The kinetic and static function of binocular disparity

Motor fusion at constant disparity

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Binocular disparity has a kinetic function as the physiological stimulus to fusion movements. The velocity of the fusion movement is a function of the magnitude of disparity. Retinal disparity also has a static function. Fixation disparity is the physiological stimulus to sustained fusional tonus.

Key words: binocular disparity, fixation, fusion, convergence, divergence.

The basis of the theory of binocular vision is the definition of corresponding points. Retinal points are said to correspond if a target that is imaged on such points is localized by each eye in the same direction. Stimulation of non-corresponding points, "disparate points," by the same target generally leads to double vision. When the disparity is small, binocular single vision is possible (sensory fusion within Panum's areas). Stereopsis is the important sensory aspect of horizontal disparity. In addition, binocular disparity has a dual motor aspect: kinetic and static.

1. The kinetic function of disparity is well known: Disparity is the physiological stimulus to fusion movements. Esodisparity (binasal stimulation) causes divergence; exodisparity (bitemporal stimulation) causes convergence. Cyclodisparity and vertical disparity are the stimuli to corresponding fusion movements.

2. The static aspect of binocular disparity is the phenomenon of fixation disparity. This is a small deviation of the visual lines (or, in the case of cyclodisparity, of the corresponding retinal meridians) in the presence of binocular vision. The deviation is smaller than the diameter of Panum's fusion areas. Spontaneous fixation disparity is a sign of oculomotor imbalance (heterophoria). Artificial fixation disparity appears when the eyes are forced to a position of vergence by prisms.

The object of this investigation is the study of static and kinetic aspects of binocular disparity and of their mutual relation. By a new method, the velocity of fusion movements could be measured as a function of ocular disparity.

Method

1. The method followed for the determination of the fixation disparity curve differs little from
Fig. 1. Schematic view of experimental set-up. Polarized nonius lines are viewed through Polaroid plates and rotating Risley prisms. The speed of rotation is registered on a kymographion. The speed of rotation necessary to keep the nonius lines aligned depends on the previous subjective distance of the nonius lines. The speed of rotation is registered on a kymographion (in prism D. per sec.).

An example will clarify the situation. The upper nonius line (seen by the right eye) is displaced at 20 minutes of arc to the right relative to the lower line (Fig. 1). The subject, who has no spontaneous fixation disparity, sees the lines at a subjective distance of 20 minutes of arc. By rotating the prisms at a certain speed (increasing base-out power), the speed of convergence can be controlled so accurately that the nonius lines are seen as one continuous line. All the time during this convergent movement, fused retinal images have an exodisparity of 20 minutes of arc. Such measurements can be repeated with different “clamped” disparities and in different directions of the fusional movement. For vertical fusion the apparatus has to be turned 90°. The measurement of the kinetic function of disparity requires some training. The author was the experimental subject.

Results

Static disparity. The fixation disparity curve of the author is pictured in Fig. 2. There is a small spontaneous esodisparity, in accordance with an esophoria of 1°. Binocular vision and fixation disparity curve are normal in all other respects.

Kinetic disparity. If disparity had only a kinetic function, as the physiological stimulus to fusion movements, it could be expected that a fusion movement at constant disparity would continue with uniform speed over the whole fusional amplitude available in that direction. Because of static disparity, this is not the case. The kinetic effect of constant disparity becomes exhausted: the vergence movement comes to a stop in that position of vergence in which the constant disparity is identical with the static fixation disparity. Fig. 3 shows the course of fusion movement in different directions and with different disparities. From the slope of the curves, the
velocity of the fusion movements can be inferred. Of course, only the initial velocity of the fusion movement can be related to the purely kinetic function of disparity. Fig. 4 shows their quantitative relation.

In the horizontal movements, the initial velocity for each disparity was averaged from the slope of ten curves in the first degree of fusion movement, in vertical fusion from ten curves at each disparity in the first 1/4° of movement.

Divergent fusion was started from a 10° convergent position. This made measurements technically easier because a larger amplitude of (relative) divergence was available.

In vertical fusion the constant disparity could not be larger than 15 minutes of arc. Larger disparities caused diplopia and made fusion impossible.

The constant disparity in Fig. 4 is not the objective distance between the nonius lines, but the extradisparity superimposed on the static fixation disparity characteristic for the binocular position at which the fusion movement started. Only the extradisparity, not the "total disparity," can be considered as a purely kinetic stimulus. This implies for the author a correction of 2 minutes of arc esodisparity in convergent movement, and 6 minutes of arc exodisparity in divergent movements. There was no spontaneous vertical fixation disparity.

Discussion

The data from Fig. 3 are quantitatively comparable to those of Rashbass and Westheimer (1961), obtained by an ingenious but entirely different method. It
is clear that binocular disparity is the stimulus that supplies the "kinetic energy" for a fusional movement. The velocity of the fusion movement is a monotonic function of disparity. Although the binocular disparity is kept constant, the vergence movement comes to a standstill. As there is no reason to assume that the retinal disparity through some unknown cause loses its stimulus value, the disparity evidently now supplies "potential energy" to maintain the eyes in a certain position of vergence. This is the motor function of "static" disparity.

In his last book, Ogle and his co-workers have given some thought to the motor function of fixation disparity. A further elaboration of the motor aspects of fixation disparity is necessary and may lead to an entirely different view on heterophoria. Up until now, fixation disparity has often been considered as "retinal slip": a lack of accuracy of fixation caused by oculomotor imbalance. The conception of the motor function of fixation disparity points to an intimate connection between fixation disparity and the fusional tonus of heterophoria—in which the disparity might even be the primary cause of the heterophoria.  

REFERENCES