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THE PERCEPTION OF THE EGOCENTRIC ORIENTATION OF A LINE[1]

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In recent years investigation of the problem of visual direction has been more or less restricted to the problem of how we perceive the upright and horizontal directions of space (**1, 2, 3, 4**). The work on this problem has led to the conclusion that there are two factors which account for our accurate perception of the upright direction under varying conditions. On the one hand it has been shown that the main lines of the scene influence the perception of the upright and horizontal directions of space since tilting the axis of the scene produces marked changes in the direction of the phenomenal upright. The phenomenal upright is displaced in the direction of the upright of the tilted scene. On the other hand it has been shown that the direction of the upright is still perceived fairly accurately even where no visual scene is present at all, as for example in a completely darkened room (**5**). It is true that if *O* is tilted in this situation, judgments of the upright are no longer quite so accurate. Nevertheless, within a certain range of error, it is still correct to say that we can perceive the general direction of the upright even under these circumstances. From this it has been concluded that the second factor is the direction of the force of gravity on the body. Ordinarily it is presumed that these two factors cooperate with each other since the direction of gravity is aligned with the vertical lines of the visual scene.

It is doubtful, however, whether these two factors tell the whole story about perception of the upright. In the situation where the visual scene is eliminated, the orientation of the image of the line whose orientation is being judged cannot in any way be determined in relation to the image of a frame of reference as is possible when a visual scene is present. Nevertheless it must be kept in mind that *O* is performing a visual task in that the judgment is based upon a visual stimulus. The problem then is, how, with the postural cues provided by a particular tilt of the body, a particular retinal orientation becomes the proximal stimulus for perception of the upright. Regardless of how this problem is eventually solved, the fact remains that the orientation of the retinal image must be one component of the stimulus situation underlying perception of the upright.

However, in addition to speaking of the orientation of a line with respect to gravity—i.e., upright, tilted, or horizontal in space—introspective examination of daily experience suggests that we may also speak of a line's phenomenal orientation with respect to the self. In this sense one might refer to the line as appearing to be parallel to the sagittal axis of the head, tilted with respect to it, etc. We have no experimental knowledge of the

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stimulus conditions which might underlie this type of experience. It is clear, however, that, as in the case of perception of the upright, such an experience must be based upon a visual stimulus, namely, the orientation of the line.

The question then arises whether—as in the case of perception of the upright—the experience of a line's orientation to the self must also depend in some way upon postural cues of the direction of the force of gravity. Since, if *O* is tilted from the upright, the direction which is upright in space (i.e., the environmental upright direction) is no longer the same as the one which is parallel to the sagittal axis of the head (i.e., the sagittal anatomical direction), it is clear that the retinal orientation which defines the former is not always the same as that which defines the latter. Nevertheless, one might suppose that perceived orientation with respect to the self also depends upon postural cues of the direction of gravity. Hence one might ask the question: Is perception of orientation with respect to the self possible without reference to postural cues as to the direction of gravity?

It is entirely possible that in the case of phenomenal orientation with respect to the self, the orientation of the retinal image alone, without any additional cues provided by the direction of gravity, is a sufficient proximal stimulus. This means that particular retinal orientations determine particular phenomenal orientations of lines with respect to the self regardless of *O*'s orientation with respect to gravity. Thus a line stimulating a sagittal retinal orientation, for example, may always be experienced as parallel to the sagittal axis of the head regardless of the position of *O* in space. For this to be established, however, it would have to be shown that the orientation of the image can mediate such perceived orientation even when the possible role of gravity has been eliminated.

In other words, although for direction with respect to the upright of space (perception of the environmental upright) both orientation of retinal image and posturally given direction of gravity are important, it may be hypothesized that for orientation of a line with respect to the self (perceived egocentric orientation), only the former is necessary. Since, in daily life, the head changes its orientation while the upright remains fixed, there is no one retinal orientation which is the constant proximal stimulus for the perception of the upright. We continue to perceive the upright accurately when we ourselves are tilted although environmentally upright lines now fall upon tilted retinal orientations (different retinal orientations for different degrees of tilt). This is why perception of the environmental upright must be mediated by the combined action of the orientation of the image and the posturally given direction of gravity as was pointed out above (leaving aside for the moment the important role of the main lines of the visual scene in situations where one is present). On the other hand, regardless of the orientation of *O* with respect to gravity or in any other respect, a line which remains parallel to, say, the sagittal axis of the head will continue to stimulate a sagittal retinal orientation. The eyes do not change their orientation to the head to any appreciable extent.[2] Hence

[2] Some changes of eye orientation with respect to the head occur because of cyclotorsion of the eyes. Also some changes occur in such unusual cases as the counterrolling of the eyes when *O* is inclined laterally. It remains to be investigated whether in such cases the egocentric orientations of lines are actually displaced.

there very well can be a retinal orientation which is the proximal stimulus for a particular experienced egocentric orientation.

The reason we speak of orientation with respect to the head, rather than with respect to the entire body, is that it is really only appropriate to speak of a possible correspondence of retinal orientation with perceived orientation of a line with respect to the *head*. A given retinal orientation can maintain its egocentric directional significance only with respect to the head simply because the eyes do not change their orientation to the head to any appreciable extent, as mentioned above. Since the head may very considerably change its orientation to the trunk, obviously no fixed relation between retinal orientation and trunk is to be expected.

It is the purpose of the experiment to be described to demonstrate that the egocentric orientation of a line can be perceived under conditions where postural cues of the direction of gravity cannot possibly play a role. Furthermore, by eliminating eye movements and other factors as possible determinants, the experiment is intended to demonstrate the dependence of egocentric orientation on retinal orientation and to make a preliminary exploration of the exact nature of this relationship. It, perhaps, should be added that the use of the term "retinal orientation" in this paper is not meant to imply anything about the anatomical location of the neural correlate of perceived egocentric orientation. "Retinal-cortical orientation" would probably be more accurate in this respect, but we are only concerned here in referring to the proximal stimulus conditions in a purely descriptive sense.

Method

The basic plan of the experiment was to require *O* to judge the orientation of a luminous line with respect to the sagittal and left-right axes of his head while lying on his back on a table (supine position) in a totally dark room. The line rotated about a vertical axis in a horizontal plane 11 in. above the level of *O*'s eyes (see Fig. 1).

Under these circumstances it may be concluded that gravity does not play any role in the judgments. The line remains in the same relation to the force of gravity at all times, namely, in a horizontal plane; hence, no one position of the line would be in any way favored with respect to it. The possibility of touch or kinesthesis influencing the judgments in any other way was eliminated by preventing *O* from lifting his arms from the table. Furthermore, since the room was completely dark, it may be concluded that the judgments were not influenced by any visual frame of reference. As a further precaution, *O* was blindfolded before entering the experimental room, disoriented after entering it, and thus brought into the supine position on the table without any knowledge whatsoever as to where he was lying with respect to the walls of the room. Hence, it cannot be argued that anything like a frame of reference represented in memory can have contributed to the outcome.

It was also decided to eliminate the possibility that the judgments were based upon or improved upon by cues from eye movements. If *O* were allowed unrestricted eye movements during the time of observation of the line, he might sweep his eyes along its length thereby providing himself with a possible cue as to the orientation of the line with respect to his head. It was not necessary to eliminate eye movements in order to prove that the egocentric orientation of a line can be perceived independently of any role of gravity since, of course, the possible kinesthetic cues based on eye movements should not be confused with kinesthetic cues having to do with gravity. As noted above, however, another purpose of this experiment was to show that perceived egocentric orientation depends upon the orientation of the retinal image and not upon any other stimulus conditions.

The following procedure was, therefore, adopted. The line could be made to flash on for a brief fraction of a second (approximately .2 sec. in duration). Prior to each exposure of the line, *O* was given a signal to fixate a small luminously painted spot ($\frac{1}{4}$ in. diameter) at the center of the line. Shortly after *O* fixated, the line was exposed. Thus, although eye movements of appreciable extent perhaps *can* occur

in less than the time of exposure of the line, it is felt that the additional feature of fixation makes such a possibility unlikely. It may also be pointed out that even if occasionally *O*'s eye did move during exposure of the line it is still unlikely that this could account for his over-all average score of many settings.

Finally, *O* was allowed to use only one eye, the other eye remaining blindfolded throughout the experiment. It is possible that binocular vision might provide cues to the orientation of the line: a double image of the line produced by far or near fixation might be a cue because the width between the images would be maximum for the egocentric sagittal and zero for the egocentric left-right direction of the line.

A word should be said in advance about how the results are to be interpreted. The hypothesis that the egocentric orientation of a line can be perceived under the conditions of this experiment does not set any exact criterion to be met for its acceptance or rejection. What the hypothesis really amounts to is the contention that *O*s will be able to accomplish this to the extent that their judgments of the direction of the line will not simply be random in the sense that any one direction would be as apt to be chosen as any other. In other words it is by no means necessary and in fact it is impossible to predict the degree of accuracy with which this task can be accomplished.

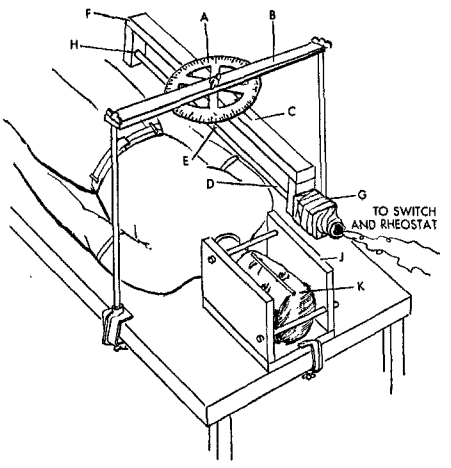

FIG. 1. Diagram of apparatus: *A*, Luminously calibrated protractor attached in fixed position to *B*; *B*, Supporting cross bar; *C*, Luminous marking for reading angular position of *F*; *D*, Lucite rod, $\frac{3}{8}$ in. in diameter and 14 in. long; *E*, Luminously painted fixation spot on underside of *D*; *F*, Lucite rod support; *G*, Wooden block containing small incandescent bulb covered with black friction tape; *H*, Silver-paper capping on end of lucite rod (hidden from view in figure); *J*, Headrest lined with foam rubber; *K*, Dowel taped along sagittal dividing line of *O*'s face serving as "zero" position.

Apparatus.—A drawing of the apparatus is shown in Fig. 1. A lucite rod is illuminated by a small incandescent bulb placed inside the wooden block so that the light can only escape through the opening in which one end of the rod is snugly fit. The other end of the rod is capped by silver paper so as to reflect back a maximum of light which illuminates the rod fairly homogeneously along its length. The bulb is connected with a telegraph key. A tap of the key turns on the light for about .2 sec. The lucite rod is directly underneath and parallel to the wooden supporting rod so that the position of the latter as indicated by the protractor reading also gives the position of the former. The intensity of the light is adjustable by a rheostat.

Procedure.—The procedure was explained to *O* outside the experimental room before he was blindfolded. He was told that he would be required to judge when a luminous line is parallel to either the long (sagittal) or the short (left-right) axis of his head; this was made fully clear by demonstrating with a pencil exactly what was meant by these two directions. Each eye was then separately blindfolded so that one eye could be uncovered when *O* was in position and the other could remain covered throughout. The *O* was led into the room, disoriented, and brought into the supine position on the table. His head was fixed firmly in the headrest, and a small dowel was taped along the sagittal dividing line of *O*'s face (see *K* in Fig. 1). This remained throughout the experiment and served as the guiding line for *E* in determining the zero or correct direction of the luminous rod for the sagittal settings (and therefore indirectly for the left-right settings). The lucite rod was brought to the zero protractor reading and the position of *O*'s head was then adjusted until the lucite rod was exactly parallel to the dowel. A small plumb line was used to bring the eye to be used directly underneath the luminous fixation spot. The headrest was then clamped to the table.

The room lights were then turned out and the blindfold was removed from one eye. The *O* was told to close the eye between each trial. At the signal "ready," he was to open his eye and look off to the side; at the signal "fix" he was to fixate the luminous spot and observe the direction of the line when it appeared.

The luminous rod was exposed at successive 5° intervals until *O* indicated its position to be correct. He was allowed to request *E* to show

TABLE 1

MEAN SETTINGS AND *SD*'S OF THE SAGITTAL AND LEFT-RIGHT EGOCENTRIC ORIENTATIONS

Observer	Settings to Equal Sagittal			Settings to Equal Left-Right		
	Mean	*SD*	σ_M	Mean	*SD*	σ_M
Left Eye						
1	1.5° CW*	5.0°	1.7°	7.0° CCW	12.2°	4.1°
Males 2	2.0 CW	2.4	.8	1.5 CCW	2.3	.8
3	4.0 CW	5.8	1.9	4.0 CW	4.4	1.5
4	4.0 CW	2.0	.7	8.5 CW	3.8	1.3
Females 5	1.5 CCW	3.2	1.1	6.0 CCW	6.6	2.2
6	4.5 CCW	6.5	2.2	10.0 CCW	7.4	2.5
Right Eye						
7	9.0 CW	3.7	1.2	9.0 CW	3.0	1.0
Males 8	3.0 CW	3.3	1.1	1.5 CW	2.3	.8
9	5.0 CW	5.5	1.8	8.5 CCW	7.8	2.6
10	5.0 CW	2.2	.7	2.0 CW	2.4	.8
Females 11	8.5 CW	3.2	1.1	4.0 CCW	5.7	1.9
12	3.5 CCW	5.5	1.8	14.0 CCW	8.0	2.7
Mean	2.7° CW	4.0°		2.2° CCW	5.5°	
SD	4.0	1.5		7.0	2.9	

* CW = Clockwise; CCW = Counterclockwise.

the rod again in a certain position or to reverse the direction in which the rod was being rotated. Trials for the left-right and sagittal directions were alternated; the rod was moved alternately in clockwise and counter-clockwise directions on trials for each of these directions. Altogether ten sagittal and ten left-right settings were obtained for each *O*. In order to prevent *O* from judging according to the constant number of intervals from the starting position the latter was varied from trial to trial anywhere from 85° to 0° from the correct position with the bulk of starting positions falling somewhere between 40° to 60° from it.

Subjects.—There were 12 *O*s varying in age from 16 to 34 yr. Six were males and six were females. Six *O*s used their left eye and six their right eye. There was no need for *O*s to be naive as to the purpose or procedure of the experiment. None, however, knew the position of the table in the room. The majority had never been in the room before.

RESULTS

The results are given in Table 1. The mean setting of each *O* was computed as an algebraic mean of the clockwise or counter-clockwise displacements of the line when it was judged to be "sagittal" ("left-right"), and is a measure equivalent to a constant error. The *SD*'s were computed from the obtained mean settings.

All *O*s were able to judge the egocentric orientation of the rod with considerable but by no means perfect accuracy and consistency. The mean settings range from 1.5° to 9.0° (clockwise or counter-clockwise) for the sagittal and from 1.5° to 14.0° (clockwise or counter-clockwise) for the left-right orientation. The *SD*'s range from 2.0° to 6.5° for the sagittal and from 2.3° to 12.2° for the left-right settings with mean *SD*'s of 4.0° and 5.5°, respectively. This means that retinal orientation does—within the limits of this accuracy and consistency—determine the egocentric orientation of a visual line. It may be mentioned in passing that in a preliminary experiment with seven *O*s, each given four trials for the sagittal

orientation only and allowed unrestricted eye movements, the results were quite comparable. The mean settings ranged from .25° to 7.75°. These similar results substantiate the assumption that eye movements do not play an important role in this task.

It should be pointed out that there is a certain limitation to the accuracy of measurements obtained in this experiment. The head is not a perfectly symmetrical geometric shape so that there are no precisely defined sagittal and left-right lines which may be taken as the zero positions for the settings. In the opinion of *E* these zero directions can only be given within a tolerance of one or two degrees.[3] Hence the settings obtained must be regarded as accurate measures of deviation from the sagittal and left-right axes of the head only within this degree of tolerance; settings deviating by this amount or less can then be taken to be nondeviating settings, whereas those deviating by more than this amount can be regarded as indications of a real difference between phenomenal and objective orientation with respect to the head.

The mean of the 12 *O* means for the sagittal settings is 2.7° clockwise (CW) and for the left-right settings is 2.2° counter-clockwise (CCW). These values are small and are not significantly greater than zero. Hence there is no evidence that there is a direction preference or constant error in the population as a whole.

On the other hand we see in Table 1 that, in several individual cases, there was a tendency to judge the rod as parallel when it was actually displaced in one particular direction. This is evidenced by the fact that for several *O*s the mean setting for the sagittal orientation or left-right orientation or sometimes both is significantly greater than zero in either the CW or CCW direction. Also in most of these cases the mean setting is sufficiently greater than 2° so that it must be regarded as really displaced from the sagittal or left-right axis of the head. This result would be understandable if we assume that the retinal orientation serving as the proximal stimulus for the phenomenal sagittal (left-right) orientation is, for many *O*s, either momentarily or permanently displaced from the objective sagittal (left-right) retinal direction in one particular direction. This interpretation makes particular sense in cases like *O* No. 7, where the mean setting for the left-right orientation is displaced in the same direction as the mean setting for the sagittal orientation and by the same amount, because one would logically expect that if one of the phenomenal directions is displaced the other would also be displaced so as to preserve the right angle relationship between them.

As noted above, half the *O*s were males and half females and half used the left eye and half the right eye. The purpose of this was simply to provide a sample which would not reflect any special conditions or type of *O*s. Nevertheless these factors might be responsible for differences in results although the number of cases in these groups is too small to warrant statistical comparisons. It might be supposed that the use of the left or right eye could influence the direction of settings. The results here were as follows: For the sagittal settings, the mean of the six means was .9° CW for the left eye and 4.5° CW for the right eye. For the left-right settings the mean of the six means was 2.0° CCW for the left eye and 2.3° CCW for the right eye. Thus the direction of error is the same for the two eyes in both cases.

In the case of sex, it might be supposed that there could be some difference in ability to perform this task. The most suitable measure of ability in this case is consistency (*SD*) since the mean settings may reflect individual constant errors and not inaccuracy as such. The mean of the *SD*'s for the six males was 4.3° and 3.8° for the six females for the sagittal settings. For the left-right settings these values were 5.3° and 5.7°, respectively. Hence the consistency of performance was, within the limits of these

[3] It might be argued that a line parallel to the direction which passes through the center of the pupils of the two eyes would serve to define precisely the *left-right* orientation. This however need not always be perpendicular to that direction which appears to bisect the face in the sagittal orientation.

small samples, about the same for maes land females.

Finally, the question arises as to whether or not there was any difference in difficulty in making the sagittal or the left-right settings. In this case there was evidence that *O*s found it more difficult to perform the latter task. This can be seen by the fact that, as determined by a *t* test, the mean of the 12 *SD*'s for the left-right trials is significantly higher than the mean of the 12 *SD*'s for the sagittal trials at the .05 level of confidence. Furthermore, whereas of the total of 120 settings made by the 12 *O*s there were only three of the sagittal orientation which deviated by as much as 15° from the zero position, there were 12 settings of the left-right orientation with this degree of error. Four of these 12 deviated by 20° and one by 25°, whereas none of the three "sagittal" cases exceeded 15°. There were also qualitative signs of the greater difficulty of the left-right trials.

Discussion

The results confirm the assumption of the dependency of perceived egocentric orientation on retinal orientation but also show that this holds only within certain limits of accuracy. The mean settings for many *O*s do not precisely coincide with the sagittal and left-right axes of the head. Furthermore, the size of the *SD* points up the fact that for a given *O* there is a range of retinal orientations within which any one may be the proximal stimulus for a particular phenomenal orientation of a line at a given moment (sometimes there is a considerable range of uncertainty for a given *O* even during a given trial). Some *O*s showed a range of 25° or more from their extreme CW to their extreme CCW settings. Nevertheless, since as noted above, the hypothesis only demanded settings which were better than random, it can certainly be regarded as having been substantiated.

To understand these results it is important to be clear about the following: The fact that the relationship of points or lines to one another in the outside scene is preserved in the retinal image (and in the pattern of excitation in the visual cortex) only means that we should expect these relationships to be preserved in visual experience. But this does not demand any correspondence between orientation of retinal stimulation and perceived orientation of a line with respect to the self. We should expect to experience an angle of 90° as a right angle because the angular relationship of lines to each other is preserved in the retinal image. But this does not logically require that this angle be experienced as in any particular orientation with respect to the self. That one of the sides of the angle happens to be parallel to the head and therefore stimulates a sagittal retinal orientation does not require us to expect, on logical grounds, that it will be experienced as parallel to the sagittal axis of the head and not, say, tilted with respect to it. The objective correspondence of a line's orientation to the head with its image's orientation to the head does not logically require a correspondence between the phenomenal orientation of the line to the head with its image's orientation to the head.

Our hypothesis that such a correspondence would nevertheless be found was therefore not based on any of the facts now known about retinal projection or the cortical representation of the retinal image. Rather, it was based on introspective observation and, as noted earlier, the fact that at least there could be a constant proximal stimulus direction for perceived egocentric orientation because of the more or less unchanging relationship of eye to head orientation. Our results show that while a fairly close correspondence between retinal orientation and phenomenal orientation to the head obtains it is not a precise correspondence. This bears out the logical consideration discussed above because by contrast the correspondence between the objective and the phenomenal orientation of two lines to each other is precise. Small differences in the orientation of a line relative to another line are readily perceived. Apparently orientation with respect to the self is not as finely discriminable.

The fact that in our experiment the orientation of the line is characterized with respect to the egocentric axes of *O*'s head should not be confused with the

question of the location of objects in space with respect to *O*. The location of objects from *O* is also given in egocentric terms, namely, left, right, above, below, but here these terms refer to the actual location, radially, from *O* (or from his mid-eye position as origin) of the object. The egocentric orientation of a line as studied in this experiment, however, refers to its orientation within a frontal-parallel plane with respect to the egocentric axes of the head and not, of course, with where the line, as a whole, is located with respect to *O*. This distinction does not mean that these two problems may not turn out to be related in certain respects.

Finally, it should be pointed out that although this experiment has demonstrated that egocentric orientation is perceived independently of postural cues of the direction of gravity, this does not mean that under other circumstances such cues may not play some role. It is possible that perception of egocentric orientation would be more accurate or at least would be changed in some way in a situation where the line rotates about a horizontal axis so as to change its orientation with respect to the direction of gravity. Hence this problem requires further exploration.

Summary

The purpose of this experiment was to test the possibility that the egocentric orientation of a line (its apparent orientation with respect to the head) can be perceived under conditions where postural cues of the direction of gravity cannot possibly play a role. This was accomplished by requiring *O*s to judge the orientation of a luminous line with respect to the sagittal and left-right axes of the head while lying in a supine position on a table in a totally dark room.

By eliminating other cues such as eye movements it was possible to show that the perception of egocentric orientation depends upon the orientation of the retinal image of the line. It was found that *O*s could accomplish this task with fairly good but by no means perfect accuracy or consistency. The study thus demonstrates the correctness of the hypothesis and presents factual data concerning how well such a task is actually performed.

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