# INTERDEPENDENCE IN SUCCESSIVE JUDGEMENTS OF THE DURATION, DISTANCE AND SPEED OF A MANUAL MOVEMENT*

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The *kappa*- and *tau*-movement effects were demonstrated in line-drawing situations. 133 subjects (98 sighted and 35 blind) took part in two sets of experiments. In the *kappa*-movement experiment, the task of the subjects was to draw the second line for a duration which seemed to be the same as that spent on drawing the first line. In the *tau*-movement experiment, the subjects produced a length which seemed to be the same as the first line.

The following conclusions were drawn: (1) If the durations for drawing two lines respectively are in fact equal, that duration will seem greater which is associated with the longer line drawn at the faster speed (the *kappa*-movement effect); (2) If the length of two lines respectivey are in fact drawn equally, that length will seem greater which is associated with the slower speed drawn for the longer time (the *tau*-movement effect); (3) The blind subjects betrayed the *kappa*- and *tau*- movement effects, but the effects were more marked amongst the sighted; (4) The effects are statistical in the sense that they do not appear for all subjects and all conditions; (5) Speed seems to be relatively more responsible than either distance or duration for the occurrence of the *kappa*- or *tau*- movement effect; (6) Experience of movement is suggested to be applicable, by way of explanation, to the *kappa*- and *tau*- effects as well as the *kappa*- and *tau*- movement effects; (7) The demonstration of the *kappa*- and *tau*- movement effects for the manual conditions employed adds further evidence to the universality of the phenomena of psychological relativity.

## 1. Introduction

Interdependence in judgements of the duration, distance and speed of movement was first demonstrated by Cohen and Cooper[1]. They experimented with blindfolded passengers in a vehicle on a road, producing situations analogous to those used in labolatory demonstrations of the *kappa*-effect[2]. The passengers were driven for equal durations, but the distances and speeds corresponding to those durations differed. Whilst studying these conditions, Cohen and Cooper were able to put forward three effects which manifested interrelations between apparent duration, distance and speed. These effects may be described as follows.

Firstly, if two parts of a journey take the same clock time, that part will seem to the subject to last longer which is associated with the longer distance and faster

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1. (1962, 1963)
2. (Cohen, Hansel & Sylvester, 1953; 1955)

speed, and *vice versa*. This was designated the *kappa*-movement effect. Secondly, if two parts of a journey are of equal distance, that part will seem greater which is associated with the longer duration and slower speed, and *vice versa*. This was designated the *tau*-movement effect. Thirdly, if two parts of a journey are travelled at the same speed, that part will seem faster which is associated with the shorter duration and shorter distance, and *vice versa*. This was designated the *kappa-tau* effect.

In a later experiment on estimates, made by vehicle drivers, of the duration, distance and speed of their journeys[3], the result tends to support the *kappa*-movement and *tau*-movement effects. However, the *kappa-tau* effect was not confirmed. The *tau*-movement effect was also studied under walking and running conditions[4]. The subjects walked in one half of a journey and ran in the other half. On the whole, the distance seemed to the subject greater when walking than when running. In line-drawing experiments, recently reported, with children in the age group of 5 to 8 years[5], the proportion of children who followed the *kappa*- and *tau*- movement effects seemed to increase with age.

## 2. Hypotheses

2–1. The works by Cohen and Cooper[6] introduced at least two new considerations for the studies of psychological relativity which had been examined as the *kappa*-effect and the *tau*-effect. Firstly, the introduction of speed or movement has led to the new effects of *kappa*- and *tau*- movement. Secondly, the interdependence of time and space seems to characterize *gross* movement of the individual, either actively or passively. The *kappa*- and *tau*- movement effects have thus been identified in different patterns of experience of the subject[7]. This would imply a certain generality in the occurrence of the two effects in various types of daily experience of movement.

Our present question is whether the *kappa*- and *tau*- movement effects characterize apparent duration and distance of a manual movement in drawing a line, where relatively *brief* intervals of time and distance are used. Thus our first hypotheses are (i) that if a subject is instructed to draw two lines for the same duration but at different speeds, that line will be drawn for an objectively shorter duration which corresponds to the longer distance and faster speed (the *Kappa*-movement effect), and (ii) that if a subject is instructed to draw two lines for the same distance but at different speeds, that line will be drawn for an objectively shorter distance which corresponds to the longer duration and slower speed (the *tau*-movement effect).

2–2. In considering the background to the *kappa*-effect, Cohen and his colleagues[8]

3. (Cohen, Ono & Skelly, 1966)
4. (Cohen, Cooper & Ono, 1963)
5. (Ono, 1968a; 1968b)
6. (1962, 1963)
7. (Cohen & Cooper, 1962; 1963; Cohen, Cooper & Ono, 1963; Cohen, Ono & Skelly, 1966)
8. (Cohen, Hansel & Sylvester, 1955)

emphasized the primacy of discrimination of movement over separate spatial or temporal discrimination. In this connection, apparent movement was often reported by the subjects who followed the *tau*-effect[9]. Hansel[10] implied some connection of apparent movement with impressions of movement experienced in daily life. Under the *kappa*- and *tau*- conditions,it is therefore probable that impressions of movement occur, whether or not based upon direct sensory evidence. We thus come to our second hypothesis. That is, in a situation where real movement is involved (e.g. the *kappa*-movement and *tau*-movement conditions), speed of movement will be an important cue for the subject judging the duration and distance of movement. Hence, the magnitude of the *kappa*- and *tau*- movement effects will increase as the difference between speeds of movement increases.

2–3. Suto[11] suggested that the tactile *kappa*-effect is directly connected with visualization of the stimulated points. The *kappa*-effect was marked in the sighted subjects who reported visual images, but not in the blind. In the experiment by Helson and King[12] on the *tau*-effect in touch, a blind subject reported no visual imagery. Yet his results were not significantly different from the sighted subjects who marked the *tau*-effect reporting visual images of the distances between the stimulated points. Thus Helson and King's results would not seem to support an explanation of the *tau*-effect in terms of visual images or visuo-motor habit.

The presence of visual imagery would seem to explain the *kappa*-effect but not the *tau*-effect. This may be partly due to the difference in the kinds of the two effects. The *tau*-effect is the dependence of apparent distance on time. Contrary, the *kappa*-effect is the dependence of apparent time on distance. The blind might have little or no experience of visualizing distance. Hence, they might not be expectd to show the *kappa*-effect as Suto suggests. We would however expect that the *tau*-effect would emerge with the blind, as is hinted with Helson and King's blind subjects.

Again, our attention should be drawn to the possible role of impressions of movement in the emergence of the *kappa*- and *tau*- effects. These impressions might not be sufficient to produce the *kappa*-effect amongst Suto's blind subjects. However, if a factor of real movement is introduced into the *kappa*- and *tau*- situations, the blind as well as the sighted might be expected to show the interdependence of time and space, since the experience of movement may reinforce the perception of time and space. For our third hypothesis, it is thus proposed that the *kappa*- and *tau*- movement effects will characterize not only the sighted but also the blind subjects.

## 3. Subjects and General Procedure

### 3–1. Subjects

98 sighted and 35 blind subjects took part in two sets of experiments. The

9. (Ono, 1960)
10. (1953)
11. (1955)
12. (1931)

average age of the sighted was lower than that of the blind, 20 years and 33 years, respectively. This difference was due to limitations on the availability of the blind subjects. 22 of them were either born blind or went blind at birth, and 13 lost their sight well after birth. The common factor for all was that they had been blind for more than ten years. Two thirds were totally blind. Variations in the degree of blindness was ascertained by a simple test. Thus all blind subjects were asked to distinguish the number of fingers presented about one foot in front of their eyes. None could distinguish the number of fingers under conditions of normal illumination.

Both the sighted and the blind subjects were divided into an experimental group and a control group. 50 sighted and 20 blind made up the experimental group. 48 sighted and 15 blind comprised the control group. The blind subjects who had been totally blind since birth and whose average age most closely resembled that of the sighted subjects were included in the blind experimental group.

### 3–2. General Procedure

In both the *kappa*-movement and the *tau*-movement experiments to be described, the subjects were first instructed to draw a straight line from left to right. This line was to be drawn either fast or slow. The subjects were then instructed to draw a second line, the speed of which varied with the conditions.

The experimental subjects drew these two lines in the order of Fast-Slow and Slow-Fast. Where the first line was drawn at a fast speed, they were instructed to halve that speed in drawing the second line. When the first line was drawn at a slow speed, they were instructed to double that speed in drawing the second line. The control subjects drew both lines at the same speed: Fast-Fast and Slow-Slow.

In the first experiment on the *kappa*-movement effect, the task of the subjects was to draw the second line for a duration which seemed to them to be the same as that spent in drawing the first line. In the second experiment on the *tau*-movement effect, the task of the subjects was to draw the second line for a length which seemed to them to be the same as the length of the first line.

The experimental subjects and control subjects were each divided into two groups. One group took part in the *kappa*-movement experiment first, and then in the *tau*-movement experiment. The order of two experiments was reversed for the other group of the subjects.

A white paper 120 cms by 50 cms was fixed between a thick cardboard backing and strips of cardboard. The subjects were provided with a ballpoint pen in order to draw lines on the paper between the strips of cardboard. A stopwatch was used to measure the times taken in drawing lines.

## 4. Experiment I: On the *Kappa*-movement Effect

### 4–1. Procedure

In the first trial, the experimental subjects drew the first line at a fast speed. The time they took to draw the line was determined by the experimenter at 5 or 10 seconds. They then drew the second line at a slow speed beneath the first line. In further two trials, the order of the speeds was reversed, the speed for the initial line being slow, and for the second line fast. In the fourth trial, the subjects repeated the conditions of the first trial. The situations were duplicated for each reference duration of 5 seconds and 10 seconds respectively, and the order of Fast-Slow and Slow-Fast conditions was reversed for a half of the subjects.

The control subjects were instructed to draw the second line at the same speed as the first line, that is, in the order of Fast-Fast, Slow-Slow, Slow-Slow and Fast-Fast. These control conditions were reversed for a half of the subjects in relation to the order of the reference durations. The sighted subjects were blindfolded, and instructed as follows.

"When the bell sounds, I want you to draw a straight line from left to right at a fast speed (or at a slow speed), until you hear the second bell ring. When I say 'Go', then draw a line again, by halving the speed (by doubling the speed, or at the same speed) for a time which seems to you the same as the time you have taken to draw the fast (or slow) line."

The instructions for the blind subjects were the same as for the sighted.

4–2. Results

4–2–1. *Sighted subjects*

(i) Lets us first consider the results from the sighted subjects. The data were set out in Tables 1 and 2. Each table shows the mean values of the first and second lengths ($l_1$ and $l_2$ in cms), first and second speeds ($S_1$ and $S_2$ in cms/sec), first and second durations ($t_1$ and produced $t'_2$ in secs), and number (N) of the subjects, corresponding to the two experimental conditions of Fast-Slow and Slow-Fast, and the two control conditions of Fast-Fast and Slow-Slow. Table 1 refers to the initial reference duration of $t_1=5$ seconds, and Table 2 to the initial reference duration of $t_1=10$ seconds.

It is clear from the tables that when a subject is asked to draw the second line for the same time as he has taken to draw the first line, his performance is related to the respective length and speed corresponding to the first duration. Thus when $l_2$ is much shorter than $l_1$ and when $S_2$ is much slower than $S_1$, then $t'_2$ is made relatively large (first row of Tables 1 and 2). When $l_2$ is much longer than $l_1$ and $S_2$ is much faster than $S_1$, then $t'_2$ is made relatively small (second row of Tables 1 and 2). By relatively large and small, we mean by comparison with the actual durations, which are 5 seconds (Table 1) and 10 seconds (Table 2).

Under both control conditions (third and fourth rows of Tables 1 and 2), there seems to be a time order effect in that on the whole the second duration is produced somewhat larger than the first.

The influence of length and speed on apparent duration can be shown more clearly by calculating the ratios of $t'_2$ to $t_1$, $l_2$ to $l_1$ and $S_2$ to $S_1$. These ratios are set out

Table 1. Mean production of the second durations ($t'_2$) at two values of $l_1$ and $l_2$, and at two values of $S_1$ and $S_2$, where $t_1=5$ seconds (The standard deviation for $t'_2$ is shown in brackets)

| Condition | $l_1$ (cms) | $l_2$ | $s_1$ (cms/sec) | $s_2$ | $t_1$ (secs) | $t'_2$ | N |
|---|---|---|---|---|---|---|---|
| Fast-Slow | 40.7 | 22.6 | 8.1 | 3.4 | 5.0 | 6.7(1.9) | 50 |
| Slow-Fast | 16.8 | 33.6 | 3.4 | 7.7 | 5.0 | 4.4(1.1) | 50 |
| Fast-Fast | 32.9 | 32.8 | 6.6 | 5.7 | 5.0 | 5.8(0.8) | 48 |
| Slow-Slow | 16.7 | 17.1 | 3.3 | 2.8 | 5.0 | 6.2(0.9) | 48 |

Table 2. Mean production of the second durations ($t'_2$) at two values of $l_1$ and $l_2$, and at two values of $S_1$ and $S_2$, where $t_1=10$ seconds (The standard deviation for $t'_2$ is shown in brackets)

| Condition | $l_1$ (cms) | $l_2$ | $s_1$ (cms/sec) | $s_2$ | $t_1$ (secs) | $t'_2$ | N |
|---|---|---|---|---|---|---|---|
| Fast-Slow | 72.0 | 38.2 | 7.2 | 3.6 | 10.0 | 10.6(1.8) | 50 |
| Slow-Fast | 33.5 | 58.2 | 3.3 | 8.4 | 10.0 | 6.9(1.8) | 50 |
| Fast-Fast | 64.4 | 65.3 | 6.4 | 6.4 | 10.0 | 10.2(1.0) | 48 |
| Slow-Slow | 34.3 | 35.1 | 3.4 | 3.3 | 10.0 | 10.8(1.0) | 48 |

in Tables 3 and 4. The magnitudes of the ratios $t'_2$ to $t_1$ are corrected for the time order effect. The correction is made by multiplying the time ratios for the experimental conditions by the reciprocal of the pooled ratios for the control conditions. There is a slight variation in the two fast initial speeds (or two slow initial speeds) between the experimental condition and the control condition. The subjects were, however, given the same instructions on drawing the initial line under both conditions, and these variations are assumed to be due to experimental error.

From the $t_2'$ to $t_1$ ratios of 1.1 and 0.8 (where $t_1=5$ seconds in Table 3), and the values 1.1 and 0.6 (where $t_1=10$ seconds in Table 4), we see that the *kappa*-movement effect seems to occur. The various comparisons between the mean durations ($t_2'$) for the experimental groups and the control groups are, on the whole, highly significant. Thus there was a significant difference in the mean values of $t'_2$ between Fast-Slow and Fast-Fast ($t=3.0$, $df=96$, $p<0.01$ where $t_1=5$ seconds), between Slow-

Table 3. Mean ratios of $l_2$ to $l_1$, $S_2$ to $S_1$ and $t'_2$ to $t_1$ (uncorrected and corrected for time error), where $t_1=5$ seconds

| Condition | Independent variables $l_2/l_1$ | $s_2/s_1$ | Dependent variables $t'_2/t_1$ | Corrected for time error $t'_2/t_1$ | N |
|---|---|---|---|---|---|
| Fast-Slow | 0.6 | 0.4 | 1.3 | 1.1 | 50 |
| Slow-Fast | 2.1 | 2.3 | 0.9 | 0.8 | 50 |
| Fast-Fast | 1.0 | 0.9 | 1.2 | | 48 |
| Slow-Slow | 1.0 | 0.8 | 1.2 | | 48 |

Table 4. Mean ratios of $l_2$ to $l_1$, $S_2$ to $S_1$ and $t'_2$ to $t_1$ (uncorrected and corrected for time error), where $t_1=10$ seconds

| Condition | Independent variables $l_2/l_1$ | $s_2/s_1$ | Dependent variables $t'_2/t_1$ | Corrected for time error $t'_2/t_1$ | N |
|---|---|---|---|---|---|
| Fast-Slow | 0.5 | 0.5 | 1.1 | 1.1 | 50 |
| Slow-Fast | 1.8 | 2.5 | 0.7 | 0.6 | 50 |
| Fast-Fast | 1.0 | 1.0 | 1.0 | | 48 |
| Slow-slow | 1.0 | 1.0 | 1.1 | | 48 |

Fast and Slow-Slow ($t=9.0$, $df=96$, $p<0.01$ where $t_1=5$ seconds: $t=13.0$, $df=96$, $p<0.01$ where $t_1=10$ seconds) and between Fast-Slow and Slow-Fast ($t=7.7$, $df=98$, $p<0.01$ where $t_1=5$ seconds: $t=9.3$ $df=98$, $p<0.01$ where $t_1=10$ seconds). The difference between Fast-Slow and Fast-Fast where $t_1$ is 10 seconds was not significant at 0.05 level ($t=1.3$, $df=96$). The *kappa*-movement effect is evident on halving speed (Fast-Slow condition) and on doubling speed (Slow-Fast condition). Doubling speed, however, appears to produce a stronger effect than halving speed.

(ii) *Conditions for emergence of the kappa-movement effect*

We can isolate more precisely the conditions under which the *kappa*-movement effect occurs, or the conditions under which a negative or neutral effect occurs. An attempt may be made by comparing the individual ratios of lengths and of speeds with the corresponding individual ratios of the second duration to the first corrected for the mean time error. The mean of the individual ratios of $l_2$ to $l_1$ and $S_2$ to $S_1$ vary as shown in Table 5 (a) to (d), according to whether the *kappa*-movement effect occurs. In the Fast-Slow conditions, the *kappa*-movement effect is positive when the ratio $t'_2$ to $t_1$ is greater than unity. In the Slow-Fast conditions, the *kappa*-movement effect is positive when the ratio $t'_2$ to $t_1$ is less than unity. For counting those cases, a minimum difference in the ratios of 0.1 from unity is used as the criterion.

When the subject is asked to halve the initial speed in producing the second, the second distance might be expected to be also halved from the initial. When he is asked to double the initial speed in producing the second, the second distance might be expected to be doubled over the initial. In both cases, he is instructed to equate the second duration to the initial.

In fact the subjects do not generally follow these principles as far as speed of drawing is concerned. On halving speed, the positive effect occurs when the second speed is made smaller than an actual half of the initial speed (first row of Table 5 (a) and (b) ). The negative effect occurs when the second speed is reduced to an actual half or more of the initial speed (second row of Table 5 (a) and (b) ). By contrast, on doubling speed, the positive effect occurs when the second speed is increased more than an actual doubled value of the initial speed (first row of Table 5 (c) and (d) ). The negative effect occurs when the increase of the second speed is less than a double of the initial speed (second row of Table 5 (c) and (d) ).

Table 5. Ratios of the first ($l_1$) and second ($l_2$) lengths and ratios of the first ($S_1$) and second ($S_2$) speeds, which correspond to a positive, negative or neutral *kappa*-movement effect, as measured by the ratio $t'_2$ to $t_1$ corrected for time error

(a) Fast-Slow condition (where $t_1=5$ seconds)

| Pattern | $t_1$ (secs) | $t'_2$ | $l_1$ (cms) | $l_2$ | $s_1$ (cms/sec) | $s_2$ | $t'_2/t_1$ | $l_2/l_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 5.0 | 7.7 | 38.5 | 22.7 | 7.7 | 2.9 | 1.3 | 0.6 | 0.4 | 31 |
| Negative | 5.0 | 5.0 | 44.2 | 22.5 | 8.8 | 4.5 | 0.8 | 0.5 | 0.5 | 19 |

(b) Fast-Slow condition (where $t_1=10$ seconds)

| Pattern | $t_1$ (secs) | $t'_2$ | $l_1$ (cms) | $l_2$ | $s_1$ (cms/sec) | $s_2$ | $t'_2/t_1$ | $l_2/l_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 10.0 | 11.9 | 70.3 | 36.4 | 7.0 | 3.1 | 1.2 | 0.5 | 0.4 | 27 |
| Negative | 10.0 | 8.9 | 73.2 | 39.0 | 7.3 | 4.4 | 0.9 | 0.5 | 0.6 | 22 |
| Neutral | 10.0 | 10.2 | 90.9 | 43.0 | 9.1 | 4.2 | 1.0 | 0.5 | 0.5 | 1 |

(c) Slow-Fast condition (where $t_1=5$ seconds)

| Pattern | $t_1$ (secs) | $t'_2$ | $l_1$ (cms) | $l_2$ | $s_1$ (cms/sec) | $s_2$ | $t'_2/t_1$ | $l_2/l_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 5.0 | 4.2 | 16.6 | 33.0 | 3.3 | 7.9 | 0.7 | 2.0 | 2.4 | 47 |
| Nagative | 5.0 | 6.9 | 20.1 | 43.2 | 4.0 | 6.2 | 1.2 | 2.1 | 1.5 | 3 |

(d) Slow-Fast condition (where $t_1=10$ seconds)

| Pattern | $t_1$ | $t'_2$ | $l_1$ | $l_2$ | $s_1$ | $s_2$ | $t'_2/t_1$ | $l_2/l_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 10.0 | 6.9 | 33.5 | 58.2 | 3.3 | 8.4 | 0.6 | 1.8 | 2.5 | 50 |

In the case of distance, however, whether the positive effect or the negative effect occurs, on the whole the second length is shortened to roughly a half of the initial length in the case of halving speed, and lengthened almost to a double of the initial length in the case of doubling speed. However, the ratios of speed seem to have a relatively more distinct bearing on the emergence of the *kappa*-movement effect than the ratios of distance.

Figures 1 and 2 show the relationship of speed ratios with time ratios. From Figure 1, we see that the ratio of $t'_2$ to $t_1$ increases as the ratio of $S_2$ to $S_1$ decreases. This means, on halving speed, that the slower the second speed, the shorter the apparently equivalent duration becomes. From Figure 2, we see that the ratio of $t'_2$ to $t_1$ decreases as the ratio of $S_2$ to $S_1$ increases. Thus on doubling speed, the faster the second speed, so the longer the apparently equivalent duration becomes. In other words, it seems likely that the magnitude of the *kappa*-movement effect increases with the difference between the initial speed and the subsequent speed.

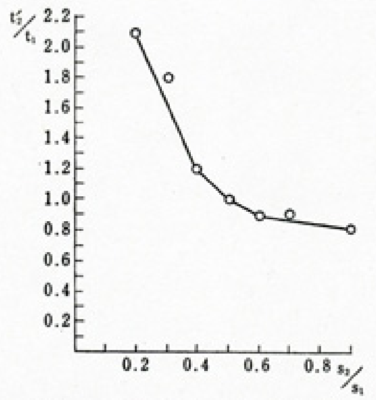


Figure 1. Relationship between $t'_2/t_1$ and $S_2/S_1$ for the Fast-Slow condition, for both $t_1=5$ secs and $t_1=10$ secs (Sighted subjects)

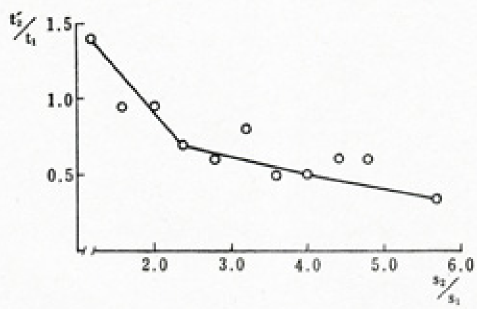


Figure 2. Relationship between $t'_2/t_1$ and $S_2/S_1$ for the Slow-Fast condition, for both $t_1=5$ secs and $t_1=10$ secs (Sighted subjects)

4–2–2. *Blind subjects*

(i) Let us now turn to the results from the blind subjects. We show in Tables 6 and 7 the mean durations ($t'_2$) as produced by the blind subjects under four conditions, where $t_1=5$ seconds and where $t_1=10$ seconds. Tables 8 and 9 indicate the ratios of produced durations ($t_2'$) to the reference durations ($t_1$), corrected for the time order effect, analogous to the results from the sighted subjects.

When $1_2$ is much shorter than $1_1$ and when $S_2$ is much slower than $S_1$, $t_2'$ is made relatively large, as compared with $t_1$. From the ratios 1.2 (where $t_1=5$ seconds) and 1.1 (where $t_1=10$ seconds) corrected for the time error (first row of Tables 8 and 9), we see that the *kappa*-movement effect occurs on halving speed. The effect is not so marked on doubling speed, as compared with the results from the sighted subjects. But from the combined value 0.9 of the two ratios 1.0 (where $t_1=5$ seconds) and 0.8 (where $t_1=10$ seconds) in the two Slow-Fast conditions (second row of Tables 8 and 9), we find the effect in the positive direction.

Table 6. Mean production of the second durations ($t'_2$) at two values of $l_1$ and $l_2$, and at two values of $S_1$ and $S_2$, where $t_1=5$ seconds
(The standard deviation for $t'_2$ is shown in brackets)

| Condition | $l_1$ (cms) | $l_2$ | $s_1$ (cms/sec) | $s_2$ | $t_1$ (secs) | $t'_2$ | N |
|---|---|---|---|---|---|---|---|
| Fast-Slow | 33.9 | 18.4 | 6.8 | 2.8 | 5.0 | 6.7(1.3) | 20 |
| Slow-Fast | 13.4 | 27.7 | 2.7 | 4.9 | 5.0 | 5.6(1.1) | 20 |
| Fast-Fast | 32.3 | 33.7 | 6.4 | 6.0 | 5.0 | 5.6(0.7) | 15 |
| Slow-Slow | 13.6 | 14.8 | 2.7 | 2.6 | 5.0 | 5.7(1.1) | 15 |

Table 7. Mean production of the second durations ($t'_2$) at two values of $l_1$ and $l_2$, and at two values of $S_1$ and $S_2$, where $t_1=10$ seconds
(The standard deviation for $t'_2$ is shown in brackets)

| Condition | $l_1$ (cms) | $l_2$ | $s_1$ (cms/sec) | $s_2$ | $t_1$ (secs) | $t'_2$ | N |
|---|---|---|---|---|---|---|---|
| Fast-Slow | 67.6 | 36.2 | 6.8 | 3.4 | 10.0 | 10.8(3.2) | 20 |
| Slow-Fast | 26.4 | 46.7 | 2.6 | 5.9 | 10.0 | 8.0(1.5) | 20 |
| Fast-Fast | 60.7 | 61.8 | 6.1 | 6.5 | 10.0 | 9.5(1.5) | 15 |
| Slow-Slow | 29.2 | 29.8 | 2.9 | 3.1 | 10.0 | 9.5(1.1) | 15 |

Table 8. Mean ratios of $l_2$ to $l_1$, $S_2$ to $S_1$, $t'_2$ to $t_1$ (uncorrected and corrected for time error), where $t_1=5$ seconds)

| Condition | Independent Variables $l_2/l_1$ | $s_2/s_1$ | Dependent Variables $t'_2/t_1$ | Corrected for time error $t'_2/t_1$ | N |
|---|---|---|---|---|---|
| Fast-Slow | 0.5 | 0.4 | 1.3 | 1.2 | 20 |
| Slow-Fast | 2.1 | 1.8 | 1.1 | 1.0 | 20 |
| Fast-Fast | 1.0 | 0.9 | 1.1 | | 15 |
| Slow-Slow | 1.1 | 1.0 | 1.1 | | 15 |

Table 9. Mean ratios of $l_2$ to $l_1$, $S_2$ to $S_1$, $t'_2$ to $t_1$ (uncorrected and corrected for time error), where $t_1=10$ seconds

| Condition | Independent Variables $l_2/l_1$ | $s_2/s_1$ | Dependent Variables $t'_2/t_1$ | Corrected for time error $t'_2/t_1$ | N |
|---|---|---|---|---|---|
| Fast-Slow | 0.5 | 0.5 | 1.1 | 1.1 | 20 |
| Slow-Fast | 1.8 | 2.2 | 0.8 | 0.8 | 20 |
| Fast-Fast | 1.0 | 1.1 | 1.0 | | 15 |
| Slow-Slow | 1.0 | 1.1 | 1.0 | | 15 |

On the whole, this conclusion is supported by a statistical examination of the means of $t'_2$. There was a significant difference in the mean values of $t'_2$ between Fast-Slow and Fast-Fast ($t=2.8$, $df=33$, $p<0.01$ where $t_1=5$ seconds: $t=1.6$, $df=33$, $p<0.10$ where $t_1=10$ seconds) and between Slow-Fast and Slow-Slow ($t=3.8$, $df=33$, $p<0.01$ where $t_1=10$ seconds), but not between Slow-Fast and Slow-Slow where $t_1$ is 5 seconds. In direct comparison between the two experimental conditions of Fast-Slow and Slow-Fast, the mean values of $t'_2$ were significantly different at 0.01 level ($t=2.8$, $df=38$ where $t_1=5$ seconds: $t=3.5$, $df=38$ where $t_1=10$ seconds).

(ii) *Conditions for emergence of the kappa-movement effect*

In the same way as was observed in the sighted subjects, the mean ratios of $l_2$ to $l_1$ and $S_2$ to $S_1$ can be used as indicators of conditions which are positive to the occurence of the *kappa*-movement effect. On halving speed, the speed ratios seem to have more influence on the occurence of the effect than the distance ratios, as shown

Table 10. Ratios of the first ($l_1$) and second ($l_2$) lengths and ratios of the first ($S_1$) and second ($S_2$) speeds, which correspond to a positive, negative or neutral *kappa*-movement effect, as measured by the ratio $t'_2$ to $t_1$ corrected for time error

(a) Fast-Slow condition (where $t_1=5$ seconds)

| Pattern | $t_1$ (secs) | $t'_2$ | $l_1$ (cms) | $l_2$ | $s_1$ (cms/sec) | $s_2$ | $t'_2/t_1$ | $l_2/l_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 5.0 | 7.2 | 31.8 | 18.0 | 6.4 | 2.5 | 1.3 | 0.6 | 0.4 | 16 |
| Negative | 5.0 | 4.8 | 42.5 | 20.2 | 8.5 | 4.2 | 0.9 | 0.5 | 0.5 | 4 |

(b) Fast-Slow condition (where $t_1=10$ seconds)

| Pattern | $t_1$ (secs) | $t'_2$ | $l_1$ (cms) | $l_2$ | $s_1$ (cms/sec) | $s_2$ | $t'_2/t_1$ | $l_2/l_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 10.0 | 13.7 | 68.7 | 37.8 | 6.9 | 2.8 | 1.4 | 0.5 | 0.4 | 10 |
| Negative | 10.0 | 7.8 | 69.2 | 36.4 | 6.9 | 4.7 | 0.8 | 0.5 | 0.7 | 9 |
| Neutral | 10.0 | 9.5 | 42.0 | 18.8 | 4.2 | 2.0 | 1.0 | 0.4 | 0.5 | 1 |

(c) Slow-Fast condition (where $t_1=5$ seconds)

| Pattern | $t_1$ (secs) | $t'_2$ | $l_1$ (cms) | $l_2$ | $s_1$ (cms/sec) | $s_2$ | $t'_2/t_1$ | $l_2/l_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 5.0 | 4.8 | 13.8 | 24.2 | 2.8 | 5.1 | 0.9 | 1.7 | 1.8 | 10 |
| Negative | 5.0 | 6.5 | 12.9 | 31.2 | 2.6 | 4.8 | 1.2 | 2.4 | 1.9 | 10 |

(d) Slow-Fast condition (where $t_1=10$ seconds)

| Pattern | $t_1$ (secs) | $t'_2$ | $l_1$ (cms) | $l_2$ | $s_1$ (cms/sec) | $s_2$ | $t'_2/t_1$ | $l_2/l_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 10.0 | 7.5 | 27.3 | 48.2 | 2.7 | 6.5 | 0.7 | 1.8 | 2.4 | 16 |
| Negative | 10.0 | 10.0 | 22.8 | 41.0 | 2.3 | 4.1 | 1.0 | 1.8 | 1.8 | 4 |

in Table 10 (a) to (d). Similarly the ratios of speeds can be plotted against the time ratios for the blind subjects.

On halving speed, the ratio of $t'_2$ to $t_1$ increases as the ratio of $S_2$ to $S_1$ decreases (Figure 3), and on doubling speed the ratio of $t'_2$ to $t_1$ decreases as the ratio of $S_2$ to $S_1$ increases (Figure 4). Thus, as with the sighted subjects, the magnitude of the *kappa*-movement effect again increases with the difference between the initial and the subsequent speeds.

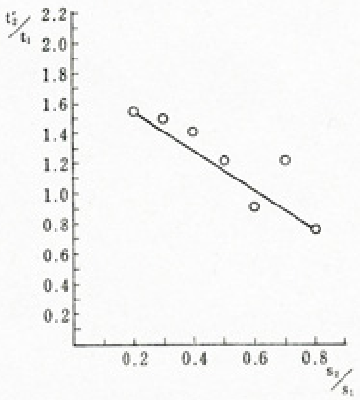

Figure 3

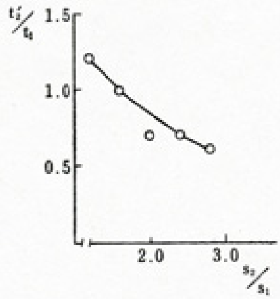

Figure 4

Figure 3. Relationship between $t'_2/t_1$ and $S_2/S_1$ for the Fast-Slow condition, for both $t_1=5$ secs and $t_1=10$ secs (Blind subjects)

Figure 4. Relationship between $t'_2/t_1$ and $S_2/S_1$ for the Slow-Fast condition, for both $t_1=5$ secs and $t_1=10$ secs (Blind subjects)

### 4–2–3. *Comparison between the blind and the sighted on the occurrence of the kappa-movement effect*

Table 11 shows for comparative purposes the mean ratios of $t'_2$ to $t_1$ for the sighted and blind subjects under the two experimental conditions of Fast-Slow and Slow-Fast. The ratios are corrected for the time error.

Based upon the mean values of $t_2'$, a significant difference between the sighted and the blind is found in the doubling condition ($t=4.0$, $df=68$, $p<0.01$ where $t_1=5$ seconds: $t=2.2$, $df=68$, $p<0.05$ where $t_1=10$ seconds). The sighted subjects therefore follow the *kappa*-movement effect in doubling to a relatively greater extent than the blind subjects.

Table 11. Comparison in corrected ratios of $t'_2$ to $t_1$ between the sighted and the blind

| Condition | $t_1$ | Sighted | Blind |
|---|---|---|---|
| Fast-Slow | 5 secs | 1.1 | 1.2 |
| | 10 secs | 1.1 | 1.1 |
| Slow-Fast | 5 secs | 0.8** | 1.0** |
| | 10 secs | 0.6* | 0.8* |

(calculation based upon mean values of $t'_2$)
Horizontally **$p<0.01$ *$p<0.05$

## 5. Experiment II. On the *Tau*-movement Effect

### 5–1. Procedure

In the first trial, the experimental subjects were instructed to draw a straight line from left to right at a fast speed. The length of this line was determined by the experimenter at 30 cms or 50 cms. The subjects were then instructed to draw a line at a slow speed, for a length which seemed to them to be the same length as that drawn at the fast speed. The second line was not drawn beneath the first in this case, since cues to distance were obviously to be avoided.

In further two trials, the speed for the initial line was slow, and for the second line fast. In a final trial, the subjects repeated the conditions of the first trial. The situations were duplicated for each reference distance of 30 cms and 50 cms respectively. The order of Fast-Slow and Slow-Fast conditions was reversed for a half of the subjects.

The control subjects were instructed to draw the second line at the same speed as the first line, that is, in the order of Fast-Fast, Slow-Slow, Slow-Slow and Fast-Fast. The control conditions were reversed for a half of the subjects in relation to the order of the reference lengths. The sighted subjects were blindfolded, and told:

> "When the bell sounds, I want you to draw a straight line from left to right at a fast speed (or at a slow speed), until you hear the second bell ring. When I say 'Go', then continue to draw a line, by halving the speed (by boubling the speed, or at the same speed), for a length which seems to you the same as the length you have drawn at the fast speed (or at the slow speed). When you have drawn this length, stop."

The instructions for the blind subjects were the same as for the sighted subjects.

5–2. Results

5–2–1. *Sighted subjects*

(i) We now come to the results from the *tau*-movement experiment on the sighted subjects. The data are set out in Tables 12 and 13. Each table shows the mean values of the first and second durations ($t_1$ and $t_2$ in seconds), first and second speeds ($S_1$ and $S_2$ in cms/sec), first and second lengths ($l_1$ and produced $l'_2$ in cms), and number (N) of the subjects, corresponding to the two experimental conditions of Fast-Slow and Slow-Fast, and the two control conditions of Fast-Fast and Slow-Slow. Table 12 refers to the initial length of $l_1=30$ cms, and Table 13 to the initial length of $l_1=50$ cms.

It is evident from the tables that when a person is asked to equate the second length to the first length, his performance is related to the respective duration and speed corresponding to the first length. Thus when $t_2$ is much longer than $t_1$ and when $S_2$ is much slower than $S_1$, then $l_2'$ is made relatively small, as compared with the reference lengths ($l_1$), 30 cms and 50 cms (first row of Tables 12 and 13). When $t_2$ is much shorter than $t_1$ and when $S_2$ is much faster than $S_1$, then $l_2'$ is made relatively large (second row of Tables 12 and 13). Under both control conditions, a time order effect emerges in that the second length is produced somewhat shorter than the first (third and fourth rows of Tables 12 and 13).

The mean ratios of $l_2'$ to $l_1$, $t_2$ to $t_1$ and $S_2$ to $S_1$, are presented in Tables 14 and 15. They indicate that apparent equivalence of length depends upon the durations

Table 12. Mean production of the second lengths ($l'_2$) at two values of $t_1$ and $t_2$, and at two values of $S_1$ and $S_2$, where $l_1$=30 cms (The standard deviation for $l'_2$ is shown in brackets)

| Condition | $t_1$ (secs) | $t_2$ | $s_1$ (cms/sec) | $s_2$ | $l_1$ (cms) | $l'_2$ | N |
|---|---|---|---|---|---|---|---|
| Fast-Slow | 5.1 | 9.1 | 5.9 | 2.8 | 30.0 | 25.8(6.4) | 50 |
| Slow-Fast | 12.1 | 5.3 | 2.5 | 7.0 | 30.0 | 36.2(7.2) | 50 |
| Fast-Fast | 5.7 | 6.2 | 5.2 | 4.8 | 30.0 | 29.4(5.3) | 48 |
| Slow-Slow | 13.1 | 11.8 | 2.3 | 2.3 | 30.0 | 27.4(5.3) | 48 |

Table 13. Mean production of the second lengths ($l'_2$) at two values of $t_1$ and $t_2$, and at two values of $S_1$ and $S_2$, where $l_1$=50 cms (The standard deviation for $l'_2$ is shown in brackets)

| Condition | $t_1$ (secs) | $t_2$ | $s_1$ (cms/sec) | $s_2$ | $l_1$ (cms) | $l'_2$ | N |
|---|---|---|---|---|---|---|---|
| Fast-Slow | 7.0 | 10.3 | 7.1 | 3.8 | 50.0 | 38.7(9.7) | 50 |
| Slow-Fast | 16.5 | 6.2 | 3.0 | 8.6 | 50.0 | 53.5(9.9) | 50 |
| Fast-Fast | 8.9 | 8.7 | 5.6 | 4.9 | 50.0 | 42.9(6.9) | 48 |
| Slow-Slow | 19.1 | 16.4 | 2.6 | 2.5 | 50.0 | 41.7(5.3) | 48 |

and speeds corresponding to each respective length. If we make a correction to allow for the influence of time order, as shown in the final column of Tables 14 and 15, we find $l_2'$ to $l_1$ ratios of 0.9 and 1.3 (where $l_1$=30 cms in Table 14) and the ratios of 0.9 and 1.4 (where $l_1$=50 cms in Table 15). Thus the *tau*-movement effect appears both in doubling speed and in halving speed.

Table 14. Mean ratios of $t_2$ to $t_1$, $S_2$ to $S_1$ and $l'_2$ to $l_1$ (uncorrected and corrected for time error) where $l_1$=30 cms

| Condition | Independent Variables $t_2/t_1$ | $s_2/s_1$ | Dependent Variables $l'_2/l_1$ | Corrected for time error $l'_2/l_1$ | N |
|---|---|---|---|---|---|
| Fast-Slow | 1.9 | 0.5 | 0.9 | 0.9 | 50 |
| Slow-Fast | 0.4 | 2.9 | 1.2 | 1.3 | 50 |
| Fast-Fast | 1.1 | 0.9 | 1.0 | | 48 |
| Slow-Slow | 0.9 | 1.0 | 0.9 | | 48 |

Table 15. Mean ratios of $t_2$ to $t_1$, $S_2$ to $S_1$ and $l'_2$ to $l_1$ (uncorrected and corrected for time error) where $l_1$=50 cms

| Condition | Independent Variables $t_2/t_1$ | $s_2/s_1$ | Dependent Variables $l'_2/l_1$ | Corrected for time error $l'_2/l_1$ | N |
|---|---|---|---|---|---|
| Fast-Slow | 1.5 | 0.5 | 0.8 | 0.9 | 50 |
| Slow-Fast | 0.4 | 2.8 | 1.1 | 1.4 | 50 |
| Fast-Fast | 1.0 | 0.9 | 0.9 | | 48 |
| Slow-Slow | 0.9 | 1.0 | 0.8 | | 48 |

The difference between the mean produced distances are highly significant. Significant differences in the mean values of $l'_2$ emerge between Fast-Slow and Fast-Fast conditions ($t=3.0$, $df=96$, $p<0.01$ where $l_1=30$ cms: $t=2.5$, $df=96$, $p<0.05$ where $l_1=50$ cms), between Slow-Fast and Slow-Slow conditions ($t=6.8$, $df=96$, $p<0.01$ where $l_1=30$ cms: $t=7.4$, $df=96$, $p<0.01$ where $l_1=50$ cms), and between Fast-Slow and Slow-Fast conditions ($t=7.4$, $df=98$, $p<0.01$ where $l_1=30$ cms: $t=7.4$, $df=98$, $p<0.01$ where $l_1=50$ cms).

(ii) *Conditions for emergence of the tau-movement effect*

The individual ratios of durations and of speeds, compared with the corresponding individual ratios of lengths corrected for the time order effect, can be used to isolate conditions which may be positive or negative for the occurrence of the *tau*-movement effect. we show in Table 16 (a) to (d) the mean of the individual ratios of $t_2$ to $t_1$ and $S_2$ to $S_1$ in the cases where the positive effect occurs and where the negative (or neutral) effect occurs.

Table 16. Ratios of the first ($t_1$) and second ($t_2$) durations and ratios of the first ($S_1$) and second ($S_2$) speeds, which correspond to a positive, negative or neutral *tau*-movement effect, as measured by the ratio $l'_2$ to $l_1$ corrected for time error

(a) Fast-Slow condition (where $l_1=30$ cms)

| Pattern | $l_1$ (cms) | $l'_2$ | $t_1$ (secs) | $t_2$ | $s_1$ (cms/sec) | $s_2$ | $l'_2/l_1$ | $t_2/t_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 30.0 | 23.1 | 5.3 | 8.9 | 5.6 | 2.6 | 0.8 | 1.7 | 0.5 | 37 |
| Negative | 30.0 | 33.2 | 4.3 | 9.8 | 7.0 | 3.4 | 1.1 | 2.3 | 0.5 | 13 |

(b) Fast-Slow condition (where $l_1=50$ cms)

| Pattern | $l_1$ (cms) | $l'_2$ | $t_1$ (secs) | $t_2$ | $s_1$ (cms/sec) | $s_2$ | $l'_2/l_1$ | $t_2/t_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 50.0 | 33.4 | 7.4 | 10.0 | 6.7 | 3.3 | 0.8 | 1.3 | 0.5 | 34 |
| Negative | 50.0 | 50.2 | 6.3 | 11.4 | 8.0 | 4.4 | 1.1 | 1.8 | 0.6 | 15 |
| Neutral | 50.0 | 42.6 | 4.4 | 4.7 | 11.4 | 9.1 | 1.0 | 1.1 | 0.8 | 1 |

(c) Slow-Fast condition (where $l_1=30$ cms)

| Pattern | $l_1$ (cms) | $l'_2$ | $t_1$ (secs) | $t_2$ | $s_1$ (cms/sec) | $s_2$ | $l'_2/l_1$ | $t_2/t_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 30.0 | 37.8 | 12.3 | 5.2 | 2.4 | 7.3 | 1.4 | 0.4 | 3.0 | 44 |
| Negative | 30.0 | 24.3 | 11.7 | 4.8 | 2.6 | 5.1 | 0.9 | 0.4 | 2.0 | 6 |

(d) Slow-Fast condition (where $l_1=50$ cms)

| Pattern | $l_1$ (cms) | $l'_2$ | $t_1$ (secs) | $t_2$ | $s_1$ (cms/sec) | $s_2$ | $l'_2/l_1$ | $t_2/t_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 50.0 | 57.8 | 17.3 | 6.4 | 2.9 | 9.0 | 1.5 | 0.4 | 3.1 | 39 |
| Negative | 50.0 | 37.8 | 14.7 | 5.8 | 3.4 | 6.5 | 1.0 | 0.4 | 1.9 | 10 |
| Neutral | 50.0 | 41.6 | 5.5 | 1.9 | 9.1 | 21.9 | 1.0 | 0.3 | 2.4 | 1 |

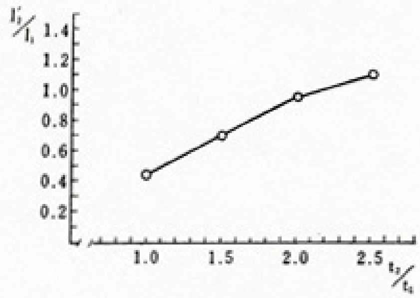


Figure 5

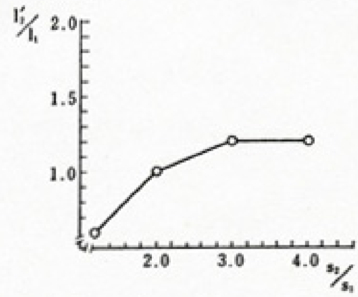


Figure 6

Figure 5. Relationship between $l'_2/l_1$ and $t_2/t_1$ for the Fast-Slow condition, for both $l_1=30$ cms and $l_1=50$ cms (Sighted subjects)

Figure 6. Relationship between $l'_2/l_1$ and $S_2/S_1$ for the Slow-Fast condition, for both $l_1=30$ cms and $l_1=50$cms (Sighted subjects)

When the subject is asked to halve the initial speed in producing an equivalent length, the second duration might be expected to be doubled over the initial duration. When he is asked to double the initial speed, the second duration might be expected to be a half of the initial duration. In both cases, the subject is instructed to equate the second length with the initial length.

In fact on halving speed (Table 16 (a) and (b) ), the second duration is less increased with the positive effect than with the negative effect. On doubling speed (Table 16 (c) and (d) ), the second speed is increased about three times over the initial speed, when the positive effect occurs. When the negative effect emerges, the increase of the second speed is about a double of the initial (second row of Table 16 (c) and (d) ).

In figure 5 the relationship between the ratios of length and the ratios of duration is shown, and in Figure 6 the ratios of length are plotted against the ratios of speed. From Figure 5 it seems that the ratio of $l'_2$ to $l_1$ decreases as the ratio of $t_2$ to $t_1$ decreases. This means, on halving speed, that the longer the apparent duration, the longer the apparent length. From Figure 6 we can see that the ratio of $l'_2$ to $l_1$ increases as the ratio of $S_2$ to $S_1$ increases. On doubling speed, therefore, the faster the speed, the shorter the apparent length becomes. The figures also indicate that on halving speed the effect of duration on apparent length is more striking than the effect of speed. Halving speed, however, appears to produce a less marked *tau*-movment effect than doubling speed, as shown in Tables 14 and 15.

### 5–2–2. *Blind Subjects*

(i) The mean lengths ($l'_2$) produced by the blind subjects are shown in Tables 17 and 18. The ratios of the produced length ($l'_2$) to the reference length ($l_1$) are set out in Tables 19 and 20.

When $t_2$ is much longer than $t_1$ and when $S_2$ is much slower than $S_1$, $l'_2$ is made

Table 17. Mean production of the second lengths ($l'_2$) at two values of $t_1$ and $t_2$, and at two values of $S_1$ and $S_2$, where $l_1=30$ cms (The standard deviation for $l'_2$ is shown in brackets)

| Condition | $t_1$ (secs) | $t_2$ (secs) | $s_1$ (cms/sec) | $s_2$ (cms/sec) | $l_1$ (cms) | $l'_2$ (cms) | N |
|---|---|---|---|---|---|---|---|
| Fast-Slow | 4.1 | 9.4 | 7.4 | 2.7 | 30.0 | 25.6(5.7) | 20 |
| Slow-Fast | 13.4 | 6.9 | 2.2 | 4.3 | 30.0 | 29.5(7.4) | 20 |
| Fast-Fast | 5.7 | 5.8 | 5.3 | 5.2 | 30.0 | 29.7(5.6) | 15 |
| Slow-Slow | 13.8 | 10.9 | 2.2 | 2.6 | 30.0 | 28.5(6.2) | 51 |

Table 18. Mean production of the second lengths ($l'_2$) at two values of $t_1$ and $t_2$, and at two values of $S_1$ and $S_2$, where $l_1=50$ cms (The standard deviation for $l'_2$ is shown in brackets)

| Condition | $t_1$ (secs) | $t_2$ (secs) | $s_1$ (cms/sec) | $s_2$ (cms/sec) | $l_1$ (cms) | $l'_2$ (cms) | N |
|---|---|---|---|---|---|---|---|
| Fast-Slow | 6.8 | 12.8 | 7.4 | 3.1 | 50.0 | 39.2(10.9) | 20 |
| Slow-Fast | 20.0 | 8.1 | 2.5 | 5.1 | 50.0 | 41.6( 9.9) | 20 |
| Fast-Fast | 9.7 | 8.2 | 5.2 | 5.4 | 50.0 | 44.4( 6.9) | 15 |
| Slow-Slow | 20.4 | 14.8 | 2.5 | 2.9 | 50.0 | 42.4( 7.3) | 15 |

Table 19. Mean ratios of $t_2$ to $t_1$, $S_2$ to $S_1$ and $l'_2$ to $l_1$ (uncorrected and corrected for time error), where $l_1=30$ cms

| Condition | Independent Variables $t_2/t_1$ | Independent Variables $s_2/s_1$ | Dependent Variables $l'_2/l_1$ | Corrected for time error $l'_2/l_1$ | N |
|---|---|---|---|---|---|
| Fast-Slow | 2.3 | 0.4 | 0.9 | 0.9 | 20 |
| Slow-Fast | 0.5 | 1.9 | 1.0 | 1.1 | 20 |
| Fast-Fast | 1.0 | 1.0 | 1.0 | | 15 |
| Slow-Slow | 0.8 | 1.2 | 0.9 | | 15 |

Table 20. Mean ratios of $t_2$ to $t_1$, $S_2$ to $S_1$ and $l'_2$ to $l_1$ (uncorrected and corrected for time error), where $l_1=50$ cms

| Condition | Independent Variables $t_2/t_1$ | Independent Variables $s_2/s_1$ | Dependent Variables $l'_2/l_1$ | Corrected for time error $l'_2/l_1$ | N |
|---|---|---|---|---|---|
| Fast-Slow | 1.9 | 0.4 | 0.8 | 0.9 | 20 |
| Slow-Fast | 0.4 | 2.1 | 0.8 | 1.0 | 20 |
| Fast-Fast | 0.9 | 1.0 | 0.9 | | 15 |
| Slow-Slow | 0.7 | 1.2 | 0.8 | | 15 |

relatively small, compared with the reference lengths ($l_1$), 30 and 50 cms (first row of Tables 17 and 18). From the length ratio of 0.9 (both where $l_1=30$ cms and where $l_1=50$ cms) corrected for the time error, we see that the *tau*-movement effect occurs on halving speed amongst these blind subjects (first row of Tables 19 and 20). On doubling speed the effect is less marked in the blind than in the sighted (second row of Tables 19 and 20). But if we combine two ratios 1.1 (where $l_1$=30 cms) and 1.0 (where $l_1$=50 cms), the pooled value of 1.1 suggests that the effect is in the expected direction. A significant difference in the mean values of $l'_2$, however, was only found at the 0.05 level ($t=2.3$, $df=33$) between the Fast-Slow and Fast-Fast conditions where $l_1$=30 cms.

(ii) *Conditions for emergence of the tau-movement effect*

As shown in Table 21 (a) and (b), the *tau*-movement effect occurs on halving speed, when the second speed is halved below a half of the initial speed. The negative effect emerges on doubling speed, as shown in Table 21 (c) and (d), when the second duration is below a half of the initial duration.

Table 21. Ratios of the first ($t_1$) and second ($t_2$) durations and ratios of the first ($S_1$) and second ($S_2$) speeds, which correspond to a positive, negative or neutral *tau*- movement effect, as measured by the ratio $l'_2$ to $l_1$ corrected for time error

(a) Fast-Slow condition (where $l_1$=30 cms)

| Pattern | $l_1$ (cms) | $l'_2$ (cms) | $t_1$ (secs) | $t_2$ (secs) | $s_1$ (cms/sec) | $s_2$ (cms/sec) | $l'_2/l_1$ | $t_2/t_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 30.0 | 22.7 | 3.7 | 8.6 | 8.2 | 3.6 | 0.8 | 2.4 | 0.3 | 15 |
| Negative | 30.0 | 34.1 | 5.3 | 11.7 | 5.7 | 2.9 | 1.1 | 2.2 | 0.5 | 5 |

(b) Fast-Slow condition (where $l_1$=50 cms)

| Pattern | $l_1$ (cms) | $l'_2$ (cms) | $t_1$ (secs) | $t_2$ (secs) | $s_1$ (cms/sec) | $s_2$ (cms/sec) | $l'_2/l_1$ | $t_2/t_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 50.0 | 33.0 | 6.1 | 11.2 | 8.2 | 2.9 | 0.8 | 1.8 | 0.4 | 13 |
| Negative | 50.0 | 50.6 | 8.0 | 15.7 | 6.3 | 3.2 | 1.1 | 2.0 | 0.5 | 7 |

(c) Slow-Fast condition (where $l_1$=30 cms)

| Pattern | $l_1$ (cms) | $l'_2$ (cms) | $t_1$ (secs) | $t_2$ (secs) | $s_1$ (cms/sec) | $s_2$ (cms/sec) | $l'_2/l_1$ | $t_2/t_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 30.0 | 34.2 | 12.2 | 7.0 | 2.5 | 4.9 | 1.2 | 0.6 | 2.0 | 12 |
| Negative | 30.0 | 22.3 | 15.1 | 6.7 | 2.0 | 3.3 | 0.8 | 0.4 | 1.7 | 8 |

(d) Slow-Fast condition (where $l_1$=50 cms)

| Pattern | $l_1$ (cms) | $l'_2$ (cms) | $t_1$ (secs) | $t_2$ (secs) | $s_1$ (cms/sec) | $s_2$ (cms/sec) | $l'_2/l_1$ | $t_2/t_1$ | $s_2/s_1$ | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive | 50.0 | 50.6 | 20.1 | 10.2 | 2.5 | 4.9 | 1.3 | 0.5 | 2.0 | 9 |
| Negative | 50.0 | 33.4 | 19.4 | 6.1 | 2.6 | 5.4 | 0.9 | 0.3 | 2.1 | 10 |
| Neutral | 50.0 | 42.2 | 25.6 | 9.1 | 2.0 | 4.6 | 1.0 | 0.4 | 2.4 | 1 |

### 5-2-3. *Comparison between the blind and the sighted on the occurrence of the tau-movement effect*

The ratios of $l'_2$ to $l_1$ for the blind are compared with those of the sighted in Table 22 for the two experimental conditions of Fast-Slow (halving) and Slow-

Table 22. Comparison in corrected ratios of $l'_2$ to $l_1$ between the sighted and the blind

| Condition | $l_1$ | Sighted | Blind |
|---|---|---|---|
| Fast-Slow | 30 cms | 0.9 | 0.9 |
| | 50 cms | 0.9 | 0.9 |
| Slow-Fast | 30 cms | 1.3** | 1.1** |
| | 50 cms | 1.4** | 1.0** |

(calculation based upon the mean values of $l'_2$)
Horizontally **$p<0.01$

Fast (doubling). The ratios in the table are corrected for the time order effect. On doubling speed, there is a significant difference in the mean values of $l'_2$ between the blind and the sighted ($t=3.4$, $df=68$, $p<0.01$ where $l_1=30$ cms: $t=4.4$, $df=68$, $p<0.01$ where $l_1=50$ cms). As in the *kappa*-movement results, doubling speed produces a stronger effect amongst the sighted subjects.

## 6. Conclusion and Explanation

### 6–1. Conclusion

#### 6–1–1. *Universality of the kappa- and tau-movement effects*

In the experiment on the *kappa*-movement effect, our subjects spent a longer duration on the whole when drawing a shorter (slower) line than the fixed duration corresponding to a longer (faster) line. Further, the subjects spent a shorter duration when drawing a longer (faster) line than the fixed duration corresponding to a shorter (slower) line. From this, we may infer that if the durations for drawing two lines respectively are in fact equal, that duration will seem shorter which is associated with the shorter line drawn at the slower speed, and that duration will seem greater which is associated with the longer line drawn at the faster speed. In other words, the *kappa*-movement effect is operating in the line-drawing situations.

In the experiment on the *tau*-movement effect, the subjects produced a shorter length when drawing a line slowly for a longer time than the reference length drawn at a faster speed for a shorter time. Further, they produced a longer length when drawing a line quickly for a shorter time than the reference length drawn at a slower speed for a longer time. From this, we may infer that if the lengths of two lines respectively are in fact drawn equally, that length will seem greater which is associated with the slower speed drawn for the longer time, and that length will seem shorter which is associated with the faster speed drawn for the shorter time. In other words, the *tau*-movement effect is operating in the line-drawing situations.

The *kappa*-and *tau*-movement effects have already been confirmed in situations of passive or active experience of movement as a passenger in a vehicle[13],

13. (Cohen & Cooper, 1962; 1963)

as a driver in a car[14], and when the subject is walking and running[15]. In all these situations, relatively gross intervals of time and distance were judged. In the present line-drawing experiments, the subjects judged relatively brief intervals of time and distance. Thus the *kappa-* and *tau-* movement effects have now been demonstrated to operate in comparatively brief and in comparatively gross intervals of time and distance, and under different movement conditions. It may be pointed out that there are a variety of structural conditions for the inclusion of movement in the *kappa-* and *tau-* types of situation, viz., active movement, passive movement, perceived movement (where the subject himself does not move) and apparent movement. Further, judgements (or productions) can be made of gross and brief intervals, and in different modalities.

Most of the evidence available points to the universality of these phenomena. The particular gap in the evidence which must await further research is a study of the interdependence of time, distance and perceived movement for brief intervals of time and distance analogous to the earlier laboratory studies of the *kappa-* and *tau-* effects[16].

6–1–2. *Dominant factors for the occurrence of the kappa-movement and tau-movement effects*

In the case of the *kappa*-movement condition, the differences between the fixed duration and the apparently equivalent duration increased as the differences between the speeds corresponding to these durations increased. By contrast, the differences between the durations did not appear to vary systematically with the differences between the lengths of line drawn. Speed, therefore, seems to be associated with the occurrence of the *kappa*-movement effect to a relatively greater extent than distance (see Table 23).

In the case of the *tau*-movement condition, the differences between the fixed

Table 23. Relationship between the magnitude of the *kappa-* and *tau-* movement effects and the apparent dominant factors for the occurrence of the effects (The combined corrected ratios of durations ($t'_2/t_1$) and lengths ($l'_2/l_1$) are shown in brackets for the *kappa*-movement conditions and *tau*-movement conditions respectively)

| Condition | Kappa-movement | | Tau-movement | |
|---|---|---|---|---|
| | Sighted | Blind | Sighted | Blind |
| Fast-Slow | Speed (1.1) | Speed (1.2) | Duration (0.9) | Unclear (0.9) |
| Slow-Fast | Speed (0.7) | Speed (0.9) | Speed (1.4) | Unclear (1.1) |

14. (Cohen, Ono & Skelly, 1966)
15. (Cohen, Cooper & Ono, 1963)
16. (Cohen, Hansel & Sylvester, 1953; 1955; Ono, 1960)

length and the apparently equivalent length increased as the differences between the speeds corresponding to these lengths increased, where the second speed is doubled (Table 23). On doubling, the differences between the distances did not appear to vary systematically with the differences between the durations of the two lines. But where the speed is halved, the magnitude of the differences between the distances seems to be more related to the differences between the corresponding durations. This relationship with duration in halving, however, is relatively less marked than the relationship observed with speed in the case of doubling. Thus, although the relationship with speed is less clear in the *tau*-movement condition than it is in the case of the *kappa*-movement condition, once more speed seems to play the more important role for the occurrence of the *tau*-movement effect.

6–1–3. *Comparison between the sighted and the blind*

We suggested that the *kappa*- and *tau*-movement effects would reveal themselves amongst the blind and sighted subjects, since the conditions involved real movement. On the whole our blind subjects support this hypothesis.

In both the *kappa*-movement and *tau*-movement conditions, the sighted subjects displayed more effects on doubling speed than they did on halving. The blind by contrast showed more marked effects on halving than on doubling. Between the sighted and the blind, the magnitude of the effects on halving were much the same. On doubling, the sighted subjects displayed the significantly greater *kappa*-movement and *tau*-movement effects than the blind. After all, therefore, the sighted and blind subjects alike betray the two effects, but both effects are less pronounced with the blind subjects (Table 23).

## 6–2. Explanation

6–2–1. *Role of movement*

Certain attempts have been made to explain the interdependence of apparent time and space. For the *tau*-effect, Helson and King[17] emphasized the physiological processes aroused by successive stimuli during a brief interval. They further suggested that the "care" or "attitude" of the subject could influence the appearance of the effect. Thus they supposed that the effect was more likely to occur if the subject concentrated on the points of stimulation on the skin. If the subject is distracted, then the effect is less likely to take place.

Cohen and his colleagues[18] emphasized "the primacy of discrimination of movement over sparate spatial or temporal discrimination" in discussing the background to the *kappa*-effect. Suto[19] implied that the tactile *kappa*-effect is directly connected with the visual image of stimulated points.

Both the *kappa*- and *tau*- effects manifest themsevles in a variety of situations,

17. (1931)
18. (1955)
19. (1955)

and not only under brief durations where some sort of physiological "interference" may take place. Furthermore, the general similarity of experimental conditions for the occurrence of the *kappa-* and *tau-* effects suggests that any explanation should in principle be equally applicable to either.

We are inclined to support an explanation based upon impression of movement. In everyday life movement is experienced not only through vision but also through other modalities, such as the tactile and kinaesthetic. Our sensory deduction from such accumulated experiences of movement may give rise to an impression of movement under certain external conditions. Our view is that an explanation of the *kappa*-effect in terms of impression of movement might be applicable to the *tau*-effect as well as directly to an account of the *kappa-* and *tau*-movement effects. Support for this outlook would be as follows.

First, the magnitude of the *kappa*-effect varies with direction of the visual display. This might be associated with everyday experience of seeing objects fall and rise[20]. Thus the magnitude of the *kappa*-effect in the downwards direction was reported to be greater than the magnitude in the upwards direction. This relationship between the magnitude of the *kappa*-effect and the direction of the visual display appears to be analogous to the temporal relation which holds between the causal impression that an object moves and the direction in which it moves[21]. The maximum temporal thresholds for the occurrence of this causal impression in the downwards direction is greater than those for the occurrence of the impression in the upwards direction.

Second, in an experiment on the visual *tau*-effect[22], apparent movement was often reported, but only by those subjects following the effect. The subjects exhibiting a negative or neural effect had no such impressions of apparent movement. This experiment was not specifically designed to examine this issue, and further experimentation is necessary to identify a clear relationship between the magnitude of the *tau*-effect (and *kappa*-effect) and the frequency of reports of apparent movement. Nevertheless, there are at least indications that apparent movement was associated with the occurrence of the effect where no real movement was involved.

Thirdly, from the present experiments in drawing a line where real movement takes place, speed seems to be relatively more responsible than either distance or duration for the occurrence of the *kappa-* or *tau-* movement effect. Thus we may conclude that the discrimination of speed of real movement is the more important cue for the *kappa-* and *tau-* movement effects than is the discrimination of spatio-temporal intervals. In the *kappa*-movement condition a faster speed, in general, creates apparently longer duration. In the *tau*-movement condition a slower speed, in general, creates apparently longer distance.

20. (Cohen, Hansel & Sylvester, 1955)
21. (Ono, 1963)
22. (Ono, 1960)

Fourthly, our blind subjects betrayed the *kappa-* and *tau-* movement effects, unlike Suto's blind subjects who did not show the *kappa*-effect in touch. Hence we may infer that the presence of the *kappa-* and *tau-* movement effects in the blind subjects might depend upon the experience or otherwise of real movement. The fact that the *kappa-* and *tau-* movement effects were more marked amongst the sighted in our line-drawing experiments may suggest a subsidiary role of visual experience for the effects.

Thus experience of movement would seem to be applicable, as an explanation, to the *kappa-* and *tau-* effects as well as to the *kappa-* and *tau-* movement effects. At the same time as placing an emphasis upon movement, either real or imaginary, it is clear that we must take account of spatial factors in the case of the *kappa*-effect, and of temporal factors in the case of the *tau-* effect. Our conclusion is that speed may be responsible for the magnitude of the *kappa-* and *tau-* movement effects, and that the spatial and temporal factors may be responsible for the direction or "quality" of the *kappa-* and *tau-* movement effects, respectively.

6–2–2. *Role of individual tempo*

In the study of the *tau*-movement effect when walking and running[23], it was emphasized that the effect does not always appear in the same direction for different individuals. A partial explanation for these individual variations was offered in terms of sensitivity to the passage of time. Thus those who are relatively more sensitive to temporal differences follow the *tau-* movement effect (Hare), and those who are relatively less sensitive to the passage of time follow the anti-*tau-* movement effect (Tortoise). The question was left as to whether these type differences are fated or specific to the experimental circumstances of walking and running.

In the present study of the *kappa-* and *tau-* movement effects in drawing a line, those who show a positive or negative effect under one experimental condition do not necessarily show the effects in the same direction under another experimental condition. Thus as far as the sighted subjects are concerned, the majority of the responses of the subjects on halving speed, about 60 per cent in the case of *kappa*-movement, and 70 per cent in the case of *tau*-movement are positive. In the case of doubling, the vast majority, almost 100 per cent (*kappa*-movement) and 80 per cent (*tau*-movement) show the positive *kappa*-and *tau*-movement effects. Some of the anti-*kappa-* and anti-*tau-* movement persons in the halving conditions are transformed to the pro-*kappa-* and pro-*tau-* states when doubling.

Secondly, the proportion of the responses following the *kappa-* and *tau-* movement effects is somewhat different amongst the blind in relation to the experimental conditions. Thus 70 per cent of the responses follow the *kappa-* and *tau*-movement effects on halving speed. In doubling, the proportion is still 70 per cent

23. (Cohen, Cooper & Ono, 1963)

for the *kappa*-movement, but is 50 per cent for the *tau*-movement conditions. The experimental conditions of halving and doubling appear to have an inverse influence on the occurrence of the *kappa*- and *tau*- movement effects amongst the sighted compared with the blind. These differences between the sighted and the blind may be related to metabolism and *tempo*. A comparative study of personal *tempo* on the sighted and blind[24] suggests that it is rather difficult for the blind to keep up constancy of their mental *tempo*.

We may conclude that the *kappa*- and *tau*-movement effects are statistical in that the majority of people follows them, but the minority displays the effects in the inverse direction. Individual *tempo* or metabolism which may differ between the sighted and the blind also varies between individuals, and may be partly responsible for the statistical difference found. It is clear, however, that the responses are also very much linked to the experimental conditions under which judgements are made.

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24. (Mishima, 1965)

## Resumé

Les effects des *kappa*- et *tau*- mouvements ont été prouvés les situations de tirer laligne. 133 sujets (dont 98 sont les voyants et 35 les aveugles) ont pris part à deux groupes d'expériences. Dans l'expérience de l'effet du *kappa*-mouvement, la tâche des sjuets a été de tirer la deuxième ligne pendant une durée du temps qui semblait être la même durée que celle qui a été employée pour tirer la remière ligne. Dans l'expérience de l'effet du *tau*-mouvement, les sujets ont produit une longueur qui semblait être la même longueur que celle premier.

Les conclusions suivates ont été tirées: (1) Dans le cas où les durées du temps de tirer deux lignes sont en réalité égaux respectivement, une durée qui correspond à une ligne plus longue tirée à vitesse plus rapide (l'effet du *kappa*-mouvement); (2) Dans le cas où les deux lignes aux longueurs égales en réaltié sont tirées respectivement, la longueur d' une ligne qui est tirée à une vitesse moins rapide pour une durée du temps plus longue parait plus longue (l'effet du *tau*-mouvement); (3) Les sujets aveugles ont trahi les effets des *kappa*- et *tau*- mouvements tous les deux, mais ces effets ont été plus clairement marquis parmi les voyants; (4)Les effets sonts statistiques au point de vue qu'ils n'apparaissent pas aux tous les sujets dans tous les conditions; (5) La vitesse semble être relative plus responsable que soit distance, soit durée à la naissance de l'effet du *kappa*- ou *tau*- mouvement; (6) Il est suggéré que l'expérience du mouvement est applciable, comme un pricipe d'explication, aux effets de *kappa* et *tau* de la même manière que les effets des *kappa*- et *tau*- mouvements; (7) La preuve positive des effets des *kappa*-et *tau*- mouvements vis à vis des conditions manuelles de mouvement employés augmente une evidence davantage à la universalité de la phénomène de relativité psychologique.

## Zusammenfassung

Die *kappa*- und *tau*- Bewegungseffekte wurden in der Situation des Linienziehens bestätigt. 133 Versuchspersonen (98 gesunde und 35 blinde) nahmen an zwei Arten des Versuchs teil. Hier in dem *kappa*-bewegungsexperiment beschäftigten sich die Versuchspersonen damit, die zweite Linie in derselben Zeitdauer zu ziehen, die erforderlich gewesen zu sein schien, die erste Linie zu ziehen. In dem Versuch des *tau*-bewegungseffektes zogen die Versuchspersonen die Linien, die ihnen ebenso lang wie die ersten schienen.

Daraus wurde die folgende Schlussfolgerung gezogen: (1) Wenn die Zeitdauer, zwei Linien zu ziehen, ganz gleich ist, wird die Zeitdauer länger zu sein scheinen, die mit der längeren mit der grösseren Schnelligkeit gezogenen Linie verbunden ist (der *kappa*-bewegungseffekt). (2) Wenn die zwei Linien in der Länge ganz gleich sind, wird die Länge der Linie noch grösser scheinen, die mit der kleineren Schnelligkeit in der längeren Zeitdauer gezogen wird. (3) Die blinden Personen zeigten beide Effekte der *kappa*- und *tau*-bewegung. Aber die beiden Effekte wurden unter den gesunden Personen klarer gemerkt. (4) Die beiden Effekte sind in dem Sinne statistisch, daß sie nicht bei allen Personen und unter allen Bedingungen erscheinen. (5) In der Hervorbringung des *kappa*- und *tau*-bewegungseffektes scheint die Schnelligkeit eine relativ gössere Rolle als die Länge oder die Zeitdauer zu spielen. (6) Es ist angedeutet, daß die Erfahrung der Bewegung als ein Erklärungsprinzip sowohl auf den *kappa*- und *tau*-effect wie auf den *kappa*- und *tau*-bewegungseffekt angewendet werden kann. (7) Die Bestätigung des *kappa*- und *tau*-bewegungseffektes für die hier aufgenommenen Bedingungen der Hände fügt eine bedeutendere Evidenz zu der Allgemeinheit der Erscheinung der psychologischen Relativität hinzu.

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