's position, hidden from S. (J) Positions x, y, and z, signifying varied starting points of the marker dot before a rotation. (K) Kymograph motor. (L) Opaque screen.

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Fig. 2. Apparatus carrying stimulus lights. (A and B) Two 1.5-V light bulbs. (C) S's viewing position. (D) Telegraph key to operate S's timer. (E) Board held by central pivot, adjustable to horizontal or vertical position (F). (G) Opaque screen. (H) Venner stopclock to record S's time judgments. (I) Venner stopclock to time duration between light flashes. (J) Connection box to Flash Lights A and B in any sequence. (K) Table. (L) E's position, hidden from S.

was recorded by E from a Venner stopclock coupled to the switch for the kymograph motors.

Using drums separately for each trial, the marker dot on each kymograph drum was rotated until it returned to its original position. S was asked to reproduce, "without counting, and intuitively," on a second Venner stopclock, the intervals of time bounded by the movement of the dots, immediately after the particular dot had stopped.

Sixteen naive adult male Ss made time judgments as follows: (1) $N = 8$, 16 trials, 8 per drum, with 4 trials at 5 sec and 4 trials at 7 sec rotation time per drum, randomized separately between drums and times for each S. The starting point of the dot was at "y" (see Fig. 1). (2) $N = 8$, 16 trials [as in (1) above], but the starting point of the dot was either at point "x" ($N = 4$) or at point "z" ($N = 4$) on all trials (see Fig. 1). This was to check on any possible effects of velocity cues appearing early (x) or late (z) in the sequence of events.

Results

The prediction failed. No significant difference appeared between large- and small-drum time judgments. Differing positions of cues to velocity had no significant effect on the results.

Conclusion

It seems that, in the presence of

actual but partial cues to rotary motion which were present for half of each time interval, the predicted phenomenon analogous to the Kappa effect was not found. This result confirms the findings of Matsuda (1968), who used stimuli for time judgments which had linear motion between two spatially separate endpoints. It seems that any effect of "imputed movement" tending to produce the Kappa effect is overruled by the presence of actual, but partial, movement cues. This result lays stress on the subjective nature of the phenomenon as it is probably found only when objective movement cues are totally lacking.

This finding linked with the consensus of results in the literature, which suggests that the Kappa effect has usually been reported when Ss are aware of the sequence in which successive stimuli will be presented, suggested an experiment to see whether this "foreknowledge" enhances the Kappa effect or whether it could be elicited with sequences unknown to S beforehand, time judgments having to be made in retrospect.

EXPERIMENT 2

This experiment tested the hypothesis that the Kappa effect would be enhanced when S could anticipate the sequence in which

successive stimuli were presented. Foreknowledge of the sequence of light flashes used to begin and end a time interval to be reproduced by S should enhance the Kappa effect.

Method

The apparatus used is shown in Fig. 2. Ss viewed two lights (A and B) mounted on a wooden board which could be held in the horizontal or vertical position in front of a vertical screen hiding E and two Venner stopclocks from S. By adjusting the switches on a connection box, E could flash Lights A and B in any temporal sequence. The first light to flash started a Venner stopclock in front of E. After approximately 9 or 10 sec, E flashed the second light which simultaneously stopped the Venner clock, allowing E to record the exact duration of the stimulus interval he had given. S reproduced this time interval between successive light flashes, his judgment being recorded on a second Venner stopclock. Light flashes of .25 sec began and ended the unfilled time intervals to be reproduced by S "without counting."

Sixty-four time intervals were presented in two blocks, the independent variable being foreknowledge of the sequence of lights to be expected as indicated by E before each trial (Block A), or no such foreknowledge (Block B). Within each block, all sequences were randomized separately for each S. On half the trials, flashes of the same light began and ended the standard interval. The stimulus light was placed at A, A', B, or B' (Fig. 2) 4 trials at each position. On the remaining 16 trials, in each block, flashes of spatially separate lights began and ended the time interval. The stimulus lights were flashed at Positions A then B, B then A, A' then B', and B' then A', with four trials being given for each sequence. The vertical and horizontal presentations constituted an empirical attempt to check on possible positional influences on "imputed movement"—e.g., "top" to "bottom" sequences might give more rapid imputed movement than the reverse, through learned gravity cues in the life of S.

Results

These are shown in Table 1. Ratio scores, Ss' reproduced time/actual time, were used throughout the study to allow for small variations in actual stimulus times.

The prediction was fulfilled, a significant Kappa effect was found (at a statistically reliable level in three out of the four comparisons), only when Ss had foreknowledge of the spatial sequences to be expected. Empirically, horizontal or vertical positioning of the lights had no significant effect, so time judgments under these conditions

were combined for analysis.

Conclusion

These results again demonstrate the subjective nature of the Kappa phenomenon, since this was enhanced when Ss could anticipate the temporal sequence of successive light flashes before the flashes occurred, whereas mere differences in physical distance alone were seemingly of less importance. This led directly to Experiment 3 to examine the role of distance factors in the Kappa effect.

EXPERIMENT 3

This experiment tested the hypothesis that with physical distance held constant subjective distance as perceived by S would be an important factor in the Kappa effect.

In an earlier series of experiments, Newman (1971) had Ss bisect the distance between a near and a far marker placed on a surface along S's line of sight. Mean judgments of the midpoint were found to be significantly different between groups of Ss who made judgments on differently textured surfaces. Within groups of Ss, on any single surface, there were considerable individual differences in judgments of the midpoint. In the experiment that follows, the same test situation was used, since it permits individual differences in perceived relative distance to be determined for each S. The extent a distance bisection marker is placed beyond the true midpoint gives a measure of how much S overestimates the further half of the surface relative to the nearer half. With stimulus lights for time intervals set at either end and at the physical midpoint of a surface, it was predicted that within groups of Ss there should be a positive correlation between the extent of discrepancies between the judged and true midpoints of the surface and the discrepancies between judgments of time intervals delimited by stimuli at "far" and "center" against "near" and "center."

Apparatus

Figure 3 shows a schematic diagram of the apparatus which has been fully described by Newman (1971). It featured a viewing box into which S looked through a monocular viewing hole, located at the front end of the box, 1.91 cm in diam and 30.5 cm above its floor. When the door in a reduction screen facing S was opened, he looked along one of two horizontal interchangeable test surfaces, both 228.6 cm long. The surfaces were painted crosswise to the Ss' line of sight with alternating black and white stripes to give the two surface textures illustrated in Fig. 3. The sides of the test surfaces were occluded by the reduction screen. Vision beyond the end of the surface was restricted by a

Table 1
Mean Time Ratio Scores With and Without Foreknowledge of Stimulus Sequences

Actual Time Interval	Group of Ss	Block of Trials and Condition	Single Light (16 Trials) Mean Reproduced Time	Separate Lights (16 Trials) Mean Reproduced Time	Wilcoxon Matched Pairs Tests (Two-Tailed) Single Light vs Separate Lights	Number of Ss Showing Kappa
			Mean Actual Time	Mean Actual Time		
9 Sec	1	Block A First 32 trials Foreknowledge (N = 20)	.9554	1.0133	N = 20 T = 27 p < .01	17
		Block B Second 32 trials No foreknowledge (N = 12)*	1.0039	1.0437	N = 12 T = 21 n.s.	8
		Block B First 32 trials No foreknowledge (N = 14)	.9937	1.0060	N = 14 T = 33 n.s.	7
	2	Block A Second 32 trials Foreknowledge (N = 14)	1.0296	1.0985	N = 14 T = 20 p < .05	10
		Block A First 32 trials Foreknowledge (N = 20)	.9346	1.0296	N = 20 T = 19 p < .01	16
		Block B Second 32 trials No foreknowledge (N = 12)*	.9980	1.0098	N = 12 T = 29 n.s.	6
10 Sec	2	Block B First 32 trials No foreknowledge (N = 14)	.9750	.9656	N = 14 T = 35 n.s.	8
		Block A Second 32 trials Foreknowledge (N = 14)	1.0075	1.0716	N = 14 T = 24 n.s.	9

*Eight Ss in Group 1 were unable to give enough time to the experiment to complete the second block of trials.

white screen, mounted vertically. Three light bulbs projected through holes cut in the test surfaces. The "far" light was positioned at the horizon end of the surface, the "near" light 30.5 cm from the end of the test surface abutting the floor of the viewing box, and the "center" light exactly midway between them but fractionally to the left of the direct line of sight between the other two lights. By adjusting the switches on a junction box, E could flash any two of the lights in any temporal sequence to give stimulus intervals for time judgments. The procedure for timing these intervals and recording Ss' judgments was the same as in Experiment 2. A distance bisection marker consisting of a small wooden rod mounted on a magnetic disk was placed on the surface above a powerful button magnet, mounted on tracks, and held immediately under the test surface. By winding a handle, S could

vary the position of the bisection marker along the direct line of sight between the near and far lights. The position of the bisection marker could be read from a scale mounted beside the test surface and visible only to E.

Two surfaces were used, since greater individual variation in judgments of the midpoint were expected on the distorted textured surface where the increase in packing density of texture elements towards the horizon provides an illusory distance scale that causes Ss to place the bisection marker objectively beyond the midpoint (Newman, 1971).

Procedure

The Ss made distance and time judgments on either the distorted textured surface or the evenly textured surface. For distance judgments, Ss were instructed to move the distance bisection marker to the physical midpoint between the far and

Fig. 3. Apparatus for time and distance judgments. (A) Viewing box. (B) Winding handle to move the distance bisection marker along the surface between Lights H and P. (C) Key to operate S's timer. (D) Monocular viewing aperture. (E) Adjustable buffers to hold S's head stationary. (F) Reduction screen with aperture limiting S's view to the center area of the right test surface. (G) Sliding door. (H) Near light. (I) Rectangular frame of apparatus. (J) Holes in test surface to permit Lights H, K, and P to show with the test surface positions interchanged. (K) Center light. (L) Magnetically operated distance bisection marker. (M) White screen. (N) Evenly textured surface having 63 stripes all equal in width. (O) Distorted textured surface with 63 stripes progressively decreasing in width, each stripe being 1/90th less wide than the previous one. (P) Far light. (Q) Scale from which to measure S's positioning of the bisection marker. (R) Venner stopclock to record S's time judgments. (S) Junction box to flash lights in any sequence. (T) Table. (U) Venner stopclock to time intervals between light flashes.

near lights. The psychophysical method of adjustment was used, and each S's point of subjective equality was taken as the average locus of the center point on four judgments. The time judgments were made as in Experiment 2. Each S made 16 judgments of the time interval between two successive stimulus lights which were flashed at the positions near then center, center then far, far then center, and center then near in successive blocks of four trials at each

position. Two standard time intervals were presented at each position in the order: 9, 10, 10, and 9 sec. Ss were given foreknowledge of the sequences of light flashes used to begin and end each standard interval of time.

Discrepancies in time judgments bounded by stimuli on opposite halves of each surface were expressed as Kappa ratios, calculated for each S as follows: (judged time of intervals bounded by stimuli at "center" and "far")/(judged time of intervals

bounded by stimuli at "near" and "center").

Results

The prediction was fulfilled: within groups of Ss, there were significant positive correlations between distance bisection scores and Kappa ratios. The Spearman rank correlation coefficients are shown in Table 2. This result confirms the findings of Lebensfeld & Wapner (1968), Sudo (1941), and Suto (1957), who flashed three light stimuli at each apex of the Mueller-Lyer figure.

SUMMARY OF CONCLUSIONS AND DISCUSSION

The Kappa effect was not found when actual cues to the velocity of circular motion were present. The Kappa effect was stronger when specific spatial stimuli could be anticipated by S. When physical distance was held constant, subjective distance as perceived by S was important in the Kappa effect. The "imputed movement" view of Kappa as suggested by Cohen et al (1955) is supported by these findings, which show that the Kappa effect is influenced by essentially phenomenological and subjective variables.

Table 2
Kappa Ratios and Distance Bisection Scores on Opposite Halves of the Surface

Group of Ss and Surface	Time	Kappa Ratio: Center and Far/ Near and Center	Distance Bisection Scores Mean and SD (cm)	Spearman Correlation Coefficients, Kappa Ratios with Distance Bisection Scores
1				
Distorted Texture (N = 16)	9 Sec	1.0123	12.60	.563*
	10 Sec	1.0268	±11.30	.553*
2				
Even Texture (N = 16)	9 Sec	1.0332	5.30	.493*
	10 Sec	.9836	±9.35	.576*

* $p < .05$ (one-tailed test)

Phenomenological assumptions, like imputed movements, and subjective variables seemingly become important when Ss are required to make judgments of time when objective cues are limited. Specifically, since Kappa was not found when actual cues to velocity were present, it is suggested that such cues may aid accuracy of time judgments. This would seem to be biologically adaptive. With static stimuli, in the absence of real velocity cues, useful in judging time, an assumed velocity seems to be "imputed" by S. This imputed velocity is of little aid to accuracy in judging time, since, initially, S has no knowledge of the time interval to be expected or any actual movement from which to judge velocity. Distance is the only basis for "forecasting." Distance may thus assume undue importance in our initial equation: $\text{phenomenal time} = \text{phenomenal distance} / \text{phenomenal velocity}$. This

would result in the Kappa effect and might have a very pervasive influence on much behavior in the field of time judgment.

REFERENCES

- ABE, S. Experimental study of the co-relation between time and space. *Tohoku Psychologica Folia*, 1935, 3, 53-68.
- BILL, J. C., & TEFT, L. W. Space-time relations: Effects of time on perceived visual extent. *Journal of Experimental Psychology*, 1969, 81, 196-199.
- COHEN, J., HANSEL, C. E. M., & SYLVESTER, J. D. A new phenomenon in time judgement. *Nature*, London, 1953, 172, 901.
- COHEN, J., HANSEL, C. E. M., & SYLVESTER, J. D. Interdependence in judgements of space, time and movement. *Acta Psychologica*, 1955, 11, 360-372.
- LEBENSFELD, P., & WAPNER, S. Configuration and space-time interdependence. *American Journal of Psychology*, 1968, 81, 106-110.
- MASHHOUR, M. *Psychophysical relations in the perception of velocity*. Stockholm: Almqvist & Wiksell, 1964.
- MATSUDA, F. Developmental study of time, space and velocity estimation: 1. *Japanese Journal of Psychology*, 1968, 39, 57-66.
- NEWMAN, C. V. The influence of visual texture density gradients on relative distance judgements. *Quarterly Journal of Experimental Psychology*, 1971, 23, 225-233.
- PARKS, T. E. The spatial separation of two light-flashes and their perceived separation in time. *American Journal of Psychology*, 1968, 81, 92-98.
- PRICE-WILLIAMS, D. R. The Kappa effect. *Nature*, London, 1954, 173, 363.
- SUDO, Y. On the effect of the phenomenal distance upon the time perception. *Japanese Journal of Psychology*, 1941, 16, 95-115.
- SUTO, Y. Role of apparent distance in time perception. *Research Reports of Tokyo Electrical Engineering College*, 1957, No. 5, 73-82.
- YOBLOCK, D. A., & SALVENDY, G. Influence of frequency on the estimation of time for auditory, visual and tactile modalities: The Kappa effect. *Journal of Experimental Psychology*, 1970, 86, 157-164.

NOTE

1. Cohen, Hansel, & Sylvester first designated this phenomenon the Kappa effect in 1953.