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The vertical-horizontal illusion in the tactual modality.

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THE VERTICAL-HORIZONTAL ILLUSION IN THE TACTUAL MODALITY

by

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A B S T R A C T

This study was an exploratory investigation of the Vertical-Horizontal Illusion in the tactual modality. A series of three experiments were carried out in which three aspects of this problem were examined. First, is there an illusion in this modality which is complementary to the one found in the visual modality? Second, by what method and procedures can this problem be examined? Lastly, what is the nature and magnitude of the side effects encountered in such a study?

The experimental subjects (Ss) were right-handed males. In Experiments I and II, S was asked to compare lengths of lines at 0, 30, 60, 90 and 120 degrees with a horizontal standard. Method of Constant Stimuli was employed in the former and Method of Limits in the latter. Experiment III was designed to measure the time-order error and the position effect occurring in I and II.

Analysis of variance and the Newman-Kuels test showed statistically significant evidence that -

1. Subjective length of a line changes with the angle of that line.
2. An illusory effect similar to the Vertical-Horizontal Illusion is found in the tactual modality for the angles selected in this study.

P R E F A C E

This investigation is the product of the author's combined interest in illusions and the question of cross-modal perception. The works of R. L. Reid, Edith Hatwell and Theodore Kunnapas contributed much to the general framework of this study.

The author is indebted to Dr. A. Arthur Smith for his advice, direction and apparatus design and he wishes to thank the subjects who contributed so willingly their time and efforts.

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CHAPTER I

INTRODUCTION

The Vertical-Horizontal Illusion in the visual modality has been known for more than a century. Fick in 1851 observed that a bright square on a dark ground looks like a vertical oblong (Kunnapas, 1955). Wundt in 1862 reported the tendency to over-estimate a vertical line as compared to a horizontal line (Kunnapas, 1955). Finger and Spelt (1948) and Kunnapas (1957) provide clear evidence for this illusion. Indeed so well established is the effect that it can be (and often is) used as a standard experiment in introductory laboratories.

Shipley, Nann and Penfield (1949) and Pollock and Chapanis (1952) discovered a greater illusory effect with lines at angles of 120 and 300 degrees. They reported that those lines were perceived as longer than vertical lines of equal physical length. Angles were defined in reference to standard geometrical coordinates with a zero degree line extending from the center of the plane horizontally to the right. The other angles were obtained by counter-clockwise rotation from zero degrees.

The influence of sex and age on the visual illusion were studied by Fraisse and Vantrey (1955). With tachistoscopic presentation, they found a greater illusory effect in women when given an unlimited exposure time. With shorter exposure times, lasting from 0.2 to 1.0 seconds, no difference was found between men and women. No conclusion about the overall effects of age

was made. It appeared to vary with the specific conditions of presentation.

Sleight and Austin (1952) investigated the Vertical-Horizontal Illusion in plain geometric figures. They found that a one inch square was often judged to be a rectangle with the major dimension vertical. In three of eight subjects the illusion was reversed under these conditions. One subject showed no illusion, and the remaining four maintained the usual illusory effect. It was concluded that the effect on the illusion when set in geometric figures varied between subjects and could not be said to hold arbitrarily.

Much work has been done on the visual illusion by Kunnapas (1957). First, he found that over-estimation of a line depends on the distance of the line from the boundary of the visual field. The shorter this distance is, the greater the subjective length of the line becomes. He then asserted that vertical direction as compared to horizontal direction is over-estimated because the retinal visual field has the shape of an oval extended in the horizontal direction. He tested the illusion in complete darkness with an illuminated set of lines. He observed a 30 per cent reduction in the size of the illusion as compared with ordinary lighting conditions. He also found interocular differences in the illusion which he attributed to the shape of the monocular visual fields.

To date there has been one study of the Vertical-Horizontal Illusion using stylus movement. Reid (1954) had 12 blindfolded

subjects move a stylus toward and away from and across the body. He instructed them to move the stylus a fixed distance in one direction. Then the subject was told to move the stylus what he judged to be an equal distance, but at right angles to his first movement. He observed that movement toward and away from the body was judged equal to across the body movement when the former was physically shorter. He assumed that toward and away movement was equivalent to up and down movement and concluded an illusion of movement existed complementary to the Vertical-Horizontal Illusion. In the present study, no assumption of "equivalence" is made. True vertical movement is tested.

One study of the illusion has been carried out in the tactual modality by Hatwell (1960). She used ten blind, right-handed subjects. They were tested on the L-shaped figure with the horizontal line constant at 31 millimeters. Each line consisted of a series of Braille perforations. Hatwell did not find a significant illusory effect under these conditions. However, there is doubt as to the validity of these findings due to the fact that when horizontal equalled vertical physically, the number of perforations in each line were equal. In addition, these perforations were equally spaced throughout. Thus, the subject had the opportunity to give an estimation on the basis of counting the dots instead of estimating one continuous length. The use of blind subjects introduces the possible practice effect with Braille which was not accounted for by Hatwell.

The aim of the present study is to examine the illusion in the tactual modality, to look at some of the alternatives available in measuring it, and finally, to assess some of the side effects related to the modality.

C H A P T E R II

The Preliminary Investigation

A pilot study using the Method of Limits was conducted to estimate the influence of using rough or smooth lines, thick or thin lines, and the effect of order of stimulus presentation. The differences found between rough and smooth lines and between thick and thin lines were so small that they are considered insignificant in this study. Order of presentation was found to be a significant factor. The second stimulus tended to be judged equal to the first when it was physically shorter. In order to eliminate the time error, in the main study, an indirect method was employed, in which lines at various orientations were compared, not directly one with another, but by reference to an external standard, which was horizontal.

CHAPTER III

Apparatus for the Main Study

The apparatus is shown in front and side view in Figs. 1 and 2. A 19 x 19 inch steel panel was mounted upright in a steel frame. The standard and comparison lines were defined by steel rods 5/32 inch in diameter. The lengths of these lines were determined by two brass stops, one at each end of the rod. These were beveled back 1/16 inch so that S could feel the entire distance of the line by feeling that segment of the rod between the two stops. The stops could be moved along the rod in either direction and were fixed at any desired point by means of a set screw.

Two metal frames were bolted into the panel, 1-1/2 inches from the bottom and equidistant from each side. The standard stimulus rod was inserted through the frames so as to be parallel with the steel panel and 3/4 inch from it. See Fig. 1. The rod position was fixed by two brass fittings screwed tightly against it and the metal frames.

The comparison stimulus rod rotated about an axis 9-1/4 inches above the standard. It was fastened to a steel shaft and two 2-1/2 inch mounting plates by a series of brass fittings. The axis shaft was inserted through a hole in the panel. One mounting plate was placed in front of the panel and the other one in back. A compression spring was located on the shaft between the panel and the back or compression plate. This helped to hold the assembly in place. The comparison rod was mounted in front of

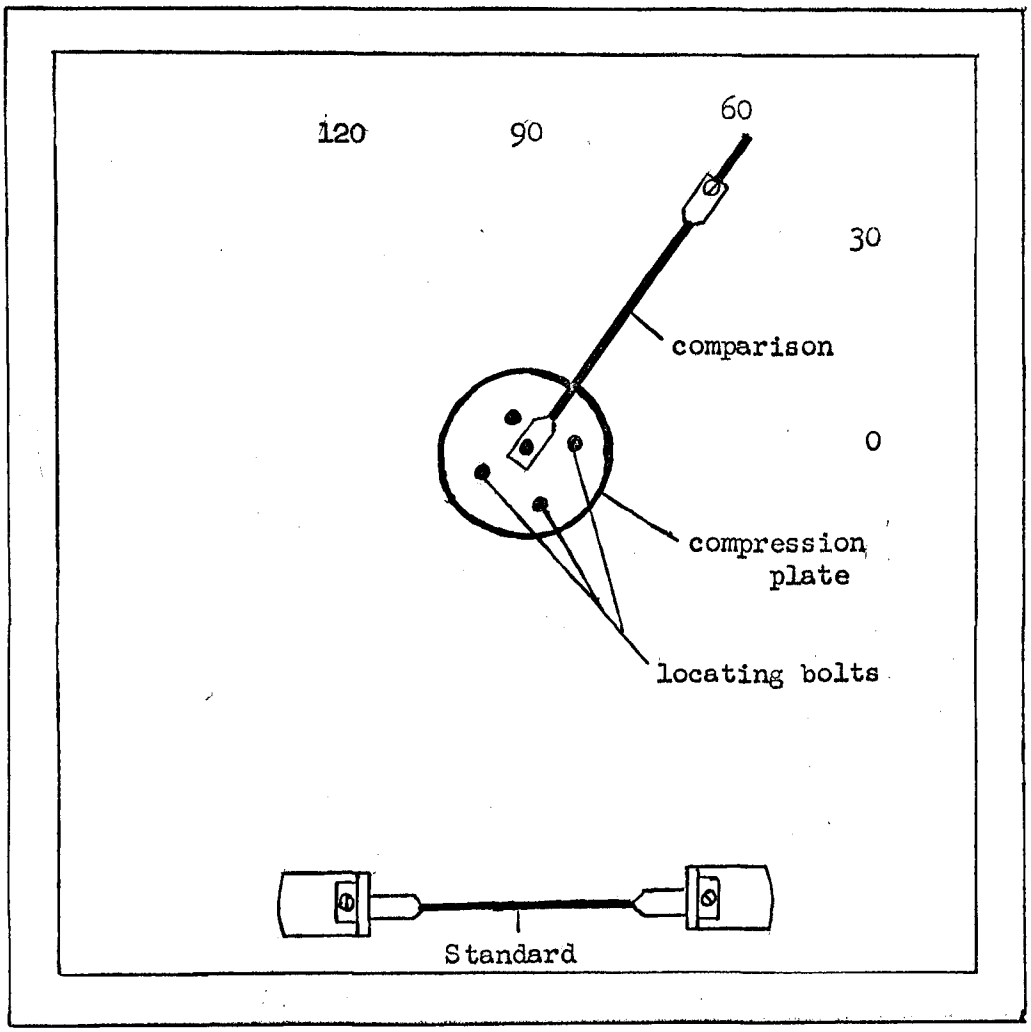

FIGURE 1 - FRONT VIEW OF APPARATUS

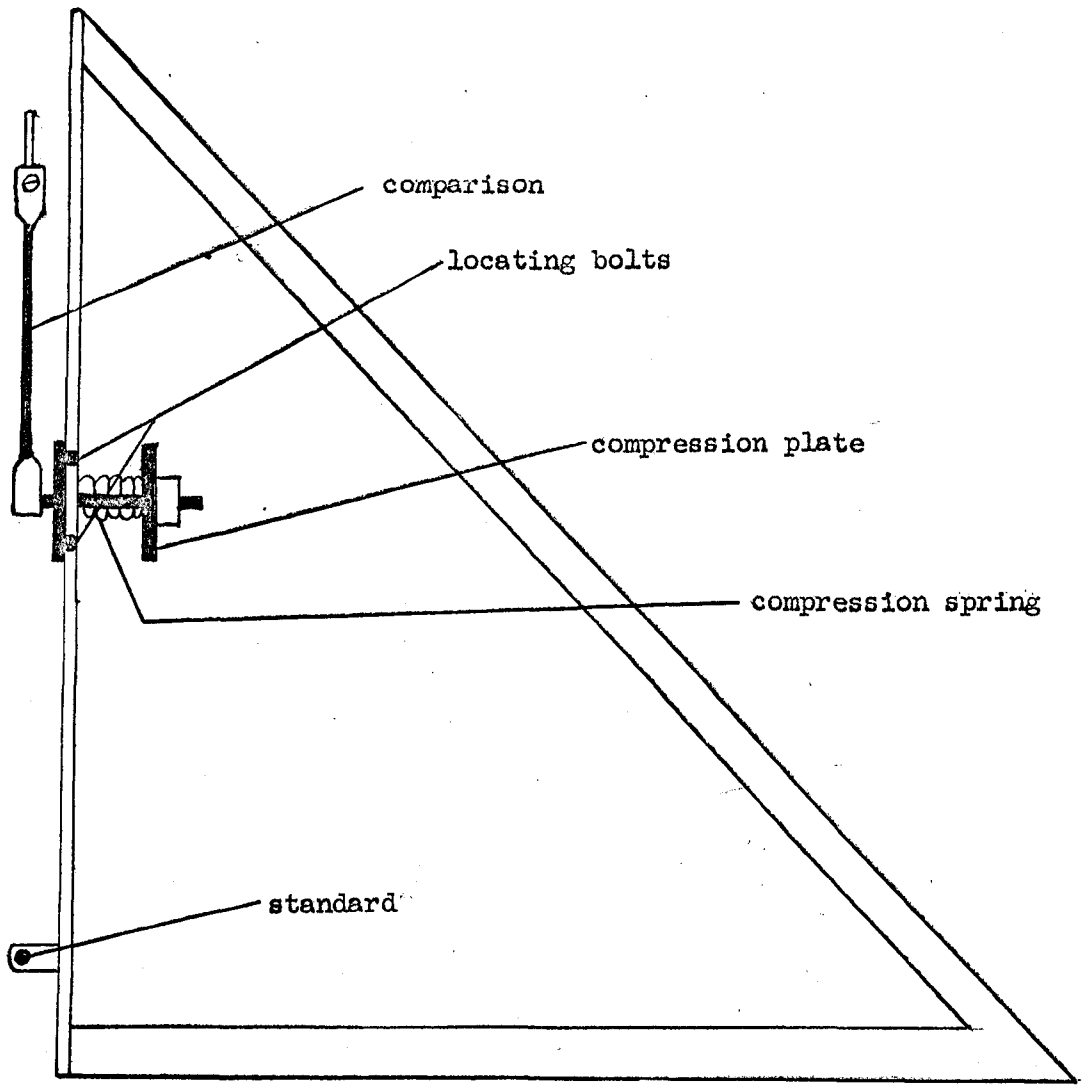

Fig. 2. - SIDE VIEW OF APPARATUS

the panel at a right angle to the shaft, parallel to the panel and 3/4 inch from it.

Four bolts with 5/32 inch round heads were fastened to the front plate with the heads facing the panel. These locating bolts mated with holes of the same diameter drilled in the panel. These holes, 12 in number, were arranged in a circle, each one being one inch from the centre shaft hole and drilled every 30 degrees. This arrangement, combined with the compression spring action facilitated quick change of angle of the comparison stimulus for 0, 30, 60, 90 and 120 degrees.

The standard stimulus rod was set at 4.5 inches and remained constant for all three experiments. For Experiment I the comparison rod had seven length settings marked for 4.2, 4.3, 4.4, 4.5, 4.6, 4.7 and 4.8 inches. These markings were placed on the rod beyond the brass stop. The stop extended along the rod far enough such that S would never feel the markings. In Experiments II and III a rod with no markings was used.

This apparatus was set on a table 30 inches high and S was seated in a high back chair with a seat level of 17-1/2 inches. A standard tape measure with readings to 1/16 inch was used. A cloth shoulder strap and two blindfolds were provided. One of the latter was a standard black cloth and the other was a pair of plastic goggles with the lens painted white.

All experiments were performed in a room with normal lighting conditions and responses were recorded by the experimenter (E). See Appendix A.

CHAPTER IV

EXPERIMENT I

Subjects: The Ss were four adult right-handed male students from the University of Windsor, Windsor, Ontario. All Ss were within average range of height and arm length and all Ss were sighted.

Method: S put on the blindfold of his choice and was seated in front of the apparatus at a distance of 24 inches. S's shoulder was strapped to the back of the chair to keep his position constant. He was instructed to trace the standard and then the comparison with his right forefinger and report whether the comparison was longer or shorter than the standard. For instructions see Appendix B1.

A Method of Constant Stimuli was used in which there were seven settings of length for each of the five angles giving 35 different comparison stimulus settings presented in random order. The randomizing was achieved by shuffling a deck of 35 cards and recording their order. This was done for each series of presentations prior to the experimental session. This series of 35 settings was repeated ten times for each S. Each of his judgments was recorded by E. The complete test was split into two sessions of approximately 45 to 55 minutes.

An analysis of variance with repeated measures over the last two factors was performed on the number of longer judgments obtained. The main effects were subjects, length of setting and angle of comparison.

Results: On the basis of number of "longer" judgments points of subjective equality (P.S.E.'s)[1] could not be calculated within designated lengths for all five angles. This was due to the fact that some Ss gave 90 per cent "longer" judgments at 120 degrees and 10 per cent "longer" judgments at 0 or 30 degrees on the comparison stimulus. Therefore, it was more appropriate to carry out an analysis of variance based on the number of "longer" judgments given for each setting at each angle. The results are shown in Table 1.

T A B L E 1

Analysis of Variance for Number of "Longer" Judgments for Each Angle at Each Length

Source	SS	df	MS	F
Total	1029.9350	139		
Between Subjects	26.0779	3		
Within Subjects	1003.8571	136		
Lengths	254.5850	6	42.4308	10.78*
Lengths X Subject (error)	71.8721	18	3.9373	
Angles	216.9707	4	54.2427	1.80
Angles X Subjects (error)	362.1721	12	30.1810	
Lengths & Angles	41.1293	24	1.7137	2.16*
Lengths X Angles X Subjects (error)	57.2179	72	.7947	

* - Significant at the .05 level.[2]

The significant length effect here is, of course trivial. It means simply that the longer the comparison stimulus, the more often is it judged longer than the standard. Only the significant interaction between length and angle is pertinent to the present investigation. This interaction effect is shown graphically in Fig. 3.

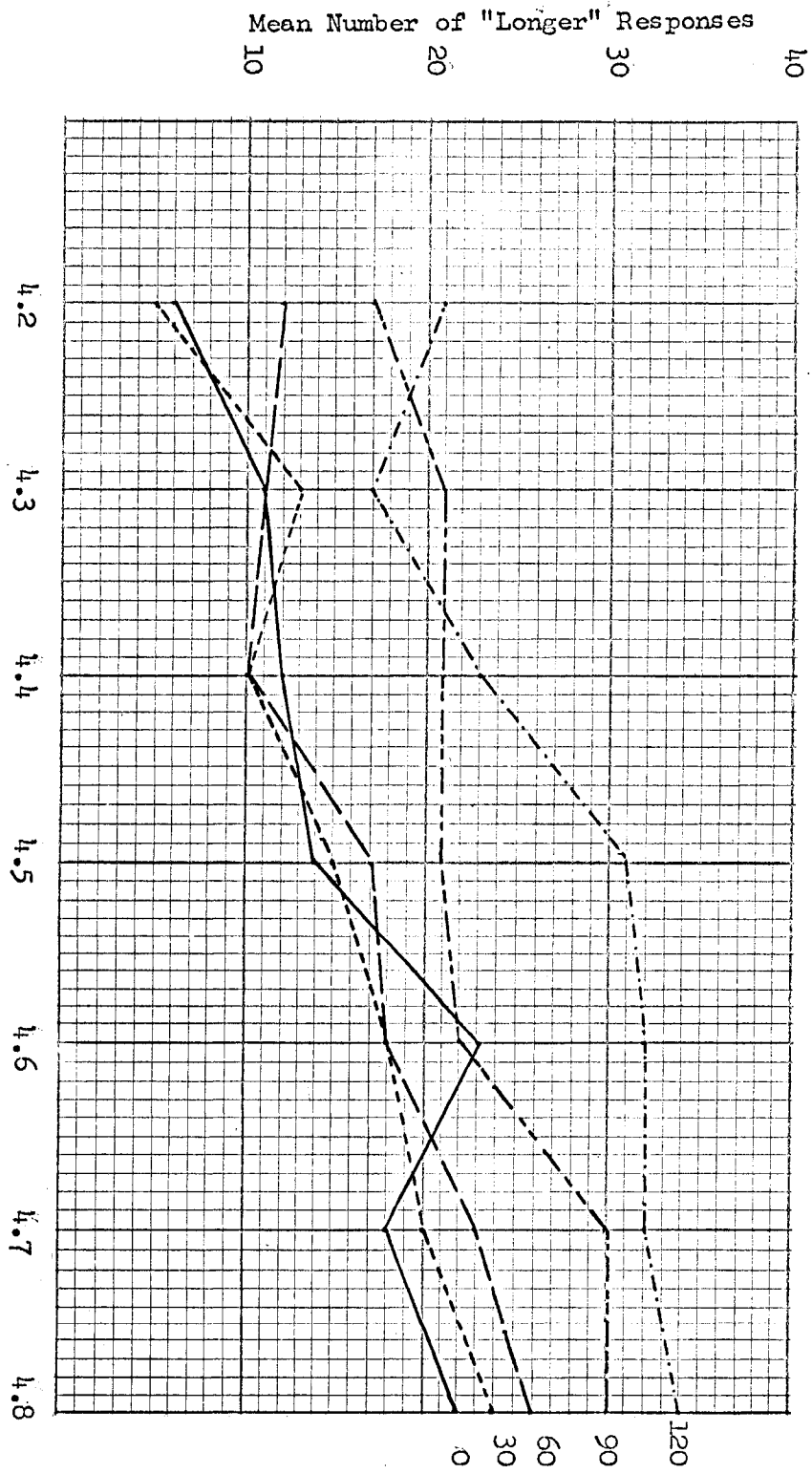

Fig. 3. Group Plot of average number of "longer" Responses for each

Here, it appears that the curves for the smaller angles (0^{o}, 30^{o}, 60^{o}) are essentially the same. They differ noticeably from that of 120 degrees, with the 90 degree curve being intermediate.

Accordingly, the effect of angle on number of larger judgments when comparison and standard rods were physically equal was examined separately. An analysis of variance was performed on the data with the results given in Table 2.

TABLE 2

Analysis of Variance for Each Angle and All Subjects at Comparison Equals 4.5 Inches

Source	SS	df	MS	F
Total	80.55	19		
Between Subjects	22.95	3		
Within Subjects	57.6	16		
Angle	49.3	4	12.425	17.95*
Residual	8.3	12	.6917	

* - Significant at the .05 level.

There is an obvious overall angle effect. This was examined more closely by the Newman-Keuls procedure comparing each angle with every other one. This test was selected because of its combined discriminative and reliability properties (Winer, 1962, p.114). Table 3 shows the pattern that results.

TABLE 3

Newman-Keuls Test for Comparison of Individual Pairs of Angles

Angles	0	30	60	90	120
0	-	-	-	*	*
30		-	-	-	*
60			-	-	*
90				-	*
120					-

* - These comparisons are significant at .05 level

It is clear that more "longer" judgments were given at the 120 degree setting than for any other position. The same holds for vertical (90) compared to horizontal (0). No marked difference appeared between 9, 30 and 60 degrees.

Conclusion: It is apparent from the above results that a vertical-horizontal illusion obtains in the tactual modality, with over-estimation of vertical lengths in comparison with horizontals. However, no measure of the magnitude of this illusion can be obtained from the above data since it is not possible to calculate P.S.E.'s. Also, preponderance of shorter judgments when both

standard and comparison stimuli are horizontal (even with the comparison 0.3 inch longer) raises an additional problem. Since comparison was always judged second in this experiment, the effect may be nothing more than the well-known time-error. However, in addition to being judged later, the comparison was above and slightly to the right of the standard. This requires a different position of the arm, and if judgment is dependent on kinesthetic feedback or muscular effort, there may be a "position" error rather than (or along with) a "time" error.

To settle these points, two additional experiments were carried out, using the Method of Limits.

One of these was to measure the magnitude of the illusory effect of angles, and the other was to separate the time from position effects.

CHAPTER V

EXPERIMENT II

Subjects: The Ss were six adult right-handed male students from the University of Windsor, Windsor, Ontario. All Ss were within average range of height and arm length and all Ss were sighted.

Method: S was situated and given the same instructions as in Experiment I. In this experiment, a Method of Limits was used in which E kept the comparison stimulus at one angle for an increasing and decreasing series of length settings. First, the comparison stimulus was set obviously shorter than the standard and moved out in small increments for each trial until S changed his judgment from "shorter" to "longer." The length of this setting was then measured by tape and recorded. The comparison was then set obviously longer and moved in in small increments for each trial until S changed his judgment from "longer" to "shorter." This length was measured and recorded in the same manner. Next, E set the comparison at another angle. This procedure was repeated ten times for each angle. The order of angle setting was randomized in the same way as in Experiment I. The test for S took two sessions lasting approximately 55 to 65 minutes.

From the data, the interval of uncertainty,[3] just noticeable difference (j.n.d.)[4] point of subjective equality (P.S.E.)[5] and constant error (C.E.)[6] were calculated for each S at each angle.

An analysis of variance was performed on the P.S.E.'s. The main effect was angle of comparison stimulus.

Results: The P.S.E.'s, j.n.d.'s and C.E.'s were calculated for each S at each angle, and from these group averages were obtained for each angle. Figure 4 is a plot of group C.E.'s and j.n.d.'s as a function of angle.

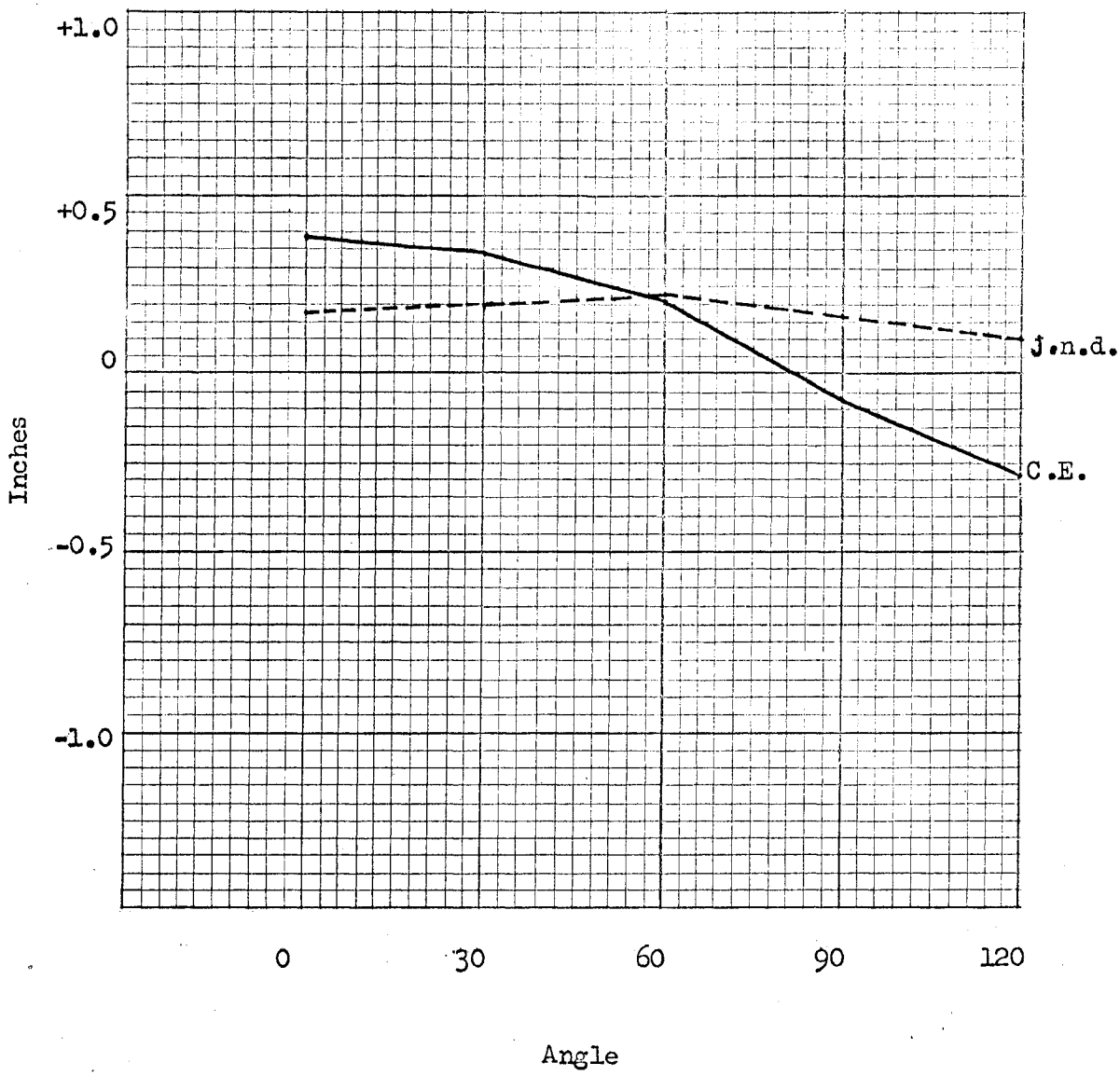

Fig. 4. Group j.n.d. and C.E. at each angle for comparison stimulus.

The greater shifts in C.E. were from 60 to 90 and from 90 to 120 degrees as found in Experiment I. From comparing j.n.d.'s and C.E., there is no apparent relationship between size of j.n.d. and size of C.E. This same conclusion applies to comparison of j.n.d. and P.S.E.

Finally, it is noted that under-estimation of the comparison occurred when comparison of 0, 30 and 60 degree angles was made.

The significance of the results are assessed by the analysis of variance shown in Table 4.

TABLE 4

Analysis of Variance for Average P.S.E. as a Function of Angle Setting

Source	SS	df	F
Total	14.766418	29	
Subjects	12.444554	5	
Within Subjects	2.312864	24	
Angles	2.016985	4	3.31*
Angles X Subjects (error)	.304879	20	

* - Significant at the .05 level.

A Newman-Keuls procedure was used to test the differences between individual means for angles. The results are given in Table 5.

TABLE 5

Newman-Keuls Test for Comparison of
Individual Pairs of Means over Angles

Angles	120	90	60	30	0
120	-	*	*	*	*
90		-	*	*	*
60			-	*	*
30				-	-
0					-

* - These comparisons are significant at the .05 level

The comparisons were found to be significantly different with one exception. No significant difference was found between the average P.S.E.'s of 0 and 30 degrees.

Conclusion: The results stated here confirm the angle effect found in Experiment I. Vertical and 120 degree lines are physically shorter than a horizontal line when both are judged equal to an external standard. Also, the comparison stimulus set at horizontal is under-estimated with reference to the horizontal standard as indicated in Fig. 4. This is the same effect observed in Experiment I and it was examined in Experiment III.

CHAPTER VI

EXPERIMENT III

Subjects: The Ss were four adult right-handed male students from the University of Windsor, Windsor, Ontario. All Ss were within average range of height and arm length and all Ss were sighted.

Method: S was situated in the same manner as the previous two experiments. His instructions differed in one regard. He was told to trace the standard first on half of his trials and the comparison stimulus first on the other half of the trials. See Appendix B2. Only two angle settings were employed for the comparison, 0 and 90 degrees. The four combinations of stimulus order and angle setting were given to all Ss with one increasing and one decreasing series of lengths for Method of Limits at each of the four conditions. Recording procedure was identical to that used in Experiment II.

The interval of uncertainty, j.n.d. and P.S.E. were calculated for each S under each condition. A 2 x 2 x 4 factorial analysis of variance was performed on the P.S.E.'s with the main effects being order and angle.

Results: The P.S.E.'s, j.n.d.'s and C.E.'s were calculated for the four Ss for both angles and both orders of presentation. Order I was defined as standard followed by comparison. Order II was defined as comparison followed by standard. The results are presented in Fig. 5, and tested for significance as shown in Table 6.

TABLE 6

Analysis of Variance for Angle of Comparison and Order of Stimulus Presentation

Source	SS	df	MS	F
Total	1.57036	15		
Between Subjects	.26013	3		
Within Subjects	1.31023	12		
Angles	.73050	1	.73050	13.29*
Angles X Subjects (error)	.16495	3	.05498	
Order	.12034	1	.12034	2.23
Order X Subjects (error)	.16165	3	.05388	
Angles X Order	.00563	1	.00563	.13
Angles X Order X Subjects (error)	.12716	3	.042386	

* - Significant at the .05 level.

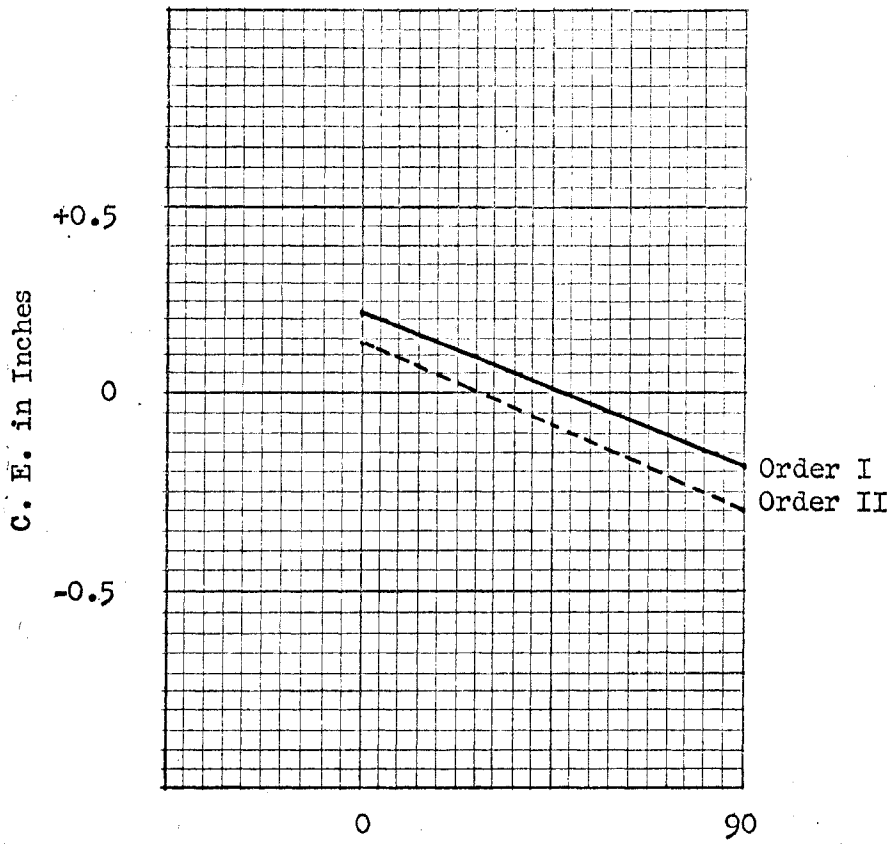

Fig. 5 C.E.'s for Order I and Order II as a function of angle.

Conclusion: The difference between horizontal and vertical is again significant, with the zero degree setting physically longer than the vertical when both are compared with the horizontal standard. No significant effect of order of presentation of comparison and standard is detected, either in the main or in interaction with the angle effect.

CHAPTER VII

DISCUSSION

Relevance to Previous Research

An illusory effect in the tactual modality is found to be similar to the one found in the visual modality for the angles selected in this study. These findings are consistent with those of Reid (1954) and contrary to those of Hatwell (1960). The present study differs from the previous works in two ways. An external standard was used and all judgments were made with reference to this standard which remained horizontal. This permitted direct comparison of all angles free from possible time-order error. This was a decided advantage over previous studies. However, it should be noted that only one set of movements were employed by S in the present study. S always moved from left to right on the standard and from axis-out on comparison. Reid and Hatwell both employed other sets of movements as well.

A significant difference was found between the P.S.E.'s of 90 and 120 degrees in Experiment II. The 120 degree line was consistently shorter than the 90 degree line when they were judged equal to the standard. This resembles the findings of Pollock and Chapanis (1952) and Shipley, Nann and Penfield (1949) for the visual modality, who reported that a line of 120 degrees was perceived as longer than a vertical line of equal physical length. In the visual modality, it has been determined that the maximum illusory effect obtains at 120 and 300 degrees. The angle at which

this occurs in the tactual modality is not known. Further tests with a sufficient selection of angles are required in order to locate this maximum.

The exact mechanism of this effect remains obscure. In the visual modality it may be suggested that the over-estimation of the vertical and no degree lines is based on a smaller size of the j.n.d. for vertical than for horizontal extensions. That is, if a Fechnerian psychophysics is adopted, the same physical length will contain more j.n.d.'s when vertical, and therefore, will be judged longer. In the present study (and in Experiment II in particular), if the j.n.d. measures can be treated as representative of the average j.n.d., there appears to be no evidence for change in size of j.n.d. with angle. Therefore, an account at the tactual illusion in these terms does not appear to be justified.

Suggestions for Further Research

Although the group data for Experiment II was significant, one S showed no real illusory effect. He did show a shift in P.S.E. from 90 to 120 degrees similar to that found between 60 and 90 degrees in the other Ss. Individual differences in curves of Ss may be related to subjective perception of horizontal and vertical. One could test for this by allowing S to define vertical and horizontal and assigning the intermediate angles according to each subjective perception of vertical and horizontal. If this does play a role, it would tend to minimize the differences between individual curves.

A number of questions can be raised in connection with the work of Werner and Wapner (1951) and (1952) on perceived verticality.

They found that,with left and right tilts of the body and the head, visual and kinesthetic perception of the vertical changes. It will be interesting to investigate the behaviour of this tactual illusion under conditions of various body tilts and slants of the visual field. For instance, what are the effects on the visual and tactual illusions when the body is tilted in either direction? What happens when the visual field is tilted? Are these effects complementary?

Another cross-modality check can be run on the illusion by testing Ss blind from birth. If the tactual illusion obtains in the same magnitude for these Ss as for sighted Ss, it may be suggested that this is the more primary illusion and that the visual one may be secondary and a result of feedback from the tactual one. Ideally, confirmation of this hypothesis could be accomplished by testing persons receiving sight some time after birth.

A more practical check would involve examination of the practice effect obtained with training in each modality. Two matched groups of Ss are tested in both modalities. One group is given practice in the visual modality and the other in the tactual for the same number of trials. Then each group is tested in the other modality and rated for degree of reduction of the illusion by comparing this last set of scores with those of the initial tests.

An indication of the power of the illusion may be tested by making S aware that an illusion exists and then measuring the effect of his judgments. Some indication of this was given by an S in Experiment I. See Appendix C for S's reactions.

Possible relations of illusory effect to age and sex as found in the visual modality by Fraisse and Vautrey (1955) may be examined by simple selection of groups for testing.

Gravitational force may play a major role in the illusion. This may be shown by testing Ss under zero gravity conditions such as obtained in a space craft.

If the tactual illusion is related to direction of movement made by S, tests run on left-handed Ss should produce a reversal from that found in the right-handed Ss.

There is a further possibility that the illusion is a function of amount of work done by the muscles involved and the time taken to perform this work. This may be studied by using electromyograph (EMG) recordings. Since level of EMG recordings is in part dependent upon individual strength of S, a co-variance adjustment is needed in any comparisons made. The appropriate adjustment may be determined by recording potentials for each S while he moves a weighted object in different directions.

Research in this area should provide some insight into tactual and kinesthetic perception of space. Also, it may assist in discovering possible types of feedback and coordination between the sense modalities. Finally, it may facilitate formulation of some predictions concerning perceptual processes in space flight where zero gravity conditions obtain.

APPENDIX A

1. Data Sheet for Experiment I with longer (L) and shorter (S) judgments recorded.

Length / Angle	0	30	60	90	120
4.2	S(9)*	S(14)	S(12)	L(28)	L(27)
4.3	S(26)	S(15)	L(22)	S(13)	L(34)
4.4	S(29)	S(10)	S(30)	L(2)	L(16)
4.5	S(18)	S(17)	S(31)	S(5)	L(3)
4.6	S(20)	S(32)	L(35)	L(21)	S(6)
4.7	S(8)	S(1)	S(33)	L(7)	L(19)
4.8	S(11)	S(25)	S(4)	L(24)	L(23)

* - Stimulus order in parentheses.

APPENDIX A

2. Data Sheet for Experiment II

	ANGLE				
	0	30	60	90	120
Out	4-5/8 (6)*	5-1/16 (1)	4-9/16 (2)	4-5/16 (4)	3-13/16 (3)
In	4-9/16	5	4-5/8	4-1/2	4-1/4
Out	5-7/16 (9)	5-1/4 (7)	4-3/4 (5)	4-9/16 (8)	4-1/2 (10)
In	4-3/4	4-3/4	4-1/4	4-5/8	4-3/8

* - Sequential order is given in parentheses.

APPENDIX A

3. Data Sheet for Experiment III with longer (L) and shorter (S) judgments recorded.

Order I		Order II	
St - H (4)*	St - V (3)	H - St (2)	V - St (1)
S-E 4-1/16	3-3/4	4-1/16	3-5/8
E-L 4-5/8	4-9/16	4-1/2	4-1/8
L-E 5-3/16	4-1/16	4-1/4	3-5/8
E-L 4-3/4	3-5/8	4-3/4	3-15/16

* - Sequential order is given in parentheses.

H = horizontal comparison

V = vertical comparison

St= standard.

APPENDIX B

1. Instructions to S for Experiments I and II.

In front of you are two lines. The lower one is horizontal and the upper one varies in angle. I will place your forefinger on both (S's forefinger is run over both lines from stop to stop). Feel the ends of each line.

When I give you the signal, trace with your forefinger the lower line lightly and quickly out its full length. Then trace the upper line lightly and quickly out its full length. Report whether the second line is longer or shorter than the first. Give your immediate judgment.

Always trace from left to right on the lower line and from axis-out on the upper line.

You may rest your arm between trials.

Try to be as accurate as possible.

This is not an I.Q. test.

APPENDIX B

2. Instructions to S in Experiment III.

In front of you are two lines, one lower and one upper. The lower line will remain horizontal. The upper line will be either vertical or horizontal. I will place your finger on each. (S's forefinger was placed on the lines and he is allowed to trace both from stop to stop). Feel the ends of each line.

When I give you the signal, trace the lower (upper) line lightly and quickly out its full length. Then trace the upper (lower) line lightly and quickly out its full length. Report whether the upper line is longer, shorter or equal to the lower line. Give your immediate judgment.

Always trace the lower line from left to right and the upper line from axis-out.

You may rest your arms between trials.

Try to be as accurate as possible.

This is not an I.Q. test.

APPENDIX C

Verbal Reactions of Ss.

All Ss were asked how they judged the lines. Three of them reported they relied on timing their movements. Ten Ss reported using a combination of timing and extent of perceived movement made by the arm or extent felt by the finger. All ten Ss indicated they relied more on timing than on perceived extent.

The S showing no illusory effect in Experiment II (S1) reported that he used only his perception of length felt in his finger.

In Experiment I, S4 was of the opinion that it took him longer to make the movements in the 90 and 120 degree directions. He said that he made a conscious effort to compensate for this, especially on the horizontal comparison.

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FOOTNOTES

1. Point of subjective equality for Method of Constant Stimuli: This is defined as the physical length setting at which S judges the comparison to be longer than the standard 50 per cent of the time.

2. The selection of the .05 level of significance here is due to the exploratory nature of this study. This facilitates detection of small differences.

3. Interval of Uncertainty: The physical length of the interval between changes of judgment of the comparison stimulus from "longer" to "shorter" and from "shorter" to "longer."

4. Just noticeable difference: Half the interval of uncertainty.

5. Point of subjective equality: The midpoint of the interval of uncertainty.

6. Constant error: Point of subjective equality minus the standard stimulus setting.

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