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nal: Psychological research

e: Modulation of the rod and frame effect: Retinal angle vs apparent size

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0340-0727 EISSN:

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mber: BF3.P65

Psychol Res (1980) 42:327–334

Psychological Research


# Modulation of the Rod and Frame Effect: Retinal Angle vs Apparent Size*

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**Summary**. Two rod and frame displays, constructed in a 3:1 linear ratio, were used to assess the apparent vertical. When viewed at the common distance of 1.5 m, the larger-appearing frame also produced the greater retinal angle. With the small frame at .5 m and the large one at 4.5 m, the smaller-appearing frame produced the greater retinal angle. In both cases the rod and frame effect increased with increasing retinal size, rather than with the apparent size of the frame.

## Introduction

The rod and frame effect (RFE) is usually taken to express the fact, emphasized by Gestalt psychologists (Koffka 1935), that many aspects of space perception, and spatial orientation in particular, are determined by relationships among the elements in the visual stimulus pattern. First investigated by Witkin and Asch (1948), the RFE occurs when, in an otherwise dark room, an observer attempts to identify the vertical position of a luminous rod that is surrounded by a tilted square luminous frame. Both rod and frame typically are co-planar and frontoparallel and are capable of rotation around a common axis at the center of the frame. With a frame tilt of about 20 deg clockwise (cw) the rod will appear upright when it too is actually cw of the gravitational direction. The magnitude of error varies greatly among individuals (e.g., Witkin and Oltman 1967) but errors averaging 6 to 9 deg in the direction of the frame are not uncommon.

There are now hundreds of studies relating performance on the rod and frame to other tasks thought to measure such states as psychological differentiation, personality characteristics, sex differences, psychomotor style, etc. (e.g., Long 1974; Sloan 1976). Nevertheless few variables capable of modulating the RFE within an individual have been isolated (e.g., Gogle and Newton 1975; Graf 1966). In this connection, several

*This research was supported by NIH Grant EY 02264 from the National Eye Institute to the first author.

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0340–0727/80/0042/0327/$ 01.60

recent experiments (Ebenholtz and Benzschawel 1977; Ebenholtz 1977) have shown that a reduction in retinal size of the frame causes a corresponding decrease in the RFE. The magnitude of this effect is such that almost complete attenuation of the RFE (to 1 or 2 deg) can be produced by reduction of the retinal angle to about 8 deg or less.

In the studies cited, either retinal size was maintained at a constant level while perceived size was varied by manipulation of the convergence cue, or retinal size decreased because of increasing distance to the frame. In the latter case perceived size either stayed constant because of size constancy or also decreased with retinal angle. In all instances the RFE varied with changes in retinal angle, while changes in perceived size seemed to be without any effect at all. It may be significant that in these studies retinal size was never placed in direct conflict with perceived size, a condition which may provide a more sensitive test of the possible role of perceived size. Accordingly in the present study, in one condition perceived size and retinal size were positively correlated whereas in a second condition the larger-appearing of two frames actually produced the smaller retinal angle.

In addition to an examination of the potential conflict between apparent and retinal size, the present experiment compared the effects of egocentric and gravitational instructions on the RFE. Since there is evidence that a tilted frame is capable of inducing an apparent head tilt opposite in direction to that of the frame (Ebenholtz and Benzschawel 1977) one would expect differential effects of instructions. For example, a gravitational reference might entail compensation for the apparent head tilt and hence should enhance the RFE relative to an egocentric reference.

## Method

*Procedure.* The RFE was measured by taking the algebraic difference between the mean of two rod settings taken with the frame upright and two additional settings with the frame-tilted 22 deg cw, always in the order as given. Half the subjects were instructed to adjust the line so that it appeared upright with respect to the gravitational direction, i.e., parallel with the unseen walls of the room. The remaining subjects received egocentric instructions to set the rod so that it appeared to be in line with their body. In all cases subjects were told to make sure the line 'appeared upright to you.' The starting position of the line alternated between 25 deg cw and ccw or true vertical and bracketing of the final position was permitted.

All subjects made estimates of the apparent vertical in two rod and frame displays, the smaller of which had one-third the linear dimensions of the larger, with order of frame size counterbalanced over subjects. After completing the second adjustment with each frame verbal estimates, in feet and inches, of the length of one edge of the frame and its distance were made.

*Apparatus.* The two rod and frame displays were made of electroluminescent panels, the larger of which measured 106.8 cm on a side, with a rod length of 85.2 cm. The width of the luminous portion of the rod and frame was 0.9 and 2.4 cm, respectively. The smaller display was proportionally one-third the size of the larger unit. Luminance was somewhat under 1 cd $m^{-2}$. The line orientation in each display was controlled by the experimenter and rotated at 1 rpm. A digital readout or a meter permitted judgments to be estimated to the nearest .5 deg.

At the start of the study the height of the chair was adjusted so that for each subject the outer canthus was at the height of the axis of rotation of the rod and frame. Throughout the study the subject was seated in a dental chair with head positioned upright through the use of a chin cup and temple clamps. For the second of the two displays the entire chair was swiveled, and hence the viewer maintained a constant posture.

Viewing was binocular and only one rod and frame display was visible at one time.

*Design.* Two groups of 24 volunteer subjects each took part. In the equal-distance condition both frames were stationed at 1.5 m from the subject, producing retinal angles of 13.6 deg and 40.8 deg for the small and large frames respectively. In the unequal-distance condition the small frame was viewed at .5 m while the large frame was placed at 4.5 m, thereby completely reversing the relationship between retinal angle and linear frame size as obtained in the equal-distance condition. In this case the large frame produced a retinal angle of 13.6 deg, the small frame that of 40.8 deg. Within each condition 12 subjects received egocentric, the remaining 12 receiving gravitational instructions.

**Results and Discussion**

*Sequence and Instructions.* For each distance condition there were two types of instructions yielding four groups of 12 subjects each. Within each of these groups half the subjects received the small frame first, half starting with the large frame. Since previous research (e.g., Ebenholtz and Benzschawel 1977) had shown an influence of prior exposure on a subsequent RFE, it was necessary to analyze each of the four groups for sequence effects. The analysis of variance proposed by Grant (1949) examined each group for effects of sequence, order and frame size on both the RFE and frame-size estimates. In three of the four groups there was a tendency for the second RFE to be influenced in the direction of the first task, but in no case did either sequence or order significantly influence the RFE or the apparent size. In all groups, frame size showed significant effects, in favor of the frame yielding the larger *retinal angle* in the case of the RFE, while size estimates increased significantly with actual frame size. Thus in the two unequal-distance subgroups retinal size and perceived size were inversely related, with the former governing the RFE. These results will be further analyzed below.

Instructional effects were evaluated separately in each distance condition after combining over sequence. In each case instruction was without significant effect on either the RFE or size estimates. Therefore in subsequent analyses groups were combined over instructional condition.

The absence of instructional effects contrasts with the results of Sigman, Goodenough, and Flannagan (1979) who found eogcentric instruction effective in reducing the RFE. Their subjects were screened and selected so as to yield a relatively large RFE. Perhaps more importantly, however, is the fact that subjects were tested at the upright as well as at 3 and 6 deg cw and ccw. The differences in RFE due to instructions tended to increase with body tilt and a significant body tilt × instructional condition was found. Although as expected in the present study the egocentric condition always produced the lower RFE, that differences were not significant is probably due to the exclusive use of the upright body posture where only small effects of the egocentric instruction prevail.

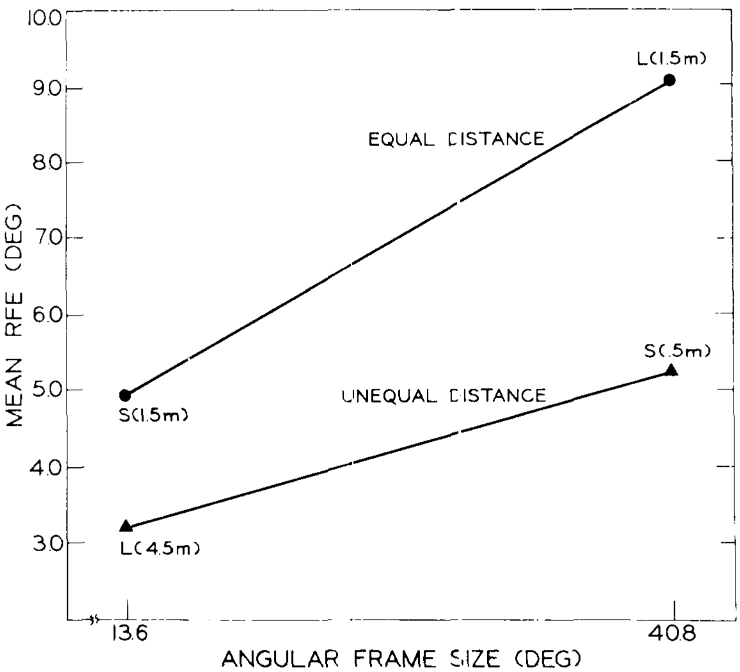


**Fig. 1.** Mean rod and frame effect (RFE) as a function of the retinal angle of the large (L) and the small (S) frames

*Frame Size.* Figure 1 represents the RFE as a function of angular frame size for each of the two distance conditions. At equal distances all 24 subjects showed an increase in RFE with frame size while in the unequal-distance condition 20 out of 24 subjects increased their RFE in response to the *small* frame at the near distance. Analysis of variance showed a significant effect of distance-condition, $F(1, 46) = 4.18$, $P < .05$, angular size, $F(1, 46) = 49.06$, $P < .01$, and the interaction of the two, $F(1, 46) = 5.60$, $P < .02$. Thus although in both distance-conditions the larger retinal angle produced a significantly greater RFE, this increase was greater when both frames were at the same distance.

Might these differences be attributable to comparable variation in perceived size with angular size? Size judgments are represented in Fig. 2. Analysis of variance on these data showed a significant effect of distance-condition, $F(1, 46) = 31.4$, $P < .01$, and the interaction of distance with angular size, $F(1, 46) = 104.37$, $P < .01$. In general size judgments tended to reflect the linear sizes of the frames and hence to some degree, the presence of size constancy. Thus in each distance condition the large frame was seen as larger than the small frame, even though at 4.5 m there was an underestimation of the size of the large frame that one may attribute to a reduction in size constancy at this distance.[1]

[1]Distance estimates, not reported in detail, showed the large frame at 4.5 m to be considerably underestimated at 2.68 m while the small frame at .5 m was rather correctly judged at .56 m. In the equal-distance condition with both frames at 1.5 m, the large frame was estimated at 1.36 m, the small one at 2.15 m

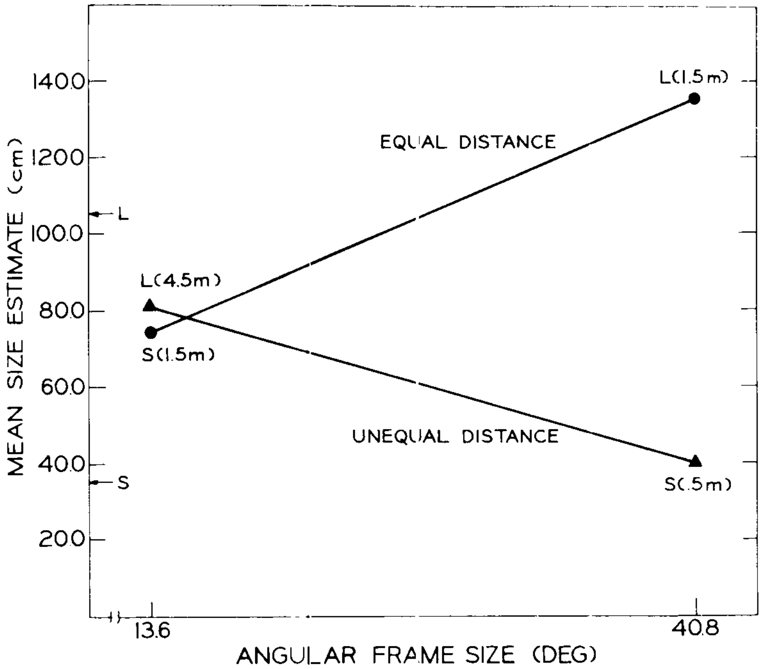


**Fig. 2.** Mean size estimates as a function of the retinal angle of the large (L) and the small (S) frames

The nature of the interaction of retinal size with distance-condition is quite different for the RFE from that for perceived size; in fact for the unequal distance condition the changes produced by increasing retinal angle were in opposite directions for the two response measures. It is clear, therefore, that retinal size, not perceived size, determines the change in RFE within individuals and this is consistent with previous research using an independent groups design (Ebenholtz 1977).

Why then was the RFE lower under the unequal distance than under the equal-distance conditions? One answer simply is that by chance there occurred either more field dependent observers or observers who were more strongly field dependent in the latter condition than in the former. Since small retinal projections limit the magnitude of the RFE for all subjects, high scoring individuals would be more likely to manifest a large RFE at larger retinal angles, thereby yielding the interaction effect in question. In previous research (Ebenholtz 1977) where the same group of subjects were exposed to both a large frame at 4.5 m and a small frame at 1.5 m so as to produce identical retinal angles, the resultant RFE was equivalent in the two groups, even though the relative linear sizes of the frames were veridically perceived. Thus it is likely that the failure to obtain equivalent levels of RFE under the two distance conditions of the present study is due simply to an uneven distribution of individual differences in performance on the RFE in the two groups. Support for this conjecture derives from the male and female composition of the two distance conditions. At unequal distances there were 12 male and 12 female subjects whereas at the equal-distance conditions, there occurred 16 female and 8 male subjects. Since gender is correlated with the RFE (Witkin, Goodenough, and Karp 1967) the proposed explanation seems likely. In any event, the crucial result remains that in the conflict condition, the RFE varied inversely with perceived size and directly with retinal angle.

**General Discussion**

When the relative retinal size of two frames was set in conflict with relative perceived size, as in the unequal-distance condition, the trend in the RFE followed the change in retinal angle and not that in perceived size. Thus, with the frames at unequal distances, the RFE increased significantly with increasing retinal angle while under the identical conditions perceived size showed a significant decrease.

The dependence of the RFE on retinal as opposed to phenomenal size offers a clear limitation to the development of a cognitive theory of the RFE. Furthermore it serves to set the RFE apart from other phenomena where attributes of phenomenal states rather than of their specific stimulus inputs serve as adequate and appropriate causal descriptions. Examples of this theoretical approach, largely developed by Rock (e.g., Rock 1970), may be found in research on the role of phenomenal vs retinal orientation in form recognition (Rock 1973), the effect of perceived depth separation on the quality of stroboscopic movement (Attneave and Block 1973), the role of apparent distance on induced self movement (Wist et al. 1975), the role of spatial adjacency (Gogel 1973), and many other phenomena including lightness perception (Gilchrist 1977) and masking (White 1976). In all these cases the results of constancy processing in the domains of orientation, size, stereoscopic depth, motion, and position are utilized at some further stage to influence the phenomenon in question. In the case of the role of frame size in the RFE, however, the results of the conflict condition of the present study are consistent with previous results (Ebenholtz 1977) in demonstrating that size constancy processing is quite irrelevant.[2] A similar conclusion seems to be warranted in the case of form processing as well (Streibel et al. 1980).

It has been proposed (Ebenholtz 1977) that the effects of retinal size on the RFE are mediated by the shift from parafoveal to peripheral stimulation that typically accompanies any increase in the size of the retinal image of the frame. The failure of apparent size to be effective implies the stimulation along pathways and/or of central projection sites associated with the peripheral retina is essential in the sense that post-constancy processing of size information is not utilized in the RFE.

The present results suggest that peripheral retinal stimulation is a significant site for the control of spatial orientation, but not merely because of the importance of maintaining invariant relationships among the elements of the retinal pattern. Rather the results support the theory of two visual systems by which a functional dichotomy between periphery and fovea is proposed (Held, Dichgans, and Bauer 1975; Johnson et al. 1976; Leibowitz and Dichgans 1979; Schneider 1967; Trevarthen 1968). Accordingly events represented peripherally enable the organism to be acted *upon* by influencing

[2]The results of Gogel and Newton (1975), however, suggest that a depth processing stage may precede the assignment of orientation to the rod in the RFE. It remains to be shown whether or not this is true only of frames projecting small retinal angles under about 10 deg of arc

body and object orientation while foveal[3] stimulation enables the organism to act *on* the environment by mediating such processes as recognition, inspection, and a variety of sensorimotor acts. This theoretical context offers a new interpretation of the individual differences typically found in studies of the RFE. Such differences including sex differences may be linked to variation in the functional differences between the two systems, field dependence, for example, reflecting the relative predominance of the peripheral orientational system.

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[3]Previous research (Ebenholtz 1977; Ebenholtz and Benzschawel 1977) suggests that the RFE diminishes to near zero when the retinal angle of the frame reaches about 8 deg. It is clear then that the parafoveal region is implicated and that the two visual systems are not merely isomorphic with the conventional rod and cone distributions

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Received April 15/November 12, 1980



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