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Short Report

Evidence for the subsystems in stereopsis: fine and coarse stereopsis

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Magnitudes of apparent depth were measured for two stereonormal and three stereoanomalous observers who had been identified by depth discrimination tasks. The two groups of observers showed different peaks of depth sensitivity to disparity. The stereoanomalous observers all reported reduced magnitudes of apparent depth and two of them, reversed depths in a range of relatively large crossed disparities, although they reported similar apparent depths to that of stereonormals in a range of relatively small disparities. These results were discussed as evidence to support the two-subsystem hypothesis of stereopsis.

Key words: fine stereopsis, coarse stereopsis, stereoanomaly, depth magnitudes, disparity processing.

Stereopsis is the sensation of relative depth brought by the images of a stimulus falling on the disparate retinal locations of the two eyes. By several investigations on stereopsis two different underlying subsystems have been distinguished: one is fine stereopsis which occurs when relatively small disparity is presented, and the other is coarse stereopsis which occurs when large disparity is presented (Bishop & Henry, 1971; Bishop, 1973). In fine stereopsis, subjects can easily fuse the images even when the eye vergence does not change and the magnitude of perceived depth increases linearly as disparity increases, while in coarse stereopsis subjects report frequently diplopia of the two images when stimuli are presented briefly and the magnitude of perceived depth does not increase linearly as disparity increases. Recently, the neurophysiological substrata of the two different subsystems were found (Fernster, 1981; Poggio & Fischer, 1977; Poggio & Talbow, 1981).

One of the ways to separate psychophysically these two subsystems is to find observers who show normal responses in the small disparity range but anomalous responses in the large disparity range. Jones (1977) and Shimono, Kondo, Shibuta, and Nakamizo (1982, 1983) have found observers who could not discriminate large disparities but had normal stereo-acuity. Their partial anomaly to large disparities implies that one of the subsystems to process large disparities (coarse stereopsis) is troubled or absent, although the other subsystem to process small disparities (fine stereopsis) is normal.

On the contrary, Richards and Kaye (1974) failed to show the dual-system of stereopsis in measuring the magnitude of perceived depth of a stereoanomalous observer who had been identified by depth discrimination tasks (Richards, 1970). His subject could not discriminate between zero and uncrossed disparity (0.5°–2°) (Richards, 1970). He perceived near-zero depth in the range of uncrossed disparity (0.05°–16°) (Richards & Kaye, 1974). These results do not seem to support the two-subsystem hypothesis of fine and coarse stereopsis. It is, however, possible to interpret the results as indicating that both the systems are troubled or absent.

In this paper, we investigated depth magnitudes perceived by two stereonormal and three stereoanomalous observers who had been identified by depth discrimina-

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tion tasks in our previous studies (Shimono et al., 1982, 1983) in order to show more evidently the dual-system of stereopsis. If stereopsis consists of two different subsystems (fine and coarse stereopsis) and one of them is troubled for stereoanomalous observers, their troubles will be reflected in the magnitude of perceived depth. The magnitude of perceived depth in the range of anomalous stereopsis will be nearly zero, for the anomalous system which cannot process the disparity presented will give rise little or no depth sensation.

Method

Apparatus. A schematic representation of the apparatus is shown in Fig. 1. Subjects viewed the display on the C. R. T. Screen (NEC PC-8083) controlled by a computer (NEC PC-8801). The stimuli consisted of one pair of vertical line targets (0.62°×0.018°), each of which was presented in each of two rectangles (1.04°× 1.12°), located at the subject's eye level and on the frontal parallel plane at the distance of 200 cm from the subject's eyes.

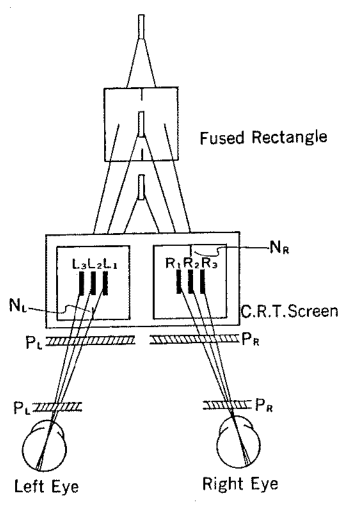

Fig. 1. A schematic representation of the apparatus: N_L, N_R—nonius lines; L1, L2, L3, R1, R2, R3—stimuli with disparity; P_L, P_R—polarizing filters. See text for description.

Each rectangle had a vertical nonius line (0.14°×0.009°) at the middle of its bottom side (N_L) or that of top side (N_R). The stimuli was viewed dichoptically through two pairs of polarizing filters placed in front of the observer's eyes and in front of the C. R. T. Screen, that is, the right eye could view the right rectangle and the left eye could view the left rectangle. When each vertical line target was presented inside (L1 and R1), on (L2 and R2), or outside (L3 and R3) the center of each rectangle, it produced crossed, zero or uncrossed disparity, respectively. When the observer's eyes were directed to the centers of the rectangles so that their images were fused, the convergence was symmetrical and the convergence distance was approximately 600 cm. The exact convergence distance varied among subjects because of individual differences in interocular distance. However, the corresponding differences in disparity were negligible. The lines presented had crossed (1′, 3′, 30′, 50′), zero and uncrossed (−1′, −3′, −30′, −50′) disparities.[2] The luminance of the stimulus was about 10 cd/m^2.

Procedure. After the subject reported that the single rectangle was seen and the nonius lines were seen in alignment, the vertical line targets with disparity were presented for 500 ms[3]. The subject was

[2] It is generally accepted that the subsystem to process small disparities operates when disparity less than ±30′ is presented and that the subsystem to process large disparities operates when disparity larger than ±30′ is presented (Jones, 1977; Richards & Kaye, 1974; Sperling, 1970). In this paper, " small " disparity refers to ±1′ and ±3′ disparities and " large " disparity refers to ±30′ and ±50′ disparities.

[3] This duration in the present experiment was based on the result of a pilot study in which a stereoanomalous observer, T.M., was investigated. It was difficult for him to report the depth magnitudes for small disparities with a sort duration (200 ms). This fact is consistent with the Jones' (1977) suggestion as to the temporal property of the stereoscopic system.

asked to estimate the apparent distance of the line target on a percentage scale based on the apparent distance of the fused rectangle: he was asked to assign the number "100" to the apparent distance of the fused rectangle and the number "100−*x*" ("100+*x*") to the apparent distance of the line target according to his relative perceived depth ("*x*") if the line target was seen in front of (behind) the fused rectangle.[4] Before the experimental session the subject carried out the practice session of 18 trials in each of which feedback was given. One hundred and eighty trials were run in two blocks of experimental session in randomized order of presentation.

Subjects. Subjects participating were two stereonormal observers: S.N. and M.K. could discriminate among large crossed, large uncrossed and zero disparities and had normal stereo-acuity, and three stereoanomalous observers: K.S. could not discriminate between large crossed and zero disparities but had normal stereo-acuity; T.M. could not discriminate among large crossed, large uncrossed and zero disparities but had normal stereo-acuity; and Y.M. could not discriminate among large crossed, large uncrossed and zero disparities and did not have normal stereo-acuity (Shimono et al., 1982, 1983). All subjects had been classified by the three-alternative forced-choice method of depth discrimination for large disparities (2°). Their stereo-acuity were measured by a test with Topcon Screeno-Scope (Tokyo Kogaku). In that test, subjects were asked to report the order in depth of five test objects that had disparities of zero, 27″, 55″, 103″, and 206″, respectively. We decided that a subject had the stereo-acuity, at least, to process the smallest disparity of the test objects, when he could report the order of them correctly. The subjects had no history of strabismus and normal visual acuity better than 20/20 as measured on Topcon Screeno-Scope.

Results

The results are shown in Fig. 2. Figures 2(a) and (b) are the data of stereonormal subjects, S.N. and M.K., and (c), (d) and (e) are the data of the stereoanomalous subjects, K.S., T.M. and Y.M., respectively. In Figs. 2(a) and (b) the perceived depth increases linearly first as disparity increases and becomes flat in a range of large disparities (±30′, ±50′). The stereonormal subjects reported their ap-

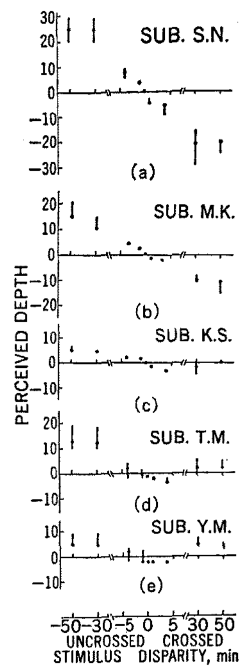

Fig. 2. Perceived depth as a function of disparity: filled circles represent the medians and vertical lines, the semi-inter quartile ranges. Perceived depth was calculated as follows:
Perceived depth = (perceived distance of the vertical targets) − (perceived distance of the fused rectangle)

[4] This procedure has been shown to produce similar results to those obtained by the method of depth-matching, in which the subject adjusted location of a probe to correspond to their perceived depth (Foley & Richards, 1972).

parent depth correctly corresponding to the sign of disparity. These data are similar to those of Richards' " stereonormal " subject (Richards, 1971, p. 412, Fig. 2, the top graph). Apparently they discriminate all disparities presented.

On the other hand, Figs. 2(c) and (d) show that the magnitudes of perceived depth for the stereoanomalous subjects, K.S. and T.M., are similar to those for stereonormal subjects in a range of small disparities but different from those for stereonormal subjects in a range of large disparities. They reported the perceived depth which increased with disparity in the range of small disparities, and the reduced magnitudes of apparent depth in the range of large crossed and uncrossed disparities; moreover, the direction of perceived depth did not correspond to the sign of disparity in the range of large crossed disparities. Therefore, it is reasonable to conclude, at least, that K.S. and T.M. have anomalous stereopsis in the range of large crossed disparities.

Figure 2(e) indicates that the magnitude of perceived depth for a stereoanomalous subject, Y.M., is different from those for stereonormal subjects: the target in the range of large crossed disparity is perceived behind the plane of fixation and the magnitudes of depth are very small, and that in the range of small disparities is perceived roughly at the plane of fixation. This means that the stereoanomalous subject could not discriminate between crossed and uncrossed disparities in either small or large disparity ranges.[5]

Discussion

The results obtained in the present study can be interpreted as evidence to support the hypothesis that stereopsis consists of two different subsystems. As described above, two subjects, K.S. and T.M., had anomalous stereopsis at least in the range of crossed large disparities. These stereoanomalous subjects had normal stereoacuity and the obtained profiles of their depth sensitivity in the range of small disparities are similar to those of stereonormal subjects. These facts indicate that the stereoanomalous subjects, K.S. and T.M., have a normal subsystem to process small disparities and an anomalous system to process large disparities. In this paper we have clarified the distinction between fine and coarse stereopsis by studying the depth magnitudes perceived by stereonormal and stereoanomalous subjects.

[5] Herring and Bechtoldt (1981) also reported the same type of subject who confused crossed and uncrossed disparities but discriminated between zero and crossed/uncrossed disparities.

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Short Report

Memory for instance information in concept learning[1]

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An experiment was conducted to investigate the nature and utilization of the stored information in memory during concept learning. Twelve subjects learned to classify 20 stimuli, strings of five letters, in the reception paradigm, and then they were given recognition and classification tests with 12 old and 18 new instances. Although recognition performance was not good, ratings of recognition confidence revealed subjects' ability to discriminate between old and new instances. It was evident that they stored some information about instances as the basis of recognition judgments, even if they did not memorize each instance itself. The property-set model (Hayes-Roth & Hayes-Roth, 1977) was modified to predict quantitatively the recognition and classification data. As for the recognition data, there were considerable differences in the goodness of fit among subjects. The fairly good fit of the model to the classification data was interpreted as reflecting the category structure. It is suggested therefore that subjects paid attention to not only different properties but also different categories.

Key words: memory for instance information, recognition and classification, property-set model, multiple regression analysis.

In the reception paradigm of concept learning, subjects are successively presented stimuli to be classified which are followed by feedback on their category membership. Once a subject find a rule to classify the instances, he or she will respond to novel instances using that rule. However, even without precise description of the concept, the subjects may act regularly to some extent, rather than act randomly, making use of memory for instances which they have encountered during learning. It has been reported that memory for instances is fairly poor, both recognition and recall being hardly above chance level (Coltheart, 1971). Although this does not seem surprising since they were not explicitly requested to memorize each instance itself, it is possible that some information drawn from instances is stored in

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