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INHIBITION AND FACILITATION OF APPARENT MOTION BY REAL MOTION

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Abstract—Observers viewed a CRT display which contained both real and apparent motion. When the apparent motion was in the same direction as the real motion, the strength of the apparent motion was enhanced. Real motion in the opposite direction completely cancelled apparent motion. However, the appearance of the real motion was not affected by apparent motion.

Apparent motion   Real motion   Gratings

INTRODUCTION

The conditions leading to perception of seen motion have historically been divided into two classes. The percept produced by viewing a continuously moving object is termed "real motion." A second class of motion, "apparent motion," may result when stationary stimuli are presented sequentially to different retinal locations. One of the oldest controversies in the visual perception literature is the nature of the relationship between the mechanisms underlying these two classes of motion. Exner (1875) originally proposed that real and apparent motion are detected by separate processes. He suggested that real motion is directly perceived while apparent motion is inferred from information about change in position. Subsequent authors, such as Wertheimer (1912) and Gibson (1954), pointed to the phenomenal similarity of real and apparent motion and concluded that both percepts are caused by a unitary mechanism. This view has been bolstered by physiological data (Grüsser-Cornehls *et al.*, 1963; Barlow and Levick, 1965) demonstrating that some visual neurons respond in like manner to both classes of motion. Presumably, real and apparent motion are processed together because these neurons cannot distinguish between them. However, it has been pointed out (MacKay, 1970; Rock, 1975) that many situations which produce apparent motion cannot be easily explained solely on the basis of motion detecting neurons. Nonetheless, the relationship between real and apparent motion has continued to be debated in the more recent literature (e.g. Kolers, 1972; Frisby, 1972).

The purpose of our experiment was to perform a direct test of the relationship between mechanisms responsible for detecting real and apparent motion. We accomplished this by employing a display which contained both classes of motion. The real motion could be varied to appear in the same or opposite direction as the apparent motion. Therefore, real and apparent motion could signal the same or conflicting information about direction. If the direction of one class of motion influenced the perception of the other class, then this would constitue evidence for a common neural locus.

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METHOD

Observers

Two emmetropic observers served as subjects in the experiment. One was the author while the other, C.v.R., had no knowledge of the purpose of the experiment.

Display

Observers binocularly viewed the display, which is schematically shown in Fig. 1. A uniform raster was created on the face of a Tektronix 602 CRT by the standard television method. The screen was divided into three sections by 8′ wide black lines. Sine-wave gratings of 0.5 c/deg were presented sequentially with various interstimulus intervals (ISIs) to the left and right (or reversed order) sections of the tripartite field. Mean luminance of each section was 6.8 cd/m^2 at all times. The purpose of the black line was to mask the sharp edges produced by truncation of the gratings. Preliminary observations showed that the edges appeared to move somewhat separately from the grating and made judgments more difficult. The black lines eliminated this problem and did not interfere with apparent motion. A fixation cross was located 1.5° below the midline of the display. Previous data (Kolers and von Grünau, 1977) have shown that apparent motion is stronger when it does not appear to pass through the fovea.

Gratings were presented in each section for a

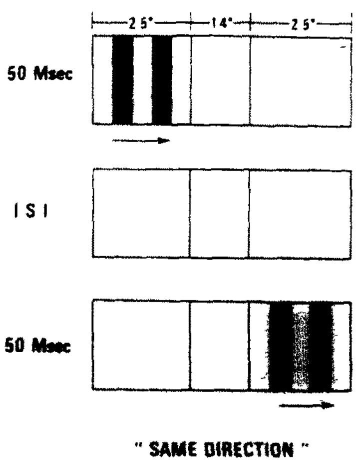

Fig. 1. Schematic representation of the display viewed by the observer. Gratings appeared for 50 msec with a variable ISI. During each exposure, the grating could be stationary or drift left or right. In the figure, the drift (symbolized by the arrow) was in the same direction as the stroboscopic sequence. The area surrounding the display was matched in color and luminance to the CRT screen.

50 msec exposure duration with contrast set either 0.25 or 1.5 log units above detection threshold. During each exposure, the gratings were presented in one of three modes: (1) stationary, (2) drifting at 6.8 Hz (13.6/s) in the same direction as the stroboscopic sequence and (3) drifting at 6.8 Hz in the direction opposite to that of the sequential presentation. Note that the drift, a distance of 0.68° during the 50 msec, occurred *within* the section and that the grating did not change "position". Therefore, real motion (grating drift) could be signaling the same or conflicting information about direction of motion as the apparent motion. Members of a grating pair were always presented in the same mode, i.e. both leftward drift, both rightward drift or both stationary.

Procedure

The observer pushed a button to view a single sequential presentation of a grating pair. Interstimulus interval, direction of motion and contrast (high or low) were varied randomly from trial to trial. The task was for the observer to state after each trial whether apparent motion had been seen. Observers signaled "yes" for any sensation of motion across the screen and were not asked to distinguish between optimal motion and phi (disembodied) motion. However, it was obvious to the author that the low contrast grating always produced optimal motion while the high contrast gratings generally produced phi motion. Data were collected for 30 trials at each ISI, contrast and direction.

RESULTS

The results obtained from the two observers are presented in Fig. 2. The top panel shows the data collected with stationary test gratings. As is typically found when test objects are separated by more than a small distance (e.g. Exner, 1875), most frequent reports of apparent motion occurred with ISIs of 50–75 msec. Apparent motion reports decreased with longer ISIs and little motion was seen beyond 150–200 msec. At shortest ISIs, the gratings tended to be seen as simultaneous while longer ISIs resulted in succession. Low contrast gratings were more effective in producing apparent motion at almost all ISIs.

The middle panel shows results obtained when real motion was in the same direction as the stroboscopic sequence. The real motion increased the frequency of apparent motion reports for both low and high contrast gratings. Moreover, apparent motion could be seen with ISIs out to 200–300 msec. This agrees with the anecdotal reports of both observers that introduction of real motion produced a more fluid apparent motion. With optimal ISIs, the individual drifts of the gratings could not be distinguished but blended completely with apparent motion to create a single motion across the screen. When the ISI was short enough to produce simultaneity or long enough to result in succession, the individual drifts could be discriminated.

The bottom panel shows that when the real motion was in the opposite direction to the stroboscopic sequence, the apparent motion was completely eliminated. The only "yes" report obtained in this condition was on the first trial of the experiment by C.v.R. Complete cancellation of apparent motion was also reported by four other observers who were tested. At the 0 msec ISI, the gratings drifting in both the same and opposite directions appeared to be present simultaneously in left and right sections of the screen. At an ISI of 0 or 25 msec naive observers initially confused real motion with the stroboscopic sequence. They reported that order of grating presentation appeared to go with the real motion, regardless of its direction. However, once it was pointed out that order of presentation was independent of direction of the grating drifts, observers were able to separate the two percepts. At longer ISIs, when same direction real motion produced fluid apparent motion, the opposite direction gratings appeared to be presented sequentially with no sensation of apparent motion. A percept of a simultaneous real motion in one direction and stroboscopic motion in the other could never be attained. It was always real motion which cancelled the apparent motion, while direction of stroboscopic presentation had no effect on the real motion. Of course, it would not be possible for the apparent motion to affect the first grating exposure since direction of stroboscopic sequence was not yet determined. However, it is logically possible for the real motion in the second grating to be cancelled, but this never occurred.

In a second experiment the sensitivity of apparent motion to various drift rates of real motion was assessed. The experiment was similar to the one

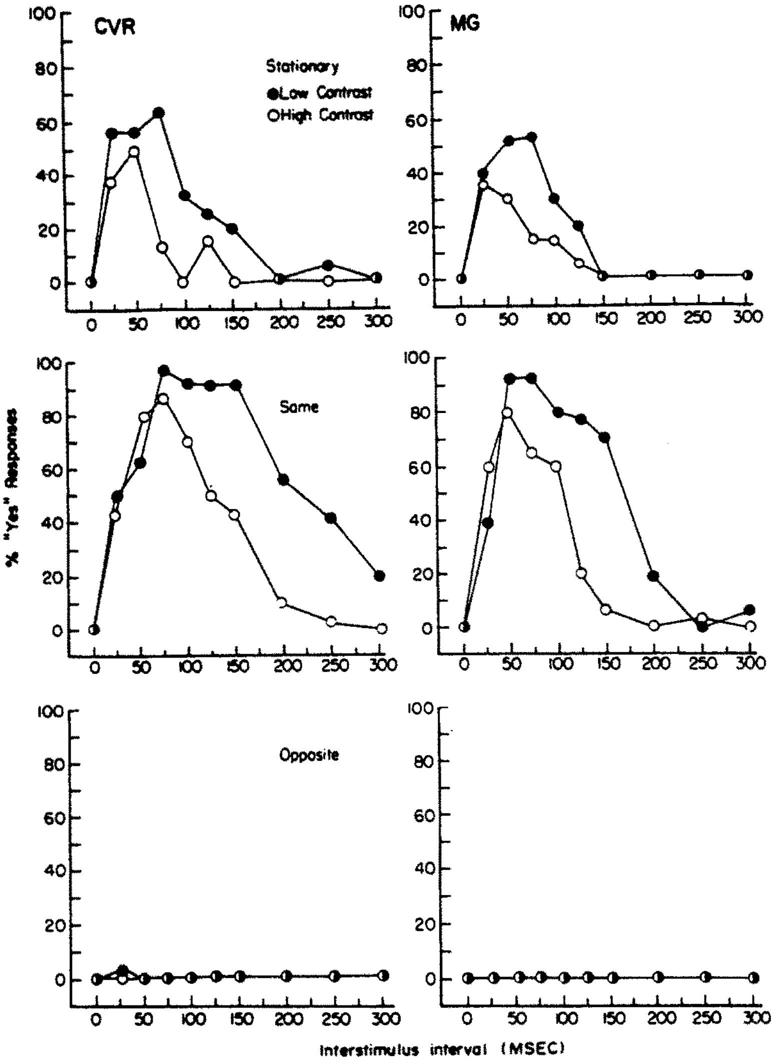

Fig. 2. Percent apparent motion ("yes") reports as a function of interstimulus interval. Top panel shows data obtained with stationary gratings, middle panel represents data obtained with gratings drifting in the same direction as the stroboscopic sequence and bottom panel shows results for conditions in which gratings drifted in the direction opposite to stroboscopic sequence.

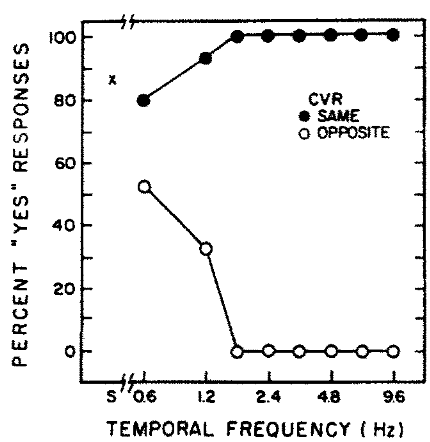

Fig. 3. Percent apparent motion seen ("yes") reports as a function of the temporal frequency of grating drift. The symbol "X" denotes data obtained with a stationary test grating.

described above except that each grating exposure was 120 msec, the drift rate was varied and the ISI was fixed at 0. (Preliminary experiments had shown that this ISI was optimal for 120 msec duration exposures.) The results, shown in Fig. 3, demonstrate that even small amounts of real motion can eliminate apparent motion. Temporal frequencies as low as 1.7 Hz completely cancelled apparent motion. With slower drift rates, apparent motion would occasionally be reported with opposite direction real motion. At a drift rate of 0.6 Hz no enhancement over stationary gratings was produced by same direction drift, while opposite direction drift caused some weakening of apparent motion. A drift rate of 0.6 Hz produced real motion that was barely perceptible. The observer was tested in a two-alternative forced-choice direction discrimination of the 0.6 Hz grating with simultaneous presentation in the left and right fields. Direction of drift could be correctly identified in only 75% of the trials.

In order to further determine the robustness of the interaction between real and apparent motion, observations were made with several variations on the basic experiment. The cancellation of apparent motion by opposite direction real motion was found (i) with test gratings of 3.0 c/deg, (ii) with single bright lines, (iii) when the distance between gratings was 3.5° and (iv) using dichoptic presentation so that each grating of a pair was viewed with a different eye. None of the conditions tested ever produced a change in the appearance of real motion contingent on direction of the stroboscopic sequence.

DISCUSSION

My data demonstrate a powerful interaction between real and apparent motion. When each of the gratings drifted in the same direction as the stroboscopic sequence, apparent motion was enhanced while drift in the opposite direction completely eliminated apparent motion. The interaction was asymmetric in the sense that direction of the stroboscopic sequence had no effect on the appearance of real motion.

It was also found that the frequency of motion reports was greater with the low contrast gratings than with the high contrast gratings. This result is consistent with data from previous studies. For example, it has been shown that the strength of motion aftereffects is increased by lowering the contrast of test gratings (Keck *et al.*, 1978) and that blurring test objects, which causes a decrease in apparent contrast, strengthens stroboscopic motion (von Grünau, 1978). Moreover, the decreasing of apparent contrast by adaptation to a stationary grating enhances sensitivity to drifting gratings (Kulikowski and McCana, 1978) and increases the strength of apparent motion (Green and von Grünau, 1983). These kinds of data have led some (Kulikowski and McCana, 1978; von Grünau, 1978) to suggest that there might be an inhibition between mechanisms which signal form and those which signal motion. It is not clear whether the low and high contrast data in the present study can be directly compared since the low contrast gratings produced optimal (beta) motion while the high contrast gratings generally produced disembodied (phi) motion. Taken at face value, however, the results suggest high contrast impairs apparent motion.

Interactions between real and apparent motion have been suggested by previous authors. Clatworthy and Frisby (1973) tested perception of apparent motion before and after adaptation to a grid which oscillated back and forth in real motion. Since adaptation of the oscillating grid reduced the amount of apparent motion reported, it was concluded that an identical mechanism for real and apparent motion had been demonstrated. However, this conclusion can be questioned for two reasons. First, they failed to show that adaptation to apparent motion would affect perception of real motion. Second, their experiment contained a serious source of confounding. The oscillating grid had to stop at the end of each screen excursion in order to change direction. As a result, the real motion had stationary endpoints, which have been shown sufficient to stimulate the mechanism of apparent motion (Kaufman *et al.*, 1971; Bonnet, 1977). Therefore, observers actually adapted to a stimulus which would stimulate both real and apparent motion detectors. In a more recent study (Green and von Grunau, 1983), observers adapted to linearly drifting gratings. Apparent motion in the same direction as the adaptation grating was reduced while apparent motion in the opposite direction was enhanced. This demonstrates direction selective adaptation between real and apparent motion.

Barbur (1981) investigated subthreshold summation between a spot in real motion and a spot flashed sequentially at different locations. He found the detection threshold was a linear sum of the luminances of the moving and flashed dots. It was concluded that real and apparent motion are detected by the same mechanism, presumably direction selective neurons. Our results are not entirely in concert with his since we suggest that while the mechanisms are related, they are not identical. The discrepancy may lie in the use of different paradigms. Barbur measured detection thresholds and never actually tested *perception* of motion while the task of our observers was to report motion. Further, Barbur presented and then dismissed the possibility that his results are simply due to the detection of separate flashes "associated with the two half fields which generate the apparent motion display". His arguments, however, are not entirely convincing. The results could still be explained without reference to motion since greatest summation occurs when the moving and flashed spots exhibit the maximum amount of spatial and temporal overlap. His conclusion is also inconsistent with our observation (Green and von Grünau, 1983) that adapting to a drifting grating failed to produce a direction-specific threshold elevation effect in stroboscopically presented tests gratings.

In the present experiment, the large effect of real motion on perception of apparent motion is consistent with a unitary mechanism view. However, the interaction between real and apparent motion was asymmetrical in the sense that direction of apparent motion had no effect on real motion. The asymmetry could be explained in at least two ways. First, it is possible that the mechanisms for real and apparent motion, while related, are not identical. For example, suppose that the mechanisms were arranged sequentially with the real motion detection located more peripherally. Then direction of stroboscopic might not affect perception of real motion. A second hypothesis is that there is only one motion detection mechanism but that it is much more weakly stimulated by apparent than by real motion. To use the analogy drawn by Gregory (1966), apparent motion might be a might poorer "key" to fit in the *lock* of the motion detection mechanism. If this were the case, then apparent motion may too weakly stimulate the single motion detector for there to be an effect on real motion while real motion easily overwhelms apparent motion. The present study does not provide the evidence to support either interpretation.

Short and long range mechanisms

One attempt to resolve the controversy over the relationship between real and apparent motion has been the proposal of separate short and long range motion detectors (Braddick, 1974). According to this view, the human visual system contains two separate motion detectors which cannot be strictly distinguished on the criterion of real vs apparent motion processing. The short range mechanism processes both real motion as well as apparent motion, providing that the size of the displacement is not large. A long range system mediates perception of apparent motion over large displacements. The size of the displacement in the present study was 1.4°, so it is likely that the apparent motion was processed by the long range mechanism while the grating drifts were detected by the short range system. Since I found an interaction between the two classes of motion it appears that the short and long range systems are not independent. Other data also suggest that there may be inhibition between systems. Pantle and Picciano (1976) described a bistable motion display which produced either "group" or "element" motion. These percepts were attributed to inhibition between two distinct motion detection mechanisms which presumably correspond to the short and long range mechanisms (Braddick and Adlard, 1978). Since I found that grating drift enhanced long range apparent motion, the present study demonstrates that the relationship between the two mechanisms can be facilitatory as well as inhibitory.

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