STUDIES IN SPACE ORIENTATION. IV. FURTHER EXPERIMENTS ON PERCEPTION OF THE UPRIGHT WITH DISPLACED VISUAL FIELDS

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I. Introduction

In previous studies of this series (1, 2, 3) the role of the visual framework in perception of the upright was investigated. The technique employed in the first two of these studies was to present the *S* with a tilted scene and to have him set a rod within it to the true vertical and horizontal. It was a limitation of this technique that the position of the surrounding scene could not be readily changed, and therefore the variety of frameworks that could be employed with any given *S* was limited.

For the study described here a new technique was developed, which permitted ready changes in the field. The normal visual field was eliminated by working in a completely darkened room, and in its place was introduced a simple luminous frame. Mounted on a shaft at its center, this frame could easily be tilted to either side by any amount. An adjustable luminous rod placed within the frame permitted a precise measure of the *S*'s perception of the upright under different conditions of the visual field. Control data for this rod-in-frame technique are available from a previous dark-room study (3), in which the *S*, with the body in various positions, adjusted a luminous rod to the upright in the absence of any visual field.

II. The Experiments

A. Procedure.—The apparatus consisted of a square frame, each side of which was one in. wide and 40 in. long. Within this frame was a rod, one in. wide and 39 in. long. The frame and rod were pivoted on the same center, but mounted on separate shafts, so that they could be rotated independently of each other. A protractor, mounted on the shaft to which the frame was attached, moved with the frame against a stationary pointer, permitting direct readings of the position of the frame. A similar arrangement allowed measurement of the position of the rod. Frame and rod were coated with luminous paint, and, during the experiment, were the only items visible in the completely darkened room. When it was necessary to present the frame alone or the rod alone, a cover, constructed of light plywood, was placed over the item to be eliminated.

* These experiments were performed in the psychological laboratories of Brooklyn College.

To take readings at the end of each trial, a small desk lamp was turned on very briefly. During this time the *S* kept his eyes closed.

The *S*'s task in this experiment was to adjust the rod to the true V (vertical) and H (horizontal), with his body and the frame in various relations. Two body positions (erect and 28° left) [1] and two frame positions (28° left and 28° right) were employed, in the four combinations possible. Twelve trials were given under each of these four conditions. On the first half of each set of 12 trials, the rod was initially tilted 28° to the same side as the frame, and on the other half it was tilted 28° to the opposite side from the frame. In the body-erect-frame-left condition, the second set of six trials was omitted, however. Under all conditions, judgments of the V were alternated with judgments of the H, so that an equal number of each was obtained. The order of testing was as follows: (1) body erect, frame left; (2) body erect, frame right; (3) body left, frame left; (4) body left, frame right. Finally, after the conclusion of this series, a control test was given in which the frame was in an upright position and the body tilted 28° left. Six trials, with the rod initially tilted 28° with the body, were given for this condition.[2]

The *S* was brought into the laboratory blindfolded, and placed in an upright position about five feet in front of the rod-in-frame apparatus. His task was outlined to him as follows. He was told that upon opening his eyes he would see a square frame, and within it a rod. His object was to make the rod V or H, as indicated at the beginning of the trial. V was defined as parallel to the walls of the outer building, and H as parallel to the floor he was standing on and the ceiling above him. At the outset of each trial, he was to state whether the rod was in the required position and, if not, which way it was tilted.

When these instructions had been given, the frame and rod were placed in position for the first trial, the lights in the room were turned off, and the *S*, who had kept his eyes closed up to this time, was asked to open them and to report on the position of the rod. If he at once perceived the rod as straight (V or H), he was questioned, to ascertain that he regarded it as straight in relation to the building and not only in relation to the frame. If he perceived it as tilted, he was told that the *E* would move it a little at a time, and that he was to say, 'More,' after each turn until he perceived it as straight, when he was to say, 'Enough.' The *E* then moved the rod in the opposite direction from the reported tilt, about 3° at a time, until the *S* said, 'Enough.' At that point the *S* was questioned, to make sure that he actually regarded it as straight in relation to the outer building. He was then told to close his eyes, the desk lamp was turned on, and a reading taken. The frame and rod were adjusted for the next trial, the lights turned off, and the *S* asked to open his eyes.

After completion of the series with body erect, the *S* with eyes still closed, was helped into a leaning position against a board tilted 28° left. This board had at its base a footrest on which the *S* stood. His left arm was placed around the board on which he was leaning, so that his head rested directly against the board. Although this varied somewhat with the *S*'s height, the head was typically about in line with the center of the frame and rod. The remaining trials were given with the *S* in this position.[3]

Fifty-three *S*s were employed in this experiment. Only 41 of these were given the body-erect and the frame-erect conditions, however.

B. Results.—The method of dealing with the measures obtained for each experimental condition was as follows. First, the amount by which the *S*'s setting of the rod was off the true V and H was determined for each trial. In establishing these values, the direction in which the setting was off—that is, whether it was clockwise or counter clockwise from the true V and H—was not taken into account. The scores for all trials given the *S* under a given condition were

[1] Preliminary tests with body tilted 28° right gave results which were very similar to those for the body tilted left. Accordingly the body-right condition was not given, since to do so would have made the series extremely long for the *S*.

[2] In some cases additional tests were given to follow up particular aspects of performance. These special tests will be described at subsequent points.

[3] For a more complete description of this leaning-board arrangement see (3).

then averaged, the result representing his mean error for that condition. Finally, to obtain the mean error for the group as a whole, the mean errors of the individual *Ss* were simply averaged. The value obtained in this way of course represents the mean deviation of the obtained settings of the V and H from the true V and H.

The mean error for each of the body-frame conditions employed are presented in Table I. The distributions of individual scores for these conditions are shown in Fig. 1.

TABLE I

MEAN ERRORS FOR EACH OF THE FRAME-BODY RELATIONS TESTED

Since the result for the two body-erect conditions are very similar, they may be treated together.

Condition	Mean Error
1. *S* Erect	
a. Frame tilted 28° left	6.2°
b. Frame tilted 28° right	5.7°
Combined mean, a and b	6.0°
2. *S* tilted 28° left	
a. Frame tilted 28° left	9.4°
b. Frame tilted 28° right	11.9°
Combined mean, a and b	10.4°
c. Frame upright	4.6°

It may be seen from Table I that, whenever the frame was tilted, errors were made in setting the rod, indicating that the tilted frame influenced the perception of the upright. The effect of the frame was smallest with body erect, where the mean error was 6.0°. With body tilted, the mean error was 9.4° when the body was tilted in the same direction as the frame, and 11.9° when it was tilted in the opposite direction. This difference in results between body erect and body tilted confirms the previous finding (2) that an erect position permits the most accurate judgment of the upright and reduces the influence of the visual framework. The larger errors for the frame-tilted-with-body condition, as compared with the frame-tilted-opposite-body condition, reflect a greater influence by the field in the former case. A similar difference between the two conditions was obtained in an earlier study (2), and the explanation offered there to account for it seems applicable here as well.

In contrast with these results for the frame-tilted conditions, it was found that when the frame was upright the errors were considerably smaller even though the body was again tilted. The mean error for 42 *Ss* was only 4.6°, with the mode at 1°. This mean of 4.6° is lower than the values of 9.4° and 11.9° for the other two body-tilted tests, where the frame was tilted. Actually, the 4.6° figure is very

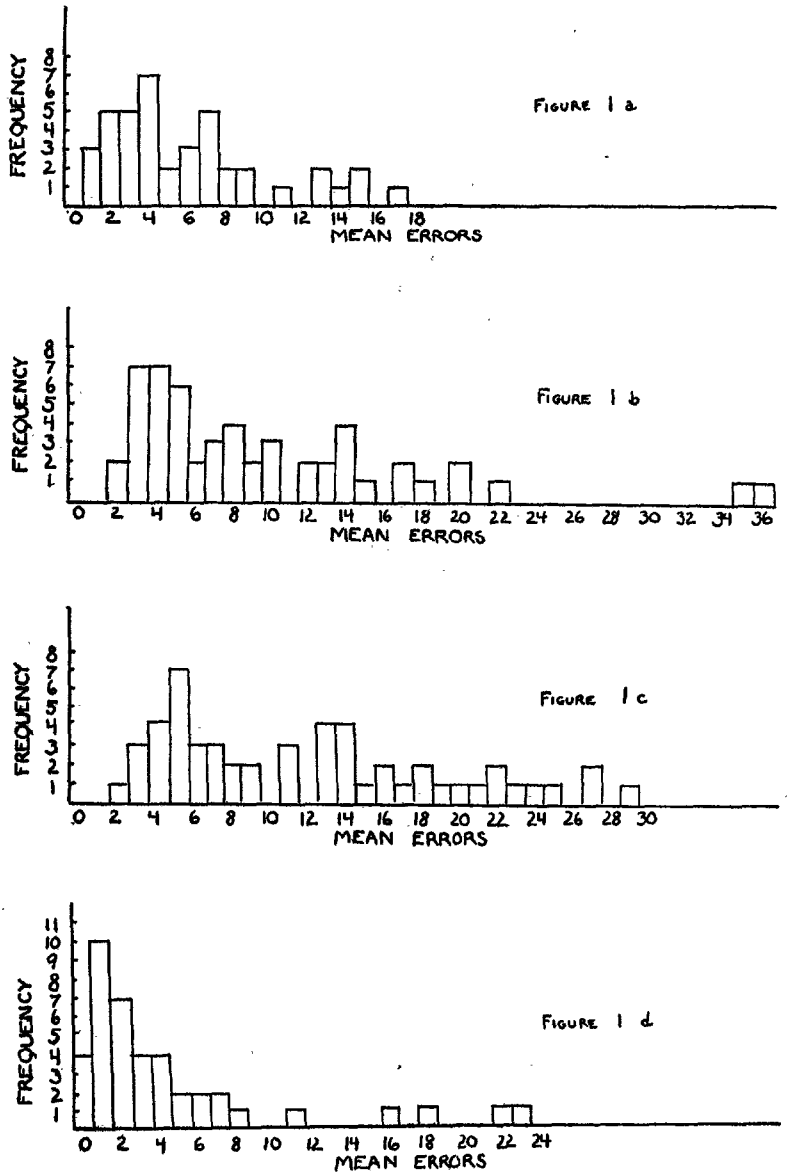

FIG. 1. Distributions of scores

FIG. 1a presents combined results for body erect, frame tilted 28° left and body erect, frame tilted 28° right; FIG. 1b presents results for body 28° left, frame 28° left; FIG. 1c for body 28° left, frame 28° right; and FIG. 1d for body 28° left, frame erect.

much exaggerated by the results of four Ss who had extremely large errors. If these four cases are omitted, the mean error for the remaining 37 Ss drops to 2.7°. It is clear from these results that the position of the frame greatly influences the perception of the upright.

The effect of the luminous frame is also reflected in the difference between the results obtained here and those obtained in the previous dark-room study (3), where the rod was adjusted in the absence of a field. With body erect, the mean error without a frame was 1.5°, whereas with the tilted frame it was 6.0°. With body tilted, the mean error without a frame was 7.9°; whereas with the tilted frame, it was 9.4° when the frame was tilted with the body and 11.9° when it was tilted to the opposite side. Thus, for each body position, the introduction of a tilted frame caused larger errors in placement of the rod than occurred in the absence of a frame. A consideration of individual performances reveals the same result. For example, with body upright, 33 of 39 Ss showed a mean error of 2° or less in adjusting the rod in the absence of a frame. The poorest S had a mean error of only 4°. When the tilted frame was present, however, as may be seen from Fig. 1a, most Ss had mean errors of considerably more than 4°; and in one case the mean error was 17°.

The influence of the frame is reflected not only in the magnitude of the errors but also in their direction. With body erect, the errors in placing the rod were in the direction of the tilt of the frame in 68.8 percent of all judgments. With body tilted, the errors were in the direction of the frame in 54.5 percent of all judgments when the frame was tilted with the body, and in 80.1 percent of all judgments when it was tilted to the opposite side from the body.[4] Thus the errors in perceiving the upright were most often in the direction of the tilted field.

These findings acquire further significance when compared with some results of the earlier rod-alone experiment. There, with body tilted 28°, the rod was adjusted to the opposite side of the true V or H from the body in 77.6 percent of all judgments. This directional error in the setting of an isolated line, which occurs with small tilts of the body, is the E-effect. In the present study also the body was tilted 28° but the rod was surrounded by the luminous frame. The results clearly indicate that the presence of even so simple a visual

[4] For the body-erect condition, the remaining judgments were distributed as follows. The rod was tilted to the opposite side of the true V and H from the frame in 18.1 percent of the judgments and brought to the true V and H in 13.2 percent of the judgments. For the body-tilted condition, they were distributed as follows. When the frame was tilted with the body, the rod was displaced to the opposite side of the upright from the frame in 38.9 percent of the judgments, and it was brought to the true V and H in 6.4 percent of the judgments. When the frame was tilted to the opposite side from the body, the rod was displaced opposite to the frame in 15.7 percent of the judgments, and in 4.0 percent the upright was correctly established.

field severely weakened and perhaps even eliminated the E-effect. As already noted, with body tilted in the absence of a frame the error was in the opposite direction from the body tilt—in accordance with the E-effect—in 77.6 percent of all judgments; but with the frame present and tilted to the same side as the body, the error was in the opposite direction from body tilt in only 38.9 percent of all judgments. In the majority of adjustments (54.5 percent), the error was in the direction of body tilt—that is, in the direction of the tilt of the frame. When the frame was tilted to the opposite side from the body, the error was in the opposite direction from body tilt, or in the direction of the frame, in 80.1 percent of all adjustments.

It has been seen that the error was more often in the direction of the frame when the frame was tilted opposite to the body (in 80.1 percent of the adjustments) than when it was tilted with the body (in 54.5 percent of the adjustments). A possible explanation of this difference is that when the frame is tilted opposite to the body its influence is in the same direction as the E-effect. Both cause the perceived V or H to shift to the opposite side of the true V or H from the tilted body. Conversely, when the frame is tilted in the same direction as the body its influence is antagonistic to the E-effect. It is reasonable that the error should more often be in the opposite direction from body tilt when both factors work toward that end than when these factors are in conflict. An alternative (or possibly a supplementary) explanation of the less-frequent conformance with the frame when the frame was tilted with the body may be derived from the manner in which the frame was at times perceived under these conditions. Although not investigated systematically, it was established that many *S*s who set the rod in the direction of body tilt and away from frame tilt perceived the frame as an upright diamond, or a diamond tipped slightly toward one side. If the frame is perceived in this fashion and is then used as a basis for judgment, then the rod, to be V must run approximately from the upper to the lower tips of the frame, and to be H must connect the two lateral tips of the frame. When the rod is adjusted in this manner, it is in its final position tilted to the opposite side of the true V or H from the frame. Often, and possibly most of the time, when in the frame-with-body condition the error is in the opposite direction from the tilt of the frame, it would be a mistake to conclude that the frame had not been involved in the judgment. Such an incorrect conclusion results from gauging the main axes of the frame according to their objective loci in space rather than according to the *S*'s perception of them. It is clear that the effect of the frame in the frame-with-body condition is greater than is indicated by the 54.5 percent figure for the with-frame adjustments of the rod.

Fig. 1 shows that there were very marked individual differences in degree of error in perceiving the upright under the influence of the tilted frame. For the body-erect condition (Fig. 1a), the mean errors range from 1° to 17°; for the body-left frame-left condition (Fig. 1b), from 2° to 36°;[5] and for the body-left-frame-right condition (Fig. 1c), from 2° to 29°. It is evident from these ranges that some *Ss* were able to judge the upright fairly accurately, despite the tilted frame, indicating some independence of the field. At the opposite extreme were *Ss* who showed a ready tendency to accept the tilted field as a frame of reference. In fact, *Ss* in the latter category perceived the frame as fully upright on some trials, despite its 28° tilt, and simply aligned the rod with the frame to make it V or H. Such complete adherence to the frame occurred for the most part with body tilted, and was most apt to occur when the body was tilted opposite to the frame.

To evaluate consistency of performance under the different conditions employed, scores for the three basic body-frame relations were intercorrelated, and the following r's obtained: (a) body erect and frame tilted vs. body and frame tilted to the same side, +.53; (b) body erect and frame tilted vs. body and frame tilted to opposite sides, +.50; (c) body and frame tilted to the same side vs. body and frame tilted to opposite sides, +.52; These values are sufficiently high to indicate that a tendency to be influenced by the tilted frame, or to remain independent of it, characterizes a person's perception of the upright under the several conditions employed. The individual differences noted above thus seem to be fairly stable.

In addition to these differences in quantitative results, there were also significant differences in quality of performance. Although most *Ss*, even when influenced by the frame, were able to make judgments without undue trouble, some encountered very serious difficulty. The latter kind of performance, obtained solely with *Ss* who were greatly affected by the frame, was characterized by marked confusion, prolonged effort in reaching a decision, very large errors, and in extreme cases an utter inability to establish the upright. Because of many significant features in their performance, detailed protocols for three such *Ss* are given below.[6]

Subject W: In the series where the body was tilted 28° left, and the frame and rod were also tilted 28° left, the *S* performed as follows. On the first trial he accepted the tilted rod as V at the very outset. In reply to a question, he stated that the rod in that position ran perpendicularly

[5] In the latter case, the rod was tilted to an even greater extent than the frame, which was only 28° from the upright. This resulted from perceptual shifts in the frame, a phenomenon to be discussed later.

[6] The results for two of these *Ss* were not included in the data presented earlier. Because so many special procedures were employed in following up particular aspects of their performance, the testing to which they were submitted deviated too much from the standard series.

from ceiling to floor. On the next trial, when an H adjustment was required, he moved the rod back and forth in a very finicky and anxious manner, and finally aligned it with the H axis of the frame. On being questioned, however, he reported that the frame was tilted. When reminded that the rod was to be made straight with the floor of the room, and not with the frame, he replied that he could not know where the floor was. The trial was repeated; and when the rod was 53° from the true V, in a direction opposite to the tilt of the frame and his own body, he reported that it was V. (His task was actually to establish the H.) In identifying the side of the frame which was nearest the ceiling, he pointed not to the side *a* (see Fig. 2), which was objectively in that position, but to the adjacent side *b*. The positions of the rod in the first V adjustment above, where the frame was perceived in an '*a*-as-top' view, and in the second V adjustment, where the frame was perceived in a '*b*-as-top' view, are illustrated in Fig. 2. With the perceptual shift in the

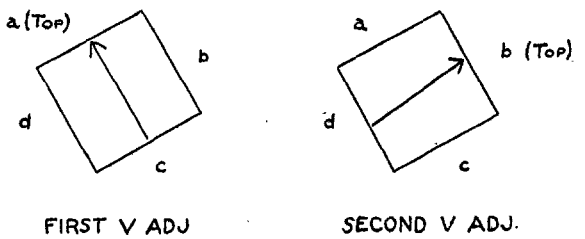

FIG. 2. Adjustments of movable rod by Subject W: (left) when side a was seen as 'top'; (right) when side b was seen as 'top.' (See text.)

main axes of the frame, the perceived upright moved 81°. In the second adjustment, the rod, when perceived as V, was objectively nearer to the H.

On the next three trials, this *S* continued to perceive the frame in its shifted orientation. For the H, he set the rod 55° to the right of the true H; for the V, 55° to the right of the true V; and for the H again, 56° to the right of the true H. The rod was thus successively placed within 7°, 9°, and 6° of the shifted axes of the frame. In each case the *S* asserted that his setting was parallel to the walls or floor of the room.

In another series, the *S* was tilted 28° left, while the frame was tilted 28° left and the rod 28° right. Continuing to see the frame in a shifted position, he misjudged the V and H on four successive trials by 49°, 55°, 52°, and 60°, respectively. The last H setting was 60° to the right of the true H. It was also 2° from the H axis of the frame in its shifted position, and was 15° nearer to the true V than to the true H, which he was attempting to establish. In the series preceding this one, the *S* had made a V adjustment which was 58° to the right of the true H (or 28° to the left of the true V); thus, on these two trials, the *S*s perceived V and H were within two degrees of each other. Under similar conditions with other *S*s, it has been observed that the appearance of the rod would suddenly shift, so that at one moment it looked properly V and at the next moment properly H.

The *S* was then tested with body 28° left and frame 28° right. In the series with the rod tilted 28° right, he accepted the frame as upright on all trials, and therefore also accepted the rod as H and V in its initial position. In the series with the rod tilted 28° left, the frame appeared almost straight, and the rod was brought to within an average of 3° of its axes in the four adjustments made. The *S* thus 'went along with' the frame throughout.

Clearly this *S*'s perception of the V and H was very strongly influenced by the visual framework. Under all conditions he adopted the main directions of the frame completely, or nearly completely. His orientation was also very labile, as demonstrated in the shifts of the visual frame of reference, and this led to large errors and considerable variability in his judgments. For example, he located the V in positions separated by 81°; perceived a line in approximately the same position as V on one trial and H on another; and set the V in positions objectively nearer to the H, and vice versa.

Subject Pe: This *S*, too, demonstrated striking lability of orientation, but less of a glib 'going along with' the frame, and more confusion in his performance.

In one series, the *S* was tilted 28° left, the frame 28° left, and the rod 28° right. On the first trial, the *S* had the rod moved 12° to the right in making it V. In describing the frame, he reported that it appeared like a diamond, but then suddenly stated that it was perfectly straight and had the rod moved to 60° to the right of the true V. In other words, the frame was perceived as upright in a shifted position (i.e., in a *b*-as-top view—see Fig. 2), and the rod was brought to within 2° of its 'new' V axis. On the successive trials, the errors were 51°, 42°, 42°, 44°, and 44°, respectively, to the right of the true V and H. Judgments were made quickly, and with no apparent difficulty.

Errors of the magnitude obtained, as well as the observed shifts in the axes of the frame, can occur only if the position of the body is disregarded. For example, when the rod was accepted as V at a displacement of 60° to the right, it was approximately at right angles to the body, which was tilted 28° to the left of the upright. For the rod to be perceived as upright in the 60° position, the body should have been lying on its side. Reference to the body would have indicated at once that this was not so.

To investigate this problem further, the *S* was asked to make the rod parallel with his body, which was tilted 28° left. This he did very successfully, placing the rod exactly 28° to the left of the upright. He was next asked to make the rod H in relation to the outer building. This time he set it at 40° to the left of the true V, or only 12° from his body, so that his setting was off by 50°. It was pointed out to the *S* that, according to his last adjustment, his body must be only slightly away from the horizontal position. He replied, "Something must be cockeyed," and asked that the rod be moved. Then he suddenly said: "I've lost my perspective of the frame to the room. I can't get my position. I've lost the relation of the frame to my slanting position. I can't straighten it out. I started out by having it."

In his initial judgment of the H, the *S* had proceeded without reference to his body. Then, when he was given the specifically 'postural' task of relating the rod to his body, he did it quite well; but as soon as the task involved more than the body alone, he became confused and unable to proceed. He apparently could not relate what he felt to what he saw. Further, the attempt to establish this relation caused the situation to become very unstable, as evident in his complaint: "I see it one way and then another." It is very likely that 'seeing it one way and then another' reflects a shift from a judgment made in relation to the body to one made without reference to the body.

The *S* was given an opportunity to redetermine the H, and now set it at 50° from the true H, or 12° from his body. He was then asked to raise his body toward the upright. Halfway up, he burst out with a loud exclamation, and began to laugh as he recognized the magnitude of his error. He was returned to the tilted position (28° left), asked to close his eyes and then open them again, and to identify the top and bottom of the frame. He answered: "I can't. I've lost it. I've lost the relation of the frame to the floor." When encouraged to proceed, he did identify the parts of the frame correctly. The test was repeated, and this time the frame was once more perceived in a shifted position, the V now being set at 64° to the right of the true V. The *S* was again asked to raise his body a little toward the upright. He now reported that the frame looked like a diamond. Straightening himself a little more, he reported that it still looked like a diamond. Finally, when he was fully upright, he reported that it no longer appeared as a diamond, but as tilted over toward one side. It is significant that, with the body erect, perception of the frame in a shifted position, whether in a *b*-as-top (Fig. 2) view or a diamond view, cannot be maintained.

Testing was now continued with the frame tilted 28° opposite to the body. In an apparent effort to 'resist' the frame—an attitude prompted by his previous experience—he avoided aligning the rod with it. Instead of moving the rod toward the upright, however, he tilted it even farther than the tilt of the frame. This kind of error reflects the absence of a basis for judgment once the visual frame is excluded from consideration. On four trials, with V and H judgments alternating, his settings were displaced toward the right by 53°, 50°, 65°, and 52°, respectively. Throughout, the *S* proceeded in a hesitant and unconfident manner.

Whatever the basis of these judgments, it persisted even when the frame was excluded. Immediately after the determinations described above, the S was tested with the rod alone. His errors on four successive settings were 42°, 45°, 53°, and 51°, again toward the right. It has been found with other *S*s also that when a given manner of determining the upright has been established with a frame present it tends to persist after removal of the frame. This suggests that a 'remembered' visual field may function as a frame of reference.

In a subsequent interview, the *S* made a number of statements of considerable significance. At one point he remarked: "It's kind of a helpless feeling. Lots of times I couldn't seem to place the floor. The room seemed empty outside the frame. The only way I could do it [make the rod straight] was to get the relation between me and the frame, and sometimes I just couldn't get it."

At another point, he said: "There were some positions where I would suddenly lose the relative position of things. Then I would become upset slightly. If I missed one, it might upset me for a few [trials] afterwards. But it would come back." This comment reflects the emotional involvement often encountered in these tasks.

This *S*'s performance provides another instance of orientation determined primarily by the visual framework and also markedly labile. It further demonstrates the severe disorientation that may result from attempts to modify the predominant visual basis of orientation through the involvement of postural experiences.

Subject P: In a lengthy series of tests, during which she stood erect, this *S* adjusted the rod to the upright very accurately, being only moderately affected by the tilted frame. When her body was tilted, however, she came very markedly under the influence of the frame, and made very large errors. With body 28° left, and frame at the same tilt, she immediately accepted the frame as perfectly upright in the shifted *b*-as-top position (see Fig. 2). On the first V setting, the rod was simply aligned with side *a*, so that it deviated from the true V by 62°. On the next three trials, the frame continued to be perceived in the shifted orientation, though not as fully upright, and the settings were off toward the right by 30°, 55°, and 53°. The most striking feature of these results is the contrast in adequacy of orientation with body upright and with body tilted. The diminished usefulness of postural experiences when the body is tilted, and the increased dependence on the visual field, are most dramatically demonstrated here.

With body again tilted 28° left, the frame was presented to this *S* at a 15° left tilt, and was perceived as straight. The S then reported that she felt dizzy and *did not know in which direction floor, walls, and ceiling were.* She also complained that she *did not know the position of her own body*—whether it was pointing toward the ceiling or toward the floor.[7] There was thus complete disorientation, involving both the body and the world beyond the frame, with accompanying dizziness. At several later points the *S* reported a similar total loss of bearings.

In subsequent tests, the rod was omitted. With body remaining tilted 28° left, and frame 15° left, the *S* perceived side *b* as almost parallel with the ceiling. That is, side *b*, which was at a 75° angle to the ceiling, was seen as nearer to the ceiling than side *a*, which was at only a 15° angle to the ceiling. The frame was then moved clockwise, a few degrees at a time, with the *S*'s eyes closed during movement. She continued to identify side *b* as the top, until the frame reached a position 17° to the right, when she reported that *b* was the right side. The *S* clearly was not aware of this sudden shift in her perception of the frame's orientation. This was demonstrated when, questioned by the *E*, she denied that side *b*, which she now identified as the right side, was the same side that she had on the turn immediately preceding called the top. At several other times when shifts occurred, she did not recognize the changed relation of the sides of the frame, although on some other occasions she did notice it.

When the frame was next presented at a tilt of 6° left, the *S* continued to see side *b* as the top, although this side was now at an 84° angle to the ceiling. The frame was then tilted 15° to the right, and still the *S* continued to perceive *b* as the top. As may be noted from the diagram below, *b* would have had to be moved 105° to be parallel to the ceiling, and was actually farther from being parallel than either side *a* or side *d*, which were 15° and 75° away, respectively. In a later observation it was found that the *S* saw *b* as topmost at an even larger displacement, when it was 112° away from being parallel with the ceiling. (A slight further move of the frame, however, to a point where *b* was at an angle of 116° to the ceiling did cause it to be seen as the right side.)

To summarize, one significant feature of this performance lies in the serious effect produced by tilting the body. Also important were the acceptance of the frame as about upright in a

[7] Another *S* in the group reported the very same experience. He complained a number of times that he had become completely disoriented—that he had lost altogether the ability to determine the angle of anything with relation to the floor. At such times he felt quite unable to make a judgment. At one point he did not know where the floor was, or at what angle his body was tilted. He also stated that he had the impression of the darkness taking on the shape of the square.

variety of different positions, and the shifts in the perceived axes of the frame while it remained in the same objective position. The extreme errors made reveal a striking loss of contact with the main axes of space, and also indicate that the position of the body could not have been taken into account in making these judgments, but that the frame, unstable as it was, constituted the main basis of perception.

Sudden perceptual shifts in the main axes of the frame, such as are described in the above protocols, undoubtedly result from the ambiguous structure of the frame. Its four sides are identical, with no intrinsically defined top, bottom, or side. It is only in relation to some external standard, as assumed proximity to the floor, that a given side becomes top or bottom. This character of the frame permits an interchange of function among its sides.

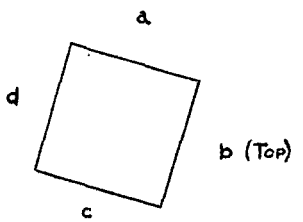

FIG. 3. Position of frame with side b tilted 15° to the right, perceived by Subject P as having side b at the top. (See text.)

The shifts in perception of the luminous frame occurred mainly when the body was tilted. Only rarely were they observed with body erect. An upright position of the body, because it provides a more effective standard of judgment, helps to stabilize the visual framework. Furthermore, these shifts occurred most often when the body was tilted to the same side as the frame. The basis for this is the fact that, though tilted by the same amount, the frame appears somewhat different when tilted with the body than when tilted opposite to it. When tilted with the body, the frame tends to look like a diamond standing on end but tipped over to one side. Though of the two uppermost sides, *a* is clearly nearer to being parallel with the ceiling than *b* (see Fig. 2), the perceptual disparity is not so great as the objective disparity. When tilted in the opposite direction from the body, on the other hand, the frame has the appearance of a tilted square, with *a* unmistakably the side nearest the ceiling. Thus, because perceptually *a* and *b* are more nearly equivalent in the frame-with-body relation, it is easier for an interchange of functions to occur and perceptual shifts are more frequent.

The shifts that occur under these circumstances from the predominant *a*-as-top view are to an upright-diamond view or to a *b*-as-top view. Perception of the frame in the diamond orientation involves, of course, a less radical dislocation of its axes, and seems to

occur as an intermediate step in the shift from the *a*-as-top to the *b*-as-top view. In one case, for example (Subject Pe for whom protocols were presented earlier), the frame was perceived in the *b*-as-top relation. As the *S* gradually straightened his body, his perception of the frame shifted successively to the diamond view and the *a*-as-top view. In another case, the diamond view occurred when, after seeing the frame in the *b*-as-top relation, the *S* was asked to try to see it with *a* as the top.

The fact that when the body is tilted, the visual framework available as a basis of judgment is unstable, may be expected to make for variability in judgments. Because the luminous frame has a very simple structure it provides a rather 'weak' frame of reference. This is additional reason to expect that judgments made in its presence will not be very consistent. To obtain evidence about individual variability of performance, ranges were computed for each *S* for the body-28°-left, frame-28°-left condition.[8] For H judgments, the mean range for all *S*s was 11.3°; for V judgments, it was 12.9°. These results indicate that the rod appeared upright over a considerable range of positions. In fact, *S*s often verbalized this point, complaining that the rod seemed straight in many different positions.

It has been noted that some of the *S*s for whom protocols were presented encountered difficulty in relating the rod to the position of the body when the rod was under the influence of the frame. At times, the frame affected the perception of the position of the body itself, making it even more difficult to judge the position of the rod. Thus it was found in several cases, where the frame became perceptually unstable, that the *S* was unable to establish the position of his own body, being unsure of which way feet and head were pointing. In other instances, movement of the frame produced the illusion that the body itself was being moved. This illusory movement was illustrated most dramatically in a special test where the *S* was in a horizontal body position and viewed the luminous framework as it was being moved slowly through 360 degrees. Under these conditions the *S* reported that the frame appeared upright *in all positions*, despite the fact that he perceived its rotation. At the same time he reported that he felt *himself* turning. As the frame was moved from the upright to 45 degrees, he stated: "I see a perfect square, only I am hanging with my head down; I am the diagonal. As you moved the frame slowly, it seemed as if somebody was picking me up by my feet while my head was sliding down. I saw the frame moving, but all the time it remained horizontal to the floor." This *S* did not experience the induced body movement equally at all points. When the frame had rotated approximately 90 degrees, or, more exactly, to the point where he felt his head hanging down vertically, he experienced suddenly a change

[8] In determining the range, the difference between the *S*'s two most extreme judgments, with account taken of sign, was computed.

of the base line to an altitude, and simultaneously the snapping back of his body to the horizontal position. He reported: "A new line became a base; I felt I couldn't turn my body any more. My body then jerked back to the horizontal position. Up to then it was moving around like the hand of a clock." It is significant that as simple a framework as the luminous frame can exert such an effect upon the perception of body position.

III. Some Further Experiments

A. Judgments of the upright with the frame at different tilts.—In the main experiment, described above, the frame was always tilted 28°. These supplementary experiments employed additional positions of the frame: (a) 15° left, (b) 30° left, (c) 60° left. The *S*s stood erect, and set the rod to the V and H with the frame at each of these angles. Two judgments of the V and two judgments of the H were obtained for each position of the frame from a group of 15 subjects.

The mean errors obtained were as follows: (a) for the 15° tilt of the frame, 8.5° for the H and 8.6° for the V; (b) for the 30° tilt of the frame, 8.9° for the H, and 9.3° for the V; (c) for the 60° tilt of the frame, 5.9° for the H, and 5.9° for the V. In most instances, the errors were in the direction of the tilt of the frame.

Although it did not seem to affect the mean errors in a systematic way, the degree of tilt of the frame did have a striking effect on the range of the errors. Considering results for individual *S*s, the errors are found to range from 2.0° to 15.0° for the frame tilt of 15°; from 2.7° to 26.4° for the tilt of 30°; and from 1.1° to 17.6° for the tilt of 60°. For the first two positions it is seen that the range of individual scores increased with the increased tilt of the frame.

In terms of both errors and ranges, the scores for the 60° position of the frame show a drop rather than the expected increase when compared with scores for the 15° and 30° positions. The basis of this result is suggested by the direction of the errors for each tilt of the frame. With the 15° and 30° positions, errors were always, except for a single *S*, in the direction of the tilt of the frame. With the 60° position, however, some of the errors were in the opposite direction from the frame tilt. If such errors are counted as negative, the range of the errors is from −15.0° to +17.6°. Computed in this way the range is actually larger than for the 15° or 30° positions of the frame. The occurrence of negative errors is explained by the fact that the frame may, in the 60° position, be perceived as either 60° to the left or 30° to the right. Because of the equivalence of the four sides, one mode of perception is just as likely as the other, although the fact that in the two preceding tests the frame had been tilted 15° and 30° left may have caused the same sides to continue their functions as base and altitude, thereby possibly favoring the 60°-left view over the 30°-right view. In any case, depending on which view of the frame is adopted, the direction of the errors may be to one side or the other of the true V and H. The possibility that the frame may serve as a standard in two alternative ways, plus the fact

that some *Ss* shifted from one standard to the other, may reduce the effect of the frame upon perception of the upright in that position. This would help account for the smaller errors found.

B. Judgment of a frame within a frame.—In all the experiments described so far, perception of a very simple visual structure (the rod) within a larger field was studied. It is possible that the appearance of such an item is particularly affected by the surrounding field. In this experiment a more complicated structure—a small square frame—was substituted for the rod, to determine whether perception of it would be more independent of the field. Each side of the small frame was 24 in.

As with the rod, this small frame was pivoted at the same center as the large frame, and the *S*'s task was to make it straight, with the larger frame in a tilted position. Duplicating the conditions of the main experiment reported previously, the body was tilted 28° left and the large frame was on some trials tilted 28° left and on other trials 28° right. The small frame was also initially tilted 28°, either with the large frame or opposite to it. Nine *Ss* were tested. With body tilted left and with the large frame also tilted left, the mean error was 9.0°. This compares with the value of 7.8° for the corresponding rod-in-frame test. With body tilted left and large frame tilted right, the mean error was 15.2°. The value for the corresponding rod-in-frame test was 13.9°. It is clear that perception of the small frame was markedly affected by the larger frame. The errors, though based on a very small number of cases, are in fact slightly larger than those for the rod-in-frame test. Apparently, being within the field of the large frame, perception of the small frame is as much affected as was the perception of the simpler rod.

C. Reproduction of directions with and without a field.—In one variation of this experiment, the *S* viewed the rod alone—tilted 15° to the left—for a one-min. period, with the instruction that he would later have to reproduce its position. The rod was then presented within the luminous frame, which on five successive trials was first straight, then tilted to the left 15°, 30°, 45°, and 60°; each time the *S* was required to place the rod in the initial 15° position. This series was repeated four times, so that four settings of the rod were obtained at each of the five positions of the frame.

In a second variation of this experiment, the *S* had to set the rod at a 45° angle, instead of a 15° angle, with the frame upright, tilted 30°, and tilted 45°. One *S* was used for each experimental condition. These were *Ss* who in other tests involving the luminous frame and rod had proved to be strongly influenced by the position of the frame in judging the rod. While their results here, which were again very extreme, are not representative, they are significant in showing the extent to which some people may depend upon the visual framework.

Following are the results obtained with the *S* for whom the 15° position of the rod was used. When the luminous frame was upright, the reproductions of the 15° tilt of the rod were highly accurate. The four adjustments averaged 12.8°, or only 2.2° off the 15° position required. As soon as the frame was tilted, however, large errors appeared. In every case the rod was set too far in the direction of the tilt of the frame. With the frame

tilted 15°, the reproduced position of the rod had a mean value of 31.0°; with the frame tilted 30°, a mean value of 45.0°; with the frame tilted 45°, a mean value of 56.3°; and with the frame tilted 60°, a mean value of 47.7°. In all positions of the frame except the last one, the rod was placed about 15° farther to the left than the frame. The 20 individual settings made by this *S* in an attempt to reproduce the initial 15° position of the rod varied from 12° to 61°. It is necessary to conclude that this *S* was not capable of reproducing the objective tilt of the rod. What he did reproduce most of the time was an angle that stood in a constant relation to the framework. This *S*, it should be noted, fully understood the instructions and realized that the changing position of the frame was introducing a distortion into his judgments.

Results very similar to these were obtained with the other *S*, who attempted to reproduce a 45° tilt of the rod. With the frame upright the average setting of the rod was 45.6°, the individual settings ranging between 42° and 49°. With the frame at 30° the average setting was 79.5°. Finally, with a 45° tilt of the frame, the average setting was 88.0°, or virtually horizontal. The individual settings for all three positions of the frame varied from 42° to 95°, though the *S* believed throughout that he was tilting the rod at a 45° angle.

These results cannot be ascribed to 'faulty memory. The accuracy of reproduction when the framework is upright conclusively rules out this possibility. The systematic relation between the rod settings and the tilt of the frame warrants the conclusion that the *S*s perceived the direction of the rod principally in relation to the frame.

IV. Discussion

The study described here has provided more dramatic evidence than did our previous ones of the importance of the visual framework in the perception of the upright. This is mainly because the framework employed was a 'weak' one, and therefore perceptually unstable for some people. Since for such people the frame was also typically adhered to as a basis of judgment in each of its shifted orientations, there resulted enormous errors in judgment of the upright. Summarized below are some of the extreme results from performances, described in Section II, of *S*s whose perception of the frame was particularly labile.

In one case a given side of the frame was perceived as topmost when it was objectively nearer to the floor than to the ceiling. In the given position it would have been necessary to move the frame 112° to make it parallel to the ceiling. Another *S* perceived a H rod as perfectly V, so that the axes of space were in effect shifted by 90°. In another case, the rod was judged to be V in positions that were 80° apart. In addition to causing these enormous errors, the perceptual instability of the frame also contributed in some *S*s to marked con-

fusion about their orientation. This was reflected first of all in increasing hesitancy and anxiety in making judgments. It was also indicated by the following kinds of experience, exhibited and reported by *Ss*: (a) inability to judge the relation of rod, body, and frame, to the point of finding it impossible to make any judgment at all; (b) inability to locate the unseen walls and ceiling of the room ("There seems to be nothing outside the frame," or "The darkness outside the frame has taken on the shape of the frame"); and (c) inability to establish the position of the body itself, to the extent of not being sure which way feet and head were pointing. Marked confusion of this kind, and enormous errors in judgment such as those cited above, never occurred in our previous studies, where the framework was more complexly structured and more stable.

Results of this kind were obtained with extreme *Ss*, and were of course not typical of the group as a whole. In fact, in most cases the 'weak' structure of the frame caused smaller errors in judgments of the V and H than were obtained with the frameworks employed in our first two studies. In brief, although the framework used here made possible enormous errors in some extreme cases, it typically did not produce very large errors. This will be evident from a comparison, to be presented later, of results for the present framework and for those used in our first two studies.

As in our first two studies, striking individual differences in performance have been found here. Although perception of the position of the rod was generally affected by the position of the luminous frame, the degree to which it was affected varied considerably among the different *Ss*. To some the tilted frame tended to appear upright most of the time, and the rod was therefore adjusted to its main axes in making it V and H. At the other extreme were *Ss* who were able to make proper allowance for the tilt of the frame and to bring the rod close to the true V and H, suggesting the use of some other basis for judgment. That a given degree of dependence on the visual framework tends to characterize a person's perception of the upright in a fairly general way, is indicated by the correlations of +0.53, +0.50, and +0.52 among the three main body-frame conditions employed.

In several ways the possibility of perceptual shifts in the framework itself made for greater individual differences in performance than were observed in earlier studies. First, in cases where shifts in the frame occurred, and the frame was adhered to in each orientation, there resulted extremely large errors and great variability in judgment of the V and H. Even if the mean error for the group as a whole was not so great with the luminous frame, the range of individual errors was extended by these extreme cases. Second, in this

study there was a distinction between *Ss* for whom the framework was unstable and *Ss* for whom it was not. This is a dimension of differentation which did not exist with the mirror or room techniques, since with these frameworks perceptual shifts were never observed. Third, the instability of the framework also made for confusion of orientation in some people, of a kind never found with the room or mirror techniques. This is another aspect of performance in terms of which *Ss* could be distinguished. To the extent that performances in the luminous-frame situation permit greater differentiation among people, it seems better suited to the study of individual differences than the room or mirror type of situation. A further advantage of the technique is that it requires a much simpler apparatus.

There is a special aspect of the problem of individual differences that merits consideration. Among *Ss* whose perception of the position of the rod was strongly affected by the position of the frame, as already noted, there were those for whom the frame underwent perceptual shifts and those for whom it did not. Aside from this difference in the relative stability of the frame, these *Ss* also differed in terms of the difficulty they encountered in arriving at their judgments. Some *Ss*, even when perceiving the frame in a shifted position, 'went along with it' in a glib, sure fashion. Others, though also greatly influenced by the frame, experienced very marked difficulty. This was seen strikingly in some of the protocols presented in section II. If we seek the basis of this 'troubled' type of performance, the evidence suggests that it occurs when people who are strongly dependent on the visual framework attempt to go counter to appearances and to use the position of the body in making their judgments. The result of such an effort seems to be that the task is changed from a 'natural' one of reporting on direct perceptual experiences to the more 'artificial' one of interpreting these experiences. The latter way of dealing with the problem may lead to even greater errors than the first; for, as noted in some of the cases described, a complete loss of bearings may result.

There are several lines of evidence to support such a view of these 'troubled' performances. One kind of evidence is illustrated by the results with Subject Pe whose protocols were presented in Section II. This *S* at first tended to set the rod toward the axes of the frame, even though the frame was perceived in a shifted position, so that very large errors resulted. The *E* then carried out some special tests, which served to make the *S* more aware of the position of his body and of the untrustworthiness of his visual impressions. As a result, the *S* attempted to take greater account of his position in judging the V and H; but this required very great effort and, in fact, proved unsuccessful to the point of producing a rather complete loss of bearings.

There thus occurred, through efforts to take account of the body, a change from a glib, visually dependent performance to a very troubled performance. If insight into the untrustworthiness of visual impressions may be provided through the efforts of the *E*, as was the case here, it is also possible that the *S* may gain such insight on his own.

A further indication that 'troubled' performances result from difficulty in relating body position to visual impressions is found in the relative ease of making judgments with the frame and without it, as observed in some cases. One *S*, who became seriously confused when the frame was present, gave accurate and rapid judgments when it was removed. Thus the difficulty disappeared when the task was changed from one in which visual and postural experiences had to be related to one in which postural factors alone were involved. The *S* specifically stated that the task was much easier in the absence of the frame. A result of similar import was noted when *S*s who were experiencing great difficulty in judging the V and H were required to align the rod with the tilted body. In this task, which again did not require relating the position of the body to the position of the frame the judgments proved to be much more accurate, and no effort or disturbance was involved.

From our first two studies (**1**, **2**) and the present study, results are available for three kinds of visual framework, graded in terms of structural complexity. The luminous frame used here, consisting of four equivalent sides, was the simplest. The tilted room of the second study provided a more definite framework, containing many verticals and horizontals and a clearly defined top and bottom. Finally, the mirror situation used in the first study presented a full, natural scene, providing the most richly articulated visual field. From the data now available for these three situations, it is possible to determine the effect of 'strength' of the visual framework upon perception of the upright.

Results with body erect and field tilted may be evaluated first. Considering the extent to which judgments of the V and H deviated from the true V and H, the following mean errors are obtained: for the luminous frame, 6.0°; for the room, 14.9°; and for the mirror, 22.0°.[9,10] There is thus a progressive increase in the amount of displacement of the rod. Equally striking results were obtained when

[9] The results for the room are taken from Situation a (**2**), and the results for the mirror from the with-tube condition (**1**).

[10] The degree of tilt of the framework was not the same for the three situations. The liminous frame was tilted 28°, the room 22°, and the mirror 30°. That differences in tilt of the frameworks did not account for the differences in magnitude of the error is clearly indicated by the finding that the errors were larger with the room than with the frame, though the tilt of the frame was greater.

the body was tilted as well as the frame. Data are available for the luminous frame and the room only, since the body-tilted condition was not used with the mirror. In the case of the room, the mean error was 19.4° when room and body were tilted to the same side, and 20.1° when they were tilted to opposite sides. In the case of the luminous frame, the corresponding values were 9.4° and 11.9°. It should be noted that in the luminous-frame test the frame and body were both tilted 28°, whereas in the room test room and body were tilted only 22°. Typically, larger body tilts lead to greater acceptance of the visual frame work, and larger tilts of the field lead to greater displacement of the perceived upright.[11] On the basis of degree of body tilt and field tilt alone, the errors should have been larger with the frame than with the room. The fact that the errors were considerably larger with the room situation therefore demonstrates in an impressive way that the difference between the two sets of results was determined by the more structured character of the room. The results obtained both with body erect and with body tilted indicate that the more highly structured the surrounding visual framework the greater its influence on perception of the upright.

Greater strength of the framework not only caused the perceived upright to be displaced farther in its direction, but also resulted in greater consistency among successive judgments. This is clearly indicated in the mean ranges obtained with these different frameworks under the same body-framework relations. With body erect and framework tilted, we find for the mirror situation a mean range[12] of 4.6° for V judgments;[13] for the room situation, a mean range of 2.0° for H judgments and 2.6° for V judgments; and for the luminous-frame situation, a mean range of 8.8° for H judgments and 9.2° for V judgments. The variability with the room and mirror is quite small though somewhat larger with the mirror. The variability with the luminous frame is very much greater than with either of the other two situations. With body tilted and framework tilted to the same side, similar results are found: for the room situation, mean ranges of 2.0° for H judgments and 2.6° for V judgments; for the luminous-frame situation, mean ranges of 11.3° for H judgments and 12.9° for V judgments.[14] Again, the more highly structured framework pro-

[11] Evidence for these generalizations will be presented in a later paper.

[12] The mean range was computed by determining the range for each *S*, and then taking the average of these. In the scores from which the *S*'s range was determined, the direction of the error was taken into account (that is, whether it was clockwise or counter clockwise from the true V and H).

[13] Data for H judgments are not available, since the *S* set the rod to the V only in that experiment.

[14] The mirror framework was not tested with body tilted.

vided by the room leads to markedly greater consistency in judgments. The same result is indicated by the direction of the errors for each situation. With body and framework both tilted to the same side, errors in judging the V and H were, in the room situation, always in the direction of the tilt of the framework. In the luminous-frame situation, on the other hand, though errors in placing the rod were most frequently in the direction of the framework, they often occurred in the opposite direction also. The latter kind of adjustment, as noted earlier, depends upon perceiving the frame with its axes shifted. Thus with the luminous frame the rod not only appears straight over a considerable range of positions but it may appear straight to either side of the true V or H. With the room, on the other hand, the rod appears straight within a very narrow range of positions and only when displaced to that side of the true V and H to which the axes of the room are displaced. It is clear from all these results that when the surrounding framework is more highly structured, perception of the upright tends to be more stable.

V. Summary

The effects of visual frameworks of different tilt and of different bodily positions upon perception of the upright were investigated in 53 adult *Ss*. The visual field consisted of a simple luminous frame contained in a completely darkened room. Within the frame was a luminous rod which the *S* had to set to the vertical and horizontal. The frame was tilted 28° right, 28° left or was erect; and the body was either erect or tilted 28° left. Tilting of the frame caused a shift in the perceived upright in the direction of the frame. The influence of the frame was smaller with body upright than with body tilted. As in previously reported investigations, individual differences were found. There were *Ss* who, despite the tilt of the frame, brought the rod close to the true vertical and horizontal; at the other extreme *Ss* perceived the tilted frame as upright, and aligned the rod with it. That these modes of perceiving the upright are characteristic of the individual is indicated by the substantial correlations obtained among performances under the different conditions. The 'weak' structure of the visual framework used resulted in smaller errors, as compared with previous studies, when the rod had to be set to the upright under the influence of the tilted frame. At the same time, the framework was relatively unstable, the top coming to be perceived as a side, and so on. Because of this in some individual cases errors very much larger than those found in previous studies were obtained. Thus, one *S* perceived the horizontal as vertical; another placed the vertical on successive tests in positions 80° apart.

In some instances, the *S* lost the ability to locate the unseen surrounding room, to establish the position of the body, or to bring the rod to the true upright. Differences were also observed in the ease with which *Ss* arrived at their judgments. A comparison of the results of the present and preceding study indicates that the effect of the visual field upon the perceived upright tends to be stronger and more consistent, the more richly articulated the field.

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