The measurement of the constancy of visual direction and of its adaptation[1]

Hans Wallach and Jerome H. Kravitz
SWARTHMORE COLLEGE

Abstract

Our experiments were concerned with the fact that one perceives the visual field as stationary during head movements. It has been correctly argued that this is the result of a compensating process by which the head movement is taken into account, but its function has never been investigated beyond demonstrating that it is adaptable. We developed a technique for measuring the accuracy with which it operates. This technique made it possible to answer the question: What latitude of motion of a visual target during a head movement is compatible with its being perceived as stationary? It also enabled us to measure with precision partial adaptation to goggles that alter the relationship among visual directions, whereas previously only verbal reports of the visual field's apparent motion or rest have had to serve. Rapid adaptation to optical minification is reported.

Introduction

When the visual field is displaced in relation to S's head while the head is kept still, the field is seen to move, but when a similar relative displacement is caused by a head movement the field appears stationary. This apparent rest of the environment during head movements seems to be the result of a compensating process in the nervous system through which the movement of the head is taken into account.[2] This interpretation is supported by the following observation: When one wears left-right reversing goggles and turns his head, the visual field appears to swing with each turn at twice the angle of the head rotation. This fact is best understood by adopting the head as frame of reference and by describing the changes produced by head rotations as displacements of the environment relative to the head. Under ordinary conditions a head movement to the right causes a displacement of the environment to the left relative to the head. A nervous process which compensates for the effect of this displacement to the left causes the left-displacing environment to be perceived as stationary. That would mean that an environment that is not displaced in the relation to the head but revolves with the head rotation to the right should appear to move to the right at the rate at which the head turns. When left-right reversing goggles are worn, the normal displacement of the environment to the left is changed into an equally large displacement to the right. Since the compensating process causes the left-displacing environment to appear stationary, the optically caused displacement of the environment to the right should lead to an apparent motion of the environment to the right amounting to twice the angle of the head rotation.

The fact that the displacement between the visual field and the head is evaluated in such a way that the stationary environment is perceived as stationary during a head movement has been called constancy of visual direction (CVD). We measured the accuracy with which CVD operates with the help of a device designed to answer the question: How nearly must the visual field remain at rest during a head movement in order to be perceived at rest? Our apparatus enabled us to present a mobile target whose objective displacement was dependent on the S's head rotations. Because the target consisted of a luminous spot in a completely dark field, it represented the S's entire visual environment. Specifically, the target motion so depended on the head movements that it was possible to have the target direction become displaced in any ratio to the head's rotation. The sense of the target displacement in relation to the head's rotation could also be varied. Thus, the target direction could be displaced by any fraction of the head's rotation with or against the direction of this rotation. This made it possible to determine the range of the target displacement ratios that lead to experience of a stationary target or the range over which inconsistent judgments are obtained. Such measurements show the accuracy with which CVD operates.

Apparatus

The device that made it possible to have the target direction displaced dependent on the head's rotation consisted mainly of a variable transmission of the disc-and-ball type. It was located above the S's head, with its input shaft in vertical position and in line with the head's rotation axis. A light headgear served to connect the shaft rigidly with the head. The target consisted of a dim light spot of 7 cm diameter on a homogeneous curved screen 2 m from the input shaft. It was produced by a stationary projector whose beam was reflected by a small mirror which was fixed to a vertical shaft; the shaft, in turn, was connected with the output shaft of the transmission, thereby putting the direction of the target spot under control by the S's head. The control shaft of the transmission, which provided continuous variation of the transmission ratio, was operated by the experimenter, enabling him to set the device for any desired ratio of displacement of target direction to head rotation. The control shaft was connected to a mechanical counter which, once it was calibrated, made it possible to arrange the presentation of various transmission ratios according to a plan. A change of the counter by one digit corresponded to a change in the "target displacement ratio" of .28%.

Since our measurements concerned a function which takes head rotations into account and since only kinesthetic cues could mediate them, it seemed appropriate to keep the torque required to turn the input shaft small so as not to change appreciably the force normally necessary to achieve a head rotation. Starting the rotation of the input shaft of our device required a torque of 1.5 in-oz. It resulted mainly from friction; gross changes in the transmission ratio did not alter it noticeably.

Procedure

Our experiments were concerned with displacement ratios, the ratio of the displacement of the target direction to the angle of the head rotation, for which our device provided continuous variation. Specifically, we wanted to measure the range of those displacement ratios which lead to apparent rest of the target. For this purpose we changed the displacement ratio (DR) in steps of .7%. Starting, for instance, with a DR which always caused apparent target motion with the head, the DR was varied stepwise toward objective target rest and beyond to target displacements that yielded judgments of motion against the head. After one set of limits of the "no-motion range" was thus established, we determined another one by running through the same steps in the opposite direction. We soon found that the no-motion range was not consistent: a certain DR that on one trial had led to apparent target rest might on another trial lead to experienced target motion. To get as exact information as possible on the accuracy with which CVD operates, we probed for the exact limits of those DR zones, which consistently elicited the same motion judgments, by repeated presentation of DR's near these limits, and determined for each S an "uncertainty range" comprising the whole DR range for which variable judgments or judgments of no motion had been obtained.

Results

For 22 randomly selected Ss the uncertainty range had a mean width of 6.6% DR, and a median width of 5.4% DR. We also computed for each S the midpoint of the range of all his no-motion judgments. The mean of these "no-motion points" differed only negligibly from objective target rest; it fell on 1.5% DR with the head movement. Nevertheless, with as many as 22 Ss involved, this value was significantly different from zero, that is, from the condition of objective target rest. One reason for such a deviation should be mentioned. It is connected with the fact that our target screen was at a finite distance from the S. The angular target displacement was therefore not only dependent on the given DR but also on the lateral displacement of the eyes caused by the head rotation, and the magnitude of this effect depends on the target distance. The role of target distance in connection with CVD will be investigated.

Measurements of CVD require that the target be given in an entirely homogeneous field. Marks that can serve as visual reference points for the target displacement alter the outcome radically. When a stationary pattern was projected on the screen, barely visible and consisting of vertical lines with gaps that formed a wide channel for the path of the shifting target, a displacement of only .28% DR in either direction from objective rest always caused a noticeable target motion.

Measuring Adaptive Changes in CVD

It is known that the compensating process which underlies CVD adapts itself to left-right reversal. When reversing goggles are worn for days, the swinging of the visual field with head movements, which was discussed above, diminishes gradually and stops altogether in about a week (Kohler, 1951). Being able to measure CVD, that is, to determine the center of the no-motion range, makes it possible to ascertain accurately partial adaptation where previously only complete adaptation yielded a well-defined experience.

Since reversing prisms cause nausea in most wearers, we used a different optical device to produce adaptive modification of CVD. Magnifying or minifying goggles, because they alter the size of visual angles, also cause the visual field to become optically displaced during head movements. We used minifying goggles of .66 power which displaced the visual field by one third of the angle of head rotation, i.e., equivalent to a DR of 33.3% with the head. After a S's uncertainty range had been measured, the goggles, which were made as light as possible and weighed including headgear 560 gm, were put on him. He was then sent out to do what he would ordinarily do when not studying. When he returned 6 hr. later, the goggles were taken off in the dark and another CVD test was given.

There was for all our 12 Ss a striking change in the no-motion point. It ranged from 10.2 to 34.5% DR, with the mean change amounting to 17.5% DR. Thus a target moving objectively in the direction of the head movement with a DR averaging 17.5% came to be perceived as stationary. No S showed an overlap of the uncertainty ranges measured before and after the adaptation period. This means that, had we presented to each S prior to adaptation a target with the DR of his no-motion point obtained after adaptation, he would have seen it move vigorously. With the rated power of the lenses corresponding to 33.3% DR, the change of the no-motion point amounted to slightly more than 50% of full adaptation. We also found that the uncertainty range after the adaptation period was not larger than it had been before; the mean uncertainty range amounted to 7.7% DR before and 6.7% DR after adaptation.

We are now studying the temporal course of the adaptation of CVD, how head rotation speed affects CVD and how rate and amount of target displacement are related in CVD measurements.

References

KOHLER, I. Ueber Aufbau und Wandlung der Wahrnehmungswelt. Sitz-Ber. Oesterr. Akad. Wiss. Philos. Histor. Kl., 1951, 227, 1-118.

Notes

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2. For a summary of previous thinking on this matter, see Teuber, Perception, Handbook of Physiology-Neurophysiology III, p. 1647.