Central Mechanisms of Stereopsis in Man

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ABSTRACT

Stereopsis or binocular depth perception is usually thought to depend on the
integration by cortical cells of binocular information transmitted by way of two
pathways: 1) the retino-thalamic pathway, via the optic chiasm; 2) the more
indirect interhemispheric route, via the corpus callosum. The present set of
studies investigated the selective effects of lesions of either pathway and as-
sessed the consequences of striate cortex damage on binocular depth perception.
Four callosal agenesis subjects, three subjects with occipital damage and one
chiasmatectomized patient were thus compared to 10 control subjects on a variety
of stereoscopic tasks. Results indicate that patients without corpus callosum
are able to succeed in most tasks although they show higher thresholds than IQ-
matched controls. Similar results were obtained with occipitally-damaged pa-
tients. Although midline coarse or global stereopsis was observed in the
chiasmatectomized patient, his stereoscopic abilities were very limited con-
firming the fact that the optic chiasm is the most important pathway in conveying
binocular information.

KEY WORDS

Stereopsis; corpus callosum; optic chiasm; occipital damage; humans

INTRODUCTION

Stereopsis or binocular depth perception is thought to depend upon the integra-
tion by binocularly driven cells of retinal images falling on disparate positions
in the two eyes (Poggio and Poggio, 1984). The anatomical substrate traditionally
presumed to convey this information to the binocular cells is the retinothalamic
pathway, partially decussating at the optic chiasm, although the involvement of
the transcortical route via the corpus callosum has also been suggested (Berlucchi
and Rizzolatti, 1968; Lepore and Guillemot, 1982). Indirect evidence of the
implication of the latter structure comes from the study of the effects of uni-
lateral occipital lesion in cats; indeed these operated animals show a reduction
of binocular activity in the contralateral hemisphere (Blakemore and others,
1983). The present set of experiments attempted to correlate these electrophysiolo-
gical findings in man with their capacity to perform binocular depth perception
tasks.

EXPERIMENT 1:   THE STUDY OF GLOBAL STEREOPSIS

The global stereopsis task consisted in determining whether the stimuli, two
random-dot stereograms, appeared in front of, or in the same plane as, a central
fixation point.   The actual procedure has been described elsewhere (Lassonde,
1986).   Briefly, the stimuli were generated by an Apple II computer and were
presented on a color monitor at various eccentricities (0°, +2.5° and +5°) using
three values of crossed and uncrossed disparities ($\pm$ 0.4°, $\pm$ 0.8° and $\pm$ 1.2).   The
subjects, wearing red and blue filters, first performed the task under a relatively
long exposure (4 s); when the performance reached a level of 90% in a series of
40 trials, stimulus duration was progressively reduced to 200 ms.   The subjects
were then submitted to a total of 480 trials.   The results in terms of percentages
of correct responses obtained by four callosal agenesis patients and four matched-
IQ subjects at eccentricities of 0° and 5° are shown in Fig. 1 A and B, respec-
tively.   The data of three patients with unilateral occipital damage (two left,
one right) are presented in Fig. 1 C and D.   For the latter group, only the
results for peripheral presentations were computed since two of the three patients
showed some macular sparing; their results are compared to those of a patient with
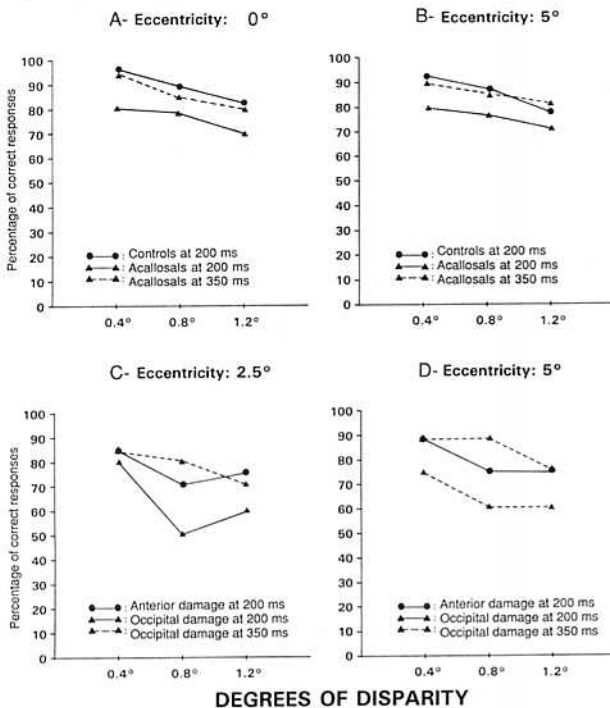anterior damage to the right hemisphere.

Fig. 1   Percentages of correct responses obtained by the
various groups in the random-dot stereograms task

At presentations of 200 ms, the acallosal subjects performed above chance levels
at all disparities and both eccentricities (Fig. 1 A, B).   However, their perfor-
mance was inferior to that of the controls, regardless of whether the retinal
images of the stimuli were conveyed to the same (eccentricity 5°)or different
hemispheres (eccentricity 0°).   This difference between acallosal and control
subjects disappeared when the former were allowed to view the stereograms for a
slightly longer period (350 ms).   Similar results were obtained from the patients
with unilateral occipital damage (Fig. 1 C, D).

On the other hand, the chiasmatectomized patient could not perform the task even when long stimulus exposures were allowed. In order to determine whether he could discriminate simpler random-dot stereograms, he was submitted to the TNO test for stereoscopic vision (Lameris, 1972). After an exploration of about 10 min, the patient could discriminate details of some of the protruding figures. His stereoacuity was evaluated to be 240-480", a rather high value with respect to a normal acuity of 60". His control subject in this task, a patient with microstrabismus, could not perform the task even after viewing the stimuli for 30 min.

EXPERIMENT 2:   THE STUDY OF COARSE STEREOPSIS

The coarse stereoscopic task consisted of judging the distance between pairs of familiar objects differing only in their color (yellow or green) and occasionally their size. The objects were positioned on a table covered with a black woolen sheet a) one to the left, the other to the right of a central red diode, with a distance of approximately 1° between each other (central condition); b) at 4.5° both to the right or to the left of the fixation point (intraperiphery condition); and c) at 4° of visual angle, one to the right, the other to the left of the central fixation point (interperiphery condition). The room was completely darkened and the objects were illuminated for the brief period of 50 ms by a stroboscopic light mounted 3 m above the fixation point. Each condition comprised 64 trials and the subject's task was to indicate which of the two objects was closer, the yellow or the green.
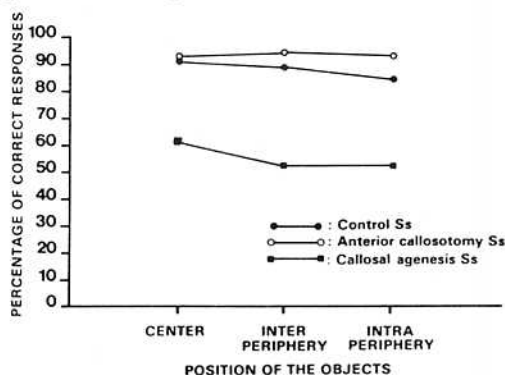

Fig. 2   Percentages of correct responses obtained in the task requiring a binocular evaluation of distance between two objects

Figure 2 shows that the four acallosal subjects were less apt to make depth judgments than their four matched-IQ controls, regardless of the position of the stimuli. For purposes of comparison, two patients who had undergone an anterior callosotomy for treatment of epilepsy were also tested under the same conditions and the results indicated that their performance was comparable to that of the other control group.

The chiasmatectomized patient and his control subjects (four normals and one with microstrabismus) were submitted to a variation of this task in which two objects or two diodes were presented centrally in front of the fixation point. Two disparity values were used: 0.25° and 0.5°. Results are presented in Fig. 3. Under monocular viewing conditions, none of the subjects could perform the task. With binocular presentations, the chiasmatectomized patient could perform the task above chance levels at a disparity of 0.5°. By contrast, the subject with microstrabismus completely failed the binocular conditions whereas the normal subjects had almost perfect scores.
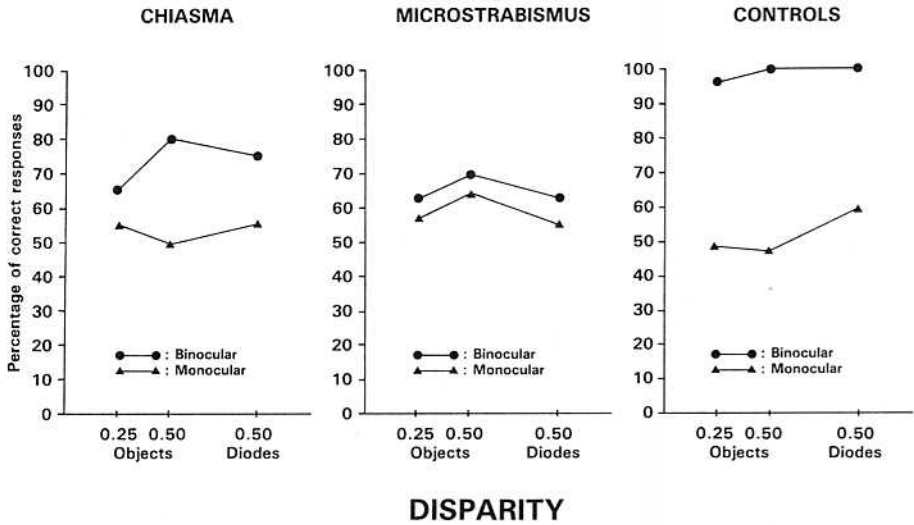
DISPARITY

Fig. 3   Percentage of correct responses obtained by the
chiastectomized patient and his controls in the coarse
coarse stereopsis task

CONCLUSIONS

The results indicate that the optic chiasm is the most important pathway in con-
veying binocular information. Without this structure, some coarse stereopsis is
possible in the midline of the visual field. High thresholds of global stereopsis
may also be achieved through long exposure times. On the other hand unilateral
occipital damage as well as callosal absence increase the shresholds to coarse and
global stereopsis but only when liminal conditions, such as brief stimulus expo-
sures, are used.

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