Reprinted from Nature, Vol. 293, No. 5828, pp. 139-141, September 10 1981

Moving and the motion after-effect

L. R. Harris, M. J. Morgan & A. W. Still

Departmant of Psychology, University of Durham,
Science Laboratories, South Road, Durham DH1 3LE, UK

The movement after-effect (MAE) is caused by inspecting a pattern in which many stimulus elements in the visual field are in coherent movement; after inspection, stationary elements seem to move in the opposite direction. By far the commonest cause of such a retinal stimulus is movement of the observer, not movement of the environment. We suggest here, therefore, that the usual laboratory stimulus for inducing the MAE presents the observer with conflicting sensory cues. The optical input is normally associated with self motion, but other cues such as the vestibular input simultaneously tell the observer that he is stationary. In these circumstances a recalibration of the relationship between optical and other information might occur and we suggest that the after-effect may be at least in part a consequence of this recalibration, rather than being entirely due to a passive fatigue-like process.

The hypothesis that the MAE is due to recalibration clearly predicts that if inspection of the moving pattern occurs in circumstances where there is not an incompatibility between visual and other information, then the MAE will be much reduced. In other words, there will be reduced adaptation if the visual movement is appropriately correlated with the observer's movements. Evidence for this is the surprising lack of a marked MAE after driving a car. To test our prediction we used the expanding/contracting MAE, in which the adapting stimulus consists of elements in centripetal or centrifugal motion respectively. Inspection of centrifugal motion results in a centripetal after-effect, and vice versa[1]. Of course, centrifugal motion of the visual world is normally produced by forward locomotion; thus we should expect from our hypothesis that adaptation would be reduced if this pattern of visual movement was indeed produced by forward bodily movement. Similarly, adaptation to centripetal visual movement should be reduced if the visual flow was produced by backward bodily movement. The other two combinations, centripetal + forward movement and centrifugal + backward motion, should, if anything, increase the after-effect because they provide even stronger incompatibilities than the normal case.

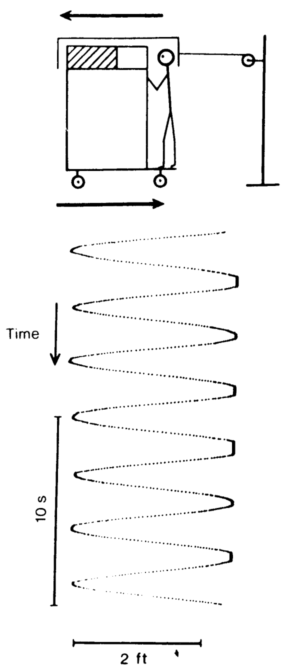

Fig. 1 The subject stood on a trolley and viewed an oscilloscope (hatched box) that was also mounted on the trolley. The trolley was attached by a string to a stationary potentiometer which passed to the computer a voltage corresponding to the subject's position. The observer and screen were under a dense black shroud. The figure also shows a typical computer record of a subject being pushed backwards and forwards approximately sinusoidally. We were able to push smoothly at ~0.4 Hz throughout the 10-min adaptation period.

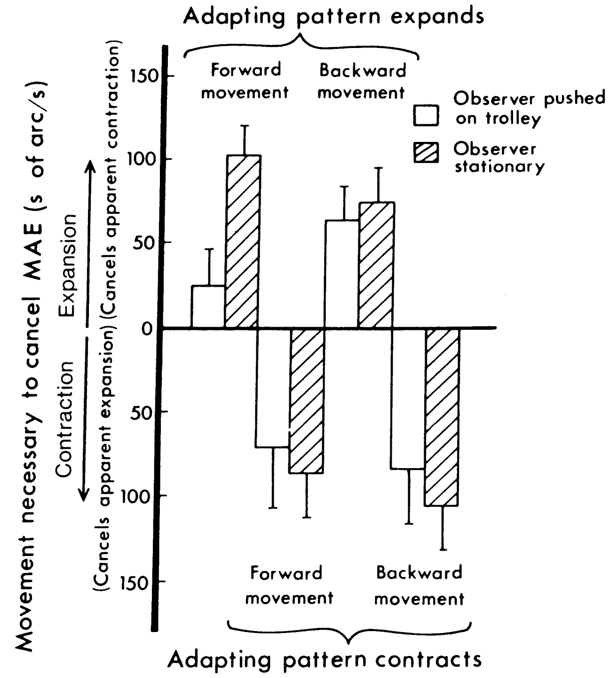

Fig. 2 The amplitude of the after-effects obtained in each of the eight forwards/backwards, expanding/contracting, moving/stationary combinations. These are the averages (±s.d.) of at least two repetitions of all eight conditions for five subjects with 10 settings at the end of each adaptation period. Trials were only carried out if the subject was initially able to set the zero point to <14 arc s per s of contraction or expansion. Analysis of variance showed a significant interaction ($F_{1,4} = 24.83$, $P < 0.001$) between the effect of self motion and its direction.

In our experiment, both the observer and the display were mounted on a trolley that was moved backwards and forwards by one of the experimenters. The screen was thus always 0.3 m away from the observer and always subtended 16.7 × 22.7 deg. This is shown diagrammatically at the top of Fig. 1. By monitoring the movement of the trolley and using a computer to generate expansion in the display based on this movement, we were able to control precisely the compatibility between the visual cue to motion and the observer's real motions (see Fig. 1). The observer and oscilloscope were covered by a shroud and the screen was viewed monocularly through a 1.5 log unit neutral density filter. In these conditions the edge of the oscilloscope was only dimly visible and then only when the display was on. The display was viewed monocularly to reduce cues as to the real distance of the screen.

The display consisted of an array of 400 randomly positioned dots on a Hewlett-Packard 1333A display oscilloscope. To produce an expanding stimulus the dots were initially confined to a 2.2 deg square, which was then continuously expanded to a maximum of 11.0 deg by multiplying the x and y coordinates of each dot by a voltage proportional to the observer's position, using the digital-to-analog converters of the Alpha minicomputer which controlled the display. The program was arranged such that the maximum size was reached at the furthest forward extent of the observer's movement. Contracting motion was produced by the reverse of this process.

The subject was pushed repetitively forwards and backwards along a short run ~1 m long. The expansion of the pattern on the screen simulated the retinal expansion that would have occurred had the subject been pushed towards a stationary display at the far end of the room. The display was blanked except for a fixation dot while the trolley was moving backwards. An adaptation trial lasted 10 min and typically included ~200 movement cycles. The magnitude of the MAE was then measured by the method of cancellation (see below). On the following day, the magnitude of the MAE was again determined, after exactly the same display expansion as before but with the trolley stationary.

In addition, the experiment was repeated with a contracting pattern visible only during the backward phase of the trolley movement cycle. The control for this was the presentation of an identical contracting pattern when the observer was stationary. Finally, we looked at the after-effects produced by the two incompatible combinations: forward motion with a contracting display and backward motion with an expanding display. These were arranged by programming the computer to scale the pattern as if the observer were moving in the reverse of the true direction. In all these conditions the pattern was blanked while the trolley was being moved to its starting position.

The size of the resulting MAEs was measured by the method of cancellation. Before and after each adaptation session the computer presented a 2.2 deg square display of 400 random dots which expanded or contracted depending on the setting of a potentiometer under the observer's control. The display was repeatedly presented for 1.4 s with intervals of 1.4 s of a blank screen. The brief exposure made it less likely that displacement was being detected rather than movement. The observer's task was to set the potentiometer so that the pattern appeared neither to expand nor to contract. He had five exposures in which to make a setting, at the end of which the objective expansion/contraction in the pattern was taken as the measure of the after-effect. This procedure was repeated 10 times and the results averaged. A random offset was added to the potentiometer on each of the 10 trials to avoid learning effects. The initial presentation on each trial alternated between expansion and contraction.

The experiment was carried out using five normally sighted observers, including ourselves, each of whom used their preferred eye for viewing the display monocularly. All the conditions and their appropriate controls (observer stationary) were repeated at least twice by each observer and the mean results are shown in Fig. 2. The main finding was the very small MAE obtained after viewing an expanding pattern during forward movement in contrast to the larger after-effects found in the other conditions.

These results were not entirely predicted, as they failed to show both the expected enhancement of the MAE by incompatible conditions of self motion and a marked suppression of the after-effect of a contracting pattern seen during backward self movement. They do, however, reveal that self motion can have a pronounced effect on what has been considered previously as an entirely visual phenomenon. Our explanation of the data is that normal experience with forward locomotion leads to a very fine calibration of the relationships between the expanding visual field and other cues to forward motion. As long as the correct metrical relationship between the two is maintained, there will be no MAE. The absence of any marked suppression of the MAE produced by visual contraction during backward motion may be due to lack of normal experience of this condition.

These experiments with varying correspondence between actual movement and visual movement show that active recalibration of the visual and vestibular systems is an integral part of the mechanism underlying the classical movement after-effect.

This work was supported by G977/865N from the MRC. L.R.H. is an Addison Wheeler Fellow in the University of Durham.

1. Wohlgemuth, A. *Br. J. Psychol. Monogr.* Suppl. **1**, 1–117 (1911).

Printed in Great Britain by Macmillan Production Ltd, Basingstoke, Hampshire