

Visual Persistence of Figures Defined by Relative Motion

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In order to measure visual persistence of figures that were solely defined by relative motion (motion-defined figures or motion figures), random-dot kinematograms were used to form stimulus figures in the two-frame, missing element task introduced by Di Lollo, V. (1977 *Nature*, 257, 241-243). Experiment 1 showed that motion-defined figures persisted for about 130 msec after the termination of the stimulus presentation (i.e. after the dots stopped moving). This was similar to but several tens of milliseconds longer than the visual persistence of figures which were defined by a luminance difference (luminance-defined figures or luminance figures) in the same random-dot pattern. Since motion detectors are not found in the retina or lateral geniculate in primates, our results strongly suggest that visual persistence is not only a retinal phenomenon but also a cortical one. Experiment 2 investigated the possible influence of motion aftereffects on the visual persistence of motion figures. The results showed that coherent movement of the dots over the whole display after the stimulus offset did not reduce the visual persistence of motion figures, suggesting that the source of this persistence is not a motion aftereffect. In Experiment 3, visual persistence for the motion-defined figures was shown to be longer than that for luminance-defined figures independently of the contrast of the stimulus figure as long as the stimuli could be seen clearly enough. This suggests that different mechanisms are involved in the visual persistence of motion-defined and luminance-defined figures.

Visual persistence ISI Motion

INTRODUCTION

A briefly presented stimulus appears to remain visible for some period after the physical offset of the stimulus. This phenomena, visual persistence, has been investigated by a number of researchers using different stimuli, procedures and conditions (e.g. see reviews by Coltheart, 1980; Long, 1980, 1985a) since the influential publication on this topic by Sperling (1960). However, it is still not clear which level or levels of the visual system contribute to persistence. Sakitt *et al.* claimed that visual persistence is located at the level of the photoreceptors, specifically the afterimage due to rod saturation (Sakitt, 1975, 1976; Sakitt & Appelman, 1978; Sakitt & Long, 1979a,b). However, other studies have shown that cones play a role in visual persistence (Adelson, 1978; Banks & Barber, 1980; Long, 1985b; Sakitt & Long, 1979a). In addition, the finding that the duration of persistence is influenced by spatial frequency content suggests that it cannot be attributed solely to the afterimage of photoreceptors (Bowling, Lovegrove & Mapperson,

1979; Meyer & Maguire, 1977; Ueno, 1983; although see also Long & Sakitt, 1981). Many investigators have proposed that higher mechanisms are involved in visual persistence in addition to afterimages of receptors (e.g. Adelson & Jonides, 1980; Coltheart, 1980; Long, 1985a). Furthermore, Coltheart (1980) predicted that visual persistence could exist in many different levels or pathways in the visual system. Since the perception of spatial form can be mediated by a variety of visual attributes such as colour, luminance, texture, binocular disparity or motion (Cavanagh, 1987), each of these processes may have individual mechanisms to extend the availability of information beyond the termination of physical stimulation.

In this report, we shall show that visual persistence exists in the motion pathway. Form organisation in the motion pathway can be isolated by using motion-defined stimuli where random dots in a figure area move in the opposite direction to dots in the background. In these stimuli, the figure is visible only when dots are moving (Anstis, 1970; Braddick, 1974; Julesz, 1971).

Many techniques to measure the duration of visual persistence have been developed. One of the most sophisticated techniques has been used by Di Lollo *et al.* (Di Lollo, 1977, 1980; Di Lollo & Bourassa, 1983; Hogben & Di Lollo, 1974). Di Lollo (1977) used 24 dots,

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each in a different cell of a regular 5×5 square matrix. One cell was unfilled. In the first frame, 12 dots were presented, followed by a blank period (interstimulus interval or ISI), and finally by the remaining 12 dots. The observers' task was to specify the cell in which no dot was presented. When the ISI is shorter than the duration of visual persistence, observers can see all 24 dots simultaneously so that they can easily identify the cell that is missing a dot. For longer ISIs, however, the two frames appear sequential and some kind of spatial memory is required to compare the two images in order to locate the missing dot. Performance is much worse in this case.

We used this technique to measure the duration of visual persistence in the motion pathway. The element in each cell in the matrix was formed by relative motion instead of luminance difference. The experiment also included conditions with figures defined by luminance differences as a comparison.

EXPERIMENT 1: VISUAL PERSISTENCE OF MOTION PATHWAY

The first experiment investigated the integration of two successively displayed images as a function of the temporal interval between the two images. The stimulus was a 4×4 matrix of squares in a random-dot field. Each square was defined by relative motion: random dots in the background moved leftward whereas dots in the squares moved rightward or vice versa. No cues were available to detect the squares when the dots were stationary.

The 16 squares of the matrix were randomly divided into two sets of 8 squares. The first set was presented in the first frame, and the second set was seen in the second frame (Fig. 1). One square was removed randomly from one of the frames and observers were asked to identify the location of the missing element. The interval between the presentation of the two frames (interstimulus interval, ISI) was varied. During the ISI, the dots in the stimulus field were static.

In addition to the condition in which the squares were defined by relative motion (motion figures), a luminance-defined version of stimulus figures was also used (luminance figures). In the luminance figure condition, the average luminance of the dots inside the element squares brightened to produce luminance contrast between the elements and background.

Method

Stimuli and apparatus. The stimulus display was a square field of random dots subtending a visual angle of 15 deg generated on a CRT (30 Hz interlaced scanning) by a computer-controlled image processor. The random-dot field was composed of 256×240 square dots. Half of the dots were black (4.3 cd/m^2) and the other half were white (47.4 cd/m^2). In the random-dot field, there were 16 squares of a 4×4 array (Fig. 1), which were visible only when the dots inside the squares moved in a different direction from that of the background dots. The dots moved horizontally on dot-size per refresh cycle of the display (60 Hz field rate), corresponding to a velocity of approx. 3.5 deg/sec . The size of each square was 40×40 dots ($2.3 \times 2.2 \text{ deg}$ in visual angle) spaced 3.2 and 3.1 deg apart centre to centre horizontally and vertically, respectively, with the whole matrix centred in the display. A bull's eye (0.5 deg dia) was located on the centre of the stimulus field to serve as a fixation spot. The monitor was mounted 1.04 m in front of the observer.

For the luminance figures, the average luminance inside the element squares was 1.215 times that of the background luminance so that the apparent contrast of luminance figures and motion figures were approximately equal when they were presented simultaneously for the duration of 167 msec as determined in a pilot experiment. The white dots brightened (58.5 cd/m^2) to increase the average luminance inside the squares while the luminance of the black dots remained unchanged (this also changed the contrast of random dots, but the relative increase was much smaller; Michelson's contrast of 83.3% became 86.3%).

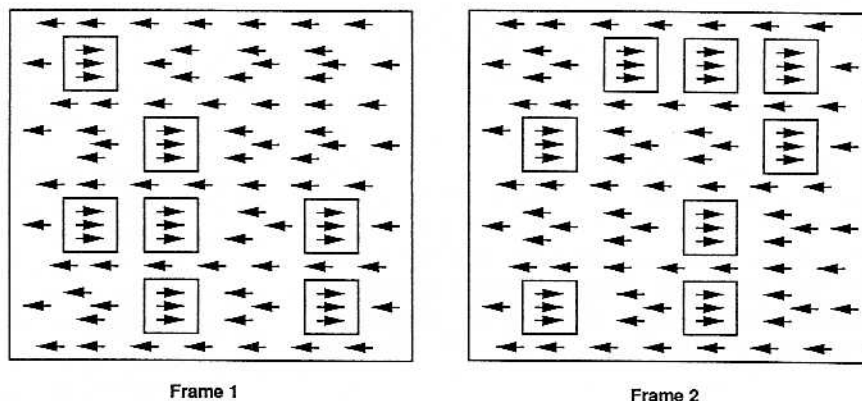


FIGURE 1. Schematic view of a sample stimulus. The stimulus figures are square shaped regions arranged in a 4×4 matrix. The squares and the background are all filled with the same random dot texture. Each element square is defined by the difference in the direction of motion in the square and in the background. Frame 1 consists of 7 (or 8) filled cells in the matrix and frame 2 consists of 8 (or 7) filled cells so that across both frames, one of the 16 cells remains unfilled.

Procedure. The sequence of a trial was as follows. The observer first fixated the bull's eye, and then moved a joystick either left or right to initiate a trial when he/she was ready for the trial. A static random-dot field was then presented for 1 sec, following which the dots started moving to present the first set of element squares (the first frame). The dots inside the element squares always moved horizontally in the opposite direction to the dots in the background. After 67 msec of the presentation of the first frame, all dots stopped moving for a given duration of ISI. The static field was followed by the presentation of the second set of element squares (the second frame), also for 67 msec. The observer then reported the position of the missing square using numbers between 1 and 16 to identify the cells in the 4×4 matrix. A sheet on which each number was written in the corresponding position of the matrix was taped under the monitor to help observers recall the labelling order. Each session comprised 128 trials: 1 trial for each of the 16 possible test locations at each of 8 ISIs. The observers viewed the display binocularly.

In order to cover a large range of ISIs, three sets of 8 different ISIs were used: $-67, -33, 0, 33, 67, 100, 133$ and 167 msec; $-50, -17, 17, 50, 83, 117, 150$ and 187 msec; and $0, 33, 67, 100, 133, 167, 333$ and 467 msec

(0 msec ISI includes a refresh interval). Negative values of ISI indicates that the onset of the second frame preceded the offset of the first frame (i.e. the absolute value of a negative ISI means the duration for which all 15 squares were simultaneously present on the screen). Two sessions were run for each of the three sets of ISIs. One observer, NB, participated in sessions for only the first two of the three ISI sets for luminance figures.

Observers. One of the authors and two naive observers participated in this experiment. All observers had normal or corrected-to-normal acuity.

Results

Motion figure. Figure 2(a) shows the percentage of correct responses as a function of ISI for the motion figures individually for each observer. Each datum point is derived from 32 observations. For each of the 6 ISIs that were tested twice, both data points are plotted. The two inflection points of a three-segment function (the solid line in each panel) were adjusted to give the best least mean squares fit to the experimental results.

For all observers, the percentage of correct responses is high and relatively constant for shorter ISIs (about 100% for CB and SS and 80% for NB). Whenever the

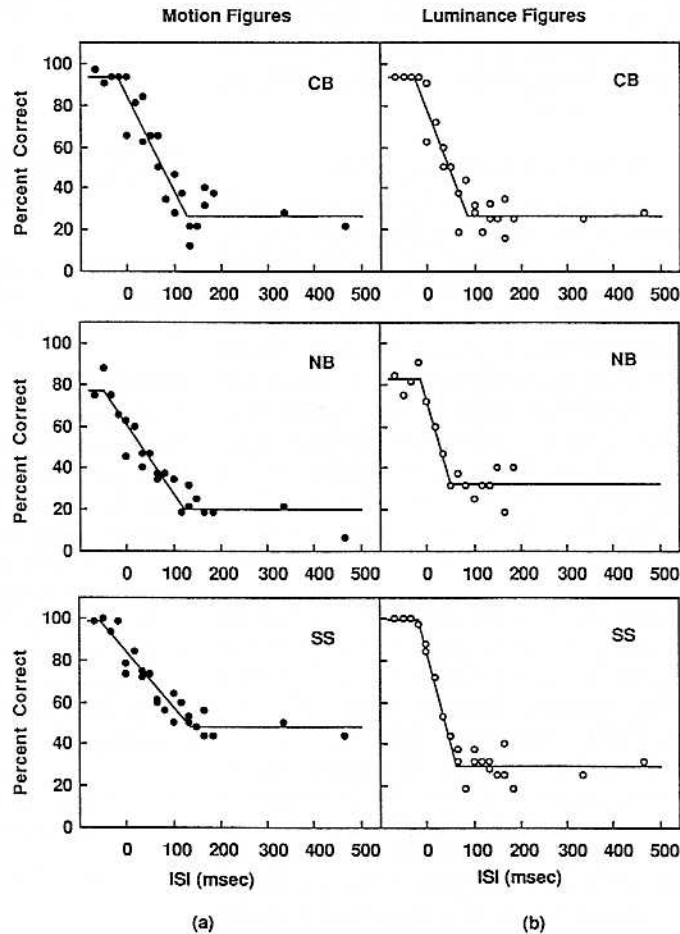


FIGURE 2. Percentage of correct responses as a function of interstimulus-interval (ISI) for (a) the condition in which the stimulus figures were defined by the difference in the motion direction of the dots and for (b) the condition in which stimulus figures were defined by luminance contrast. The solid curves show the best fitting three-segment functions.

presentation of the two frames overlapped at all (ISI is less than 0 msec), the visual system integrated the two frames of element squares as well as in the condition of simultaneous onset and offset of all elements (-67 msec of ISI). Beyond this initial plateau, performance decreases with increasing ISI until it reaches a lower plateau at around 130 msec ISI where the percentage of correct responses remains approximately constant (about 25% for CB, 20% for NB and 45% for SS). We take the point at which this constant performance begins, about 130 msec, to indicate the end of visual persistence.

The relatively constant performance obtained for ISIs longer than 130 msec is higher than chance performance. A random response selected from the missing cells of the second frame produces a correct response on one-eighth or one-ninth of trials (12.6 or 11.1%). The better than chance performance of our observers may be due to contributions from other types of persistence or memory that have longer decay periods (e.g. visual short-term memory; Phillips, 1974; Kikuchi, 1987).

Luminance figure. Figure 2(b) shows the percentage of correct responses as a function of ISI for the luminance-defined figures. Similar to the results for the motion figures (Fig. 2), the integration performance is consistently high for ISIs shorter than about 60 msec (about 95% for CB, 80% for NB and 100% for SS), and decreases until it reaches a minimum level where it remains out to the longest ISIs tested (about 25% for CB, 30% for NB and SS).

Comparison of motion and luminance figures

Figure 3 compares the results for the motion and luminance figures in the same panel. The solid line is the function that represents percentage of correct response for the motion figures and dashed line is that for the luminance figures (replicas of the functions in Fig. 2). One can see a similar time course for visual persistence for both the motion and luminance figures. There are, however, two major differences which are common to all three observers. Firstly, performance declines more gradually with increasing ISI for the motion figures than it does for the luminance figures. Secondly, the ISI at which the performance reaches the minimum value is shorter for the luminance figures than for the motion figures.

As a persistence duration, we obtained the ISI beyond which the percentage of correct responses is constant at a low value (critical ISI); i.e. the ISI at which the oblique line of the three-segment function intersects to the lower plateau. Table 1 shows the critical ISIs for both the motion and luminance figures. The critical ISI for motion figures is longer than that for luminance figures by 43 msec for CB and 74 msec for NB and SS.

The difference between the persistence duration for motion figures and luminance figures might not be due to differences between motion and luminance processing *per se*, but might arise from other differences between the two experimental conditions. In particular, persistence duration may depend on the visibility or the contrast

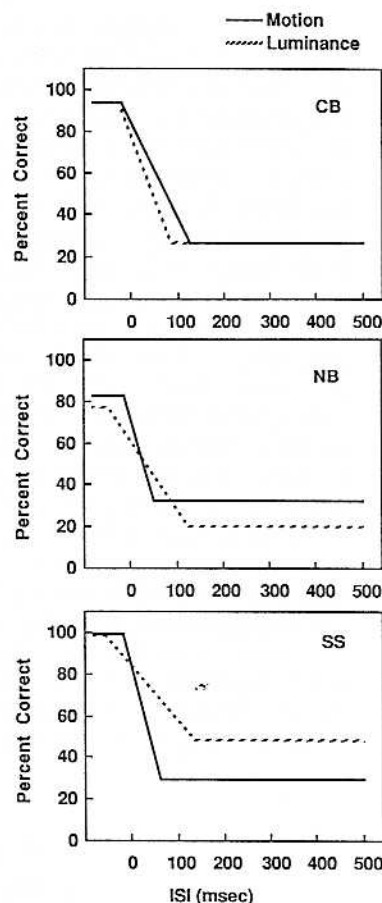


FIGURE 3. Comparison of results for the motion figures (solid line) and for the luminance figures (dashed line). The functions shown are the best fitting functions from Fig. 2.

of figures. To examine this possibility, the effect of stimulus contrast for both luminance and motion figures is studied in Expt 3.

Discussion

The most important finding of Expt 1 was that figures that are defined solely by relative motion persisted for some period after their offset. This is a strong evidence that the cortical mechanisms contribute to the persistence of briefly presented figures. Only visual processes that follow motion analysis, which in primates emerges first in the visual cortex (see a review by Grüsser & Grüsser-Cornehils, 1973), can register the presence of motion-defined figures.

If the visual persistence of motion figures arises during the analysis of motion, the motion aftereffect will be a candidate for the source of the persistence. When a

TABLE 1. The duration of visual persistence in msec. These values are the critical ISIs taken from Fig. 2

	Observer		
	CB	NB	SS
Motion figures	128.1	123.7	136.3
Luminance figures	85.1	50.2	62.6

motion aftereffect is present, the processes that organise forms based on relative motion might continue to respond, even though the processes themselves do not retain any information of stimulus. To examine whether the motion aftereffect might be the source of the persistence for motion-defined figures, Expt 2 used ISI fields in which the random dots were moving so that the visibility of the motion aftereffect would be weakened.

EXPERIMENT 2: MOVING ISI

Experiment 1 showed visual persistence for figures defined by relative motion. It is possible that this persistence is mediated by a motion aftereffect. The stimulus presentation was very short (67 msec) and observers did not report that any motion aftereffect was visible at the offset of the stimulus. Nevertheless, an aftereffect might be so brief as to go unnoticed and yet still contribute to the results of Expt 1. In order to examine the possible influence of motion aftereffects, all dots in the field were moved during the ISI. We assume that the presence of real motion during the ISI will mask a motion aftereffect. If a motion aftereffect contributes to the persistence of motion figures, motion during the ISI should reduce the duration of the persistence.

In the first condition of Expt 2, the dots moved before the first frame and after the second frame in addition to during the ISI. In this case, the random dots were moving both before and after the presentation of both frames and only the direction of motion of the dots within the presented squares changed at the onset and offset of the frames. This first condition produced somewhat better performance than in Expt 1, rather than worse, leading us to suspect that the constant movement of the background dots before and after the stimulus might have improved the effective contrast of the stimulus squares. We therefore ran a second condition in which the random-dot field was stationary before and after the presentation of the stimulus but moved during the ISI.

Method

The procedure and stimuli were almost identical to that in Expt 1 except that in the first condition, the random dots always moved while the dots were on the screen: from 1 sec before the onset of the first frame to 1 sec after the offset of the second frame, including during ISI. One observer, SS, participated in two sessions: in one the dots moved upward during the ISI (and before and after the stimulus), and in the other they moved downwards. The other two observers, CB and NB, completed only one session, the dots moved upward for one observer and they moved downward for the other during ISI. The direction of dot movement in element squares was left when the dots in the ISI field moved upward and right when the dots in the ISI field moved downward. One observer, SS, also completed sessions with horizontal movements of dots during ISI and before and after the stimulus. The movement of the dots during these periods was in the same direction as

that of the background during the presentation of the stimuli.

In the second condition, the random dots moved vertically during ISI, but they were static before and after the stimulus. Two observers were used. One observer, SS, participated in two sessions (the dots moved upward during ISI in one session and downward in the other session) and the other CB repeated one session (the dots moved upward).

Eight different ISIs were examined; -67, -33, 0, 17, 33, 50, 67 and 100 msec.

Results and discussion

Figure 4 shows the percentage of correct responses as a function of ISI for the first condition. Each point was served from 32 trials for observer SS and 16 trials for the other two observers. The solid line in each panel is from Expt 1 (replica from Fig. 2).

When the dots moved during the ISI and before and after the stimulus presentation, the performance was somewhat better than that in Expt 1 where the dots moved only during the presentation of the element squares. In each panel, almost all data points of the

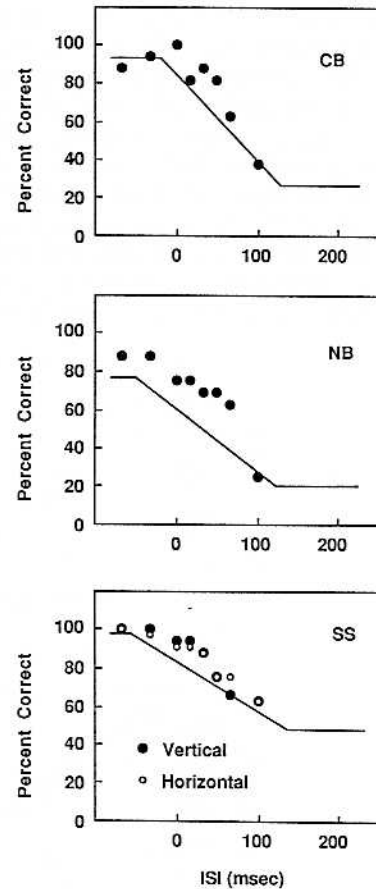


FIGURE 4. Percentage of correct responses as a function of interstimulus-interval (ISI) with moving background during ISI as well as before and after the stimulus presentation. Data for vertical motion of the background. For observer SS, data also for horizontal background motion during ISI as well as before and after the stimulus presentation. The solid lines are the best fitting functions from Fig. 2 representing the results for the motion figures in Expt 1.

present experiment fall above the solid line from Expt 1. The results of SS show that this is true both for vertical and horizontal movement of the dots during the ISI. These results do not lend support to the assumption that motion aftereffects contribute to the visual persistence of motion figures.

A close look of Fig. 4 suggests that the improved performance for moving ISI conditions does not appear to increase visual persistence, at least not by the criterion that we have used to measure it. The percentage of correct response at the longest ISI used (100 msec) is very close to the solid line from Expt 1, while it lies above the line for shorter ISIs (between 0 and 67 msec). This may indicate that the overall duration of persistence was not affected by the movement of the dots during ISI but that the information was more easily available immediately after the stimulus offset.

The improved performance in the present condition may be attributed to an increase in the visibility of the stimulus figures. The observers reported that the element squares were more clearly seen in the present condition than in Expt 1 perhaps because they stood out more against a background that was always moving. The abrupt onset and/or offset of motion coincident with the stimulus onset and/or offset in Expt 1 may have briefly masked the available information. In the second condition, the dots were static before and after the stimulus presentation but still moved during the ISI.

Figure 5 shows the results of this second condition compared to the representative function for the motion-defined figures of Expt 1 (solid line). The data now fall fairly close to the solid line at all ISIs. The movement of the dots during ISI still produced little or no deterioration of performance compared to Expt 1. However, unlike the first condition of this experiment,

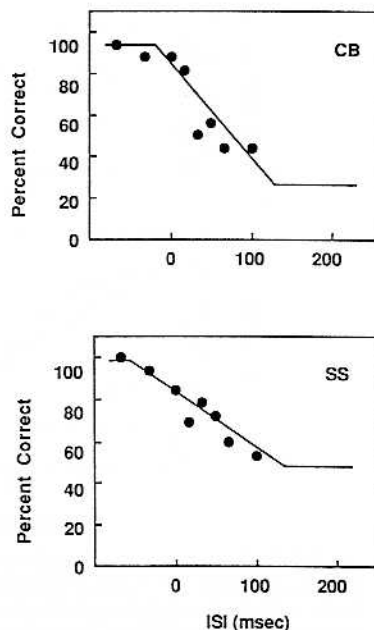


FIGURE 5. The same as in Fig. 4 but for background motion (vertical) only during the ISI. The background was static before and after the stimulus presentation.

no facilitation (compared to Expt 1) was obtained at shorter ISIs. This suggests that the facilitation seen in the first condition was due to the movement of the dots before and after the stimulus presentation, not to the movement during the ISI.

EXPERIMENT 3: EFFECT OF CONTRAST OF THE FIGURES

Experiment 1 showed that visual persistence for motion-defined figures is somewhat longer than that for the luminance-defined figures. But how comparable were our luminance- and motion-defined stimuli? For luminance stimuli, the duration of persistence depends on luminance level (Cohen, 1975; Long & McCarthy, 1982; Long & Sakitt, 1981; Pollack, 1973; Sakitt, 1976; Sakitt & Long, 1979a,b; Wilson, 1983; but see also Adelson & Jonides, 1980; Haber & Standing, 1969; Hogben & Di Lollo, 1974), contrast (Bowling *et al.*, 1979), stimulus duration (Di Lollo, 1977, 1980; Long & Sakitt, 1980) and task (see reviews by Long, 1985a; Hawkins & Shulman, 1979; Di Lollo, 1984). We used the same duration, task, and background luminance level for both the motion and luminance figures.

The contrast chosen for the luminance figures used in Expt 1 was selected based on a pilot study of subjective impressions of contrast. The luminance contrast of the squares was adjusted until it appeared to have equal contrast to that for the motion figures (dots in element squares and in the background moving 3.5 deg/sec in opposite directions). However, this subjective judgement may not be appropriate for the comparison of visual persistence between motion and luminance figures. In Expt 3, we examined the effect of stimulus contrast of both luminance and motion figures on visual persistence. For the luminance figures, subjective contrast of the element squares was controlled by changing the luminance of the dots in the squares. For motion figures, we varied the relative velocities of the dots.

Method

For the luminance figures, 8 levels of contrasts were used: -83.3, -23.8, -11.0, -7.0, 7.0, 10.4, 21.5 and 70.1%, where the values indicate the percentage of additional luminance in stimulus figures compared to the background luminance (i.e. contrast = $100 \cdot (L_t - L_b) / L_b$, where L_t represents the average luminance in the squares and L_b represents the average luminance of the background). The stimulus figures were darker than the background for the conditions with negative values of contrast. The luminance level was controlled by varying the intensity of the white dots while keeping the black dots at a constant intensity. At -83.3% contrast, the element squares were uniformly dark since at that point the luminance of the light dots in the square was equal to that of the black dots (both 4.3 cd/m²). For the motion figures, the velocity of the dots was varied over four levels; 3.5, 7.0, 10.5 and 14.0 deg/sec. Over this range, the figures become less visible at higher velocities.

The procedure was identical to that used in Expt 1. Only one observer, SS, participated in this experiment. Four sessions were run for all conditions. Eight ISIs used in two of the sessions were -67, -33, 0, 33, 67, 100, 133 and 167 msec and those in the other sessions were -50, -17, 17, 50, 83, 117, 150 and 187 msec.

Results and discussion

Figure 6 shows the percentage of correct responses for all of the twelve conditions separately, Fig. 6(a) for luminance figures and Fig. 6(b) for motion figures. The solid line is the best fitting, three-segment function fitted to the experimental data in each panel as in Fig. 2. The results of luminance figures show that the performance starts to decline for an ISI of about 0 msec and reached a minimum before 100 msec for all conditions. Similar results were obtained for both directions of contrast. An effect of contrast on the performance is only noticeable at the lowest contrast ($\pm 7\%$) where the results show a more gradual decline and a longer critical duration. The visibility of the element squares was also affected at the lowest contrast as can be seen from the drop in performance level at the -67 msec ISI which corresponds to simultaneous presentation of the two frames. Performance was 100% for the three highest

contrasts at this ISI, but dropped to 80 or 90% at the $\pm 7\%$ contrasts.

Somewhat different results were obtained for the motion figures. The performance at the two slowest velocities was quite similar starting at about 100% for the simultaneous presentation (ISI of -67 msec) with performance continuing to decline at ISIs of 130 msec or more. At the two highest velocities, performance again starts from less than 100% indicating a loss of visibility similar to that seen for the 7% contrast conditions of the luminance figures. However, the decline in performance as a function of ISI now becomes steeper so that the critical ISI is reached earlier. In fact, the critical ISI for the highest velocity is reached even while the two frames still have some temporal overlap. This unexpected finding may indicate some lateral inhibition between the stimulus elements of the first and second frame. Possibly the receptive fields capable of extracting motion-defined shapes become larger for higher velocities so that the individual squares become difficult to resolve (this may be related to the physiological finding that cells in MT tune to higher velocities and have larger receptive fields than cells in V1; Van Essen, 1985).

The critical ISI (the ISI beyond which percentage of correct responses is constant) was evaluated for each

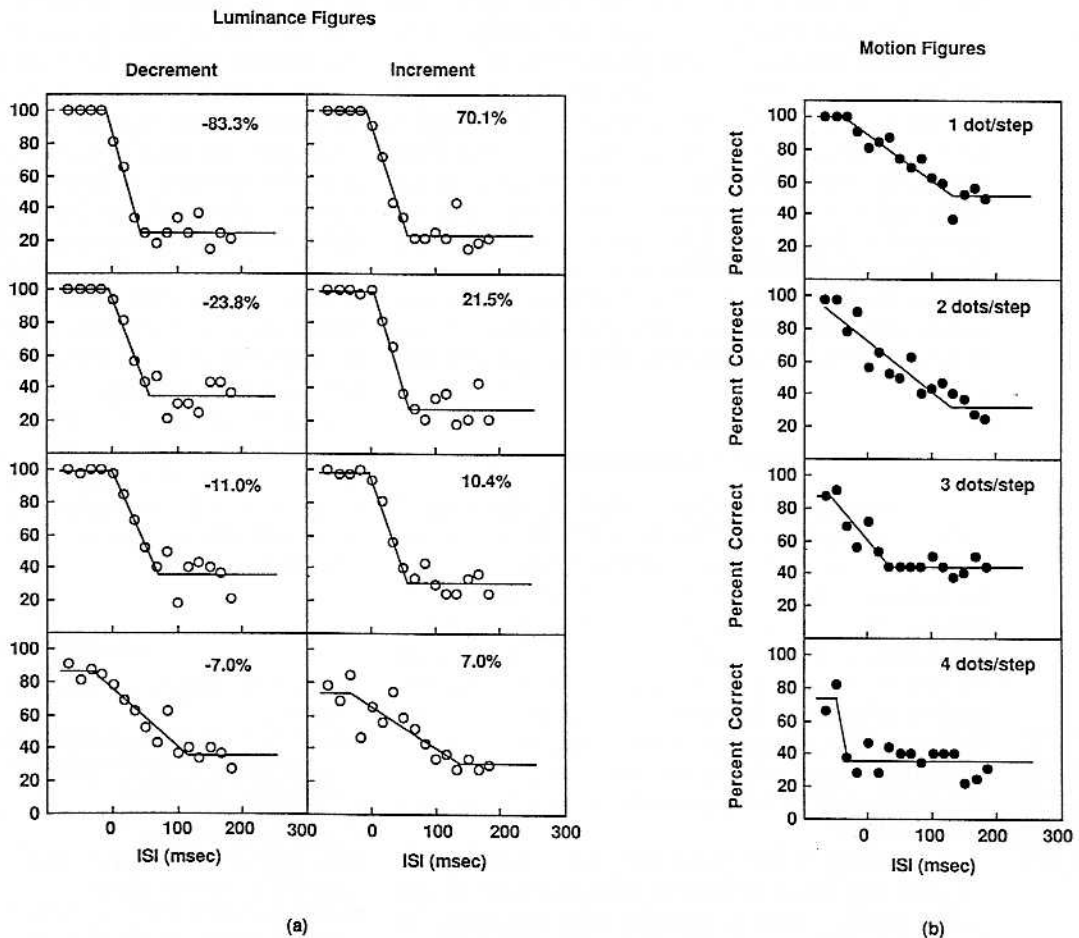


FIGURE 6. Percentage of correct responses as a function of ISI for different contrast conditions. (a) Each panel shows the results for a different luminance contrast between the squares and the background. (b) Each panel shows the results for a different relative velocity defining the squares.

TABLE 2. The duration of visual persistence for different conditions (msec)

	<i>Motion figure</i>			
Velocity	3.5	7.0	10.5	14.0
Critical ISI	133.3	130.0	35.6	-32.4
	<i>Luminance figure (negative contrast)</i>			
Contrast (%)	-83.3	-23.8	-11.0	-7.0
Critical ISI	41.6	57.0	71.1	113.3
	<i>Luminance figure (positive contrast)</i>			
Contrast (%)	70.1	21.5	10.4	7.0
Critical ISI	55.8	58.4	57.5	136.7

condition as in Expt 1 and shown in Table 2. The critical ISI varied between about 40 and 140 msec for luminance figures and the range for motion figure is between about -30 and 140 msec.

There are two important findings in this experiment. The first concerns the range of effective contrasts where the stimuli start to lose visibility. Specifically, we find that the effect of these low contrasts is very different for the two types of stimuli, prolonging the availability of information for luminance stimuli but shortening it for motion-defined stimuli. We are unclear about the cause of this difference.

The second and more important finding concerns the range of effective contrasts for which both types of stimuli were clearly visible (i.e. with nearly 100% performance for simultaneous presentation of the two frames, -67 msec ISI). This range covers 3 octaves of luminance contrast for the luminance figures and 1 octave of velocity for the motion figures. Within these ranges, the critical ISIs for both stimulus types remain fairly stable and comparable to the values that we measured in Expts 1 and 2. We take this to indicate that the differences in critical ISIs that we measured—about 60 msec for luminance figures and 130 msec for motion figures—are real differences and not a result of mismatching of subjective contrast for the two stimulus types.

GENERAL DISCUSSION

We demonstrated in Expt 1 that the duration of visual persistence for motion-defined figures was about 130 msec. This value was somewhat longer than that for luminance-defined figures. Since the duration of the persistence was not markedly affected by the motion of the random-dot background during the ISI (Expt 2), the visual persistence does not appear to be mediated by motion aftereffects. Experiment 3 suggested that the difference of persistence duration between motion and luminance figures was robust over variations in the effective contrast of the stimuli as long as the figures were clearly visible.

Our finding of the persistence for motion figures suggests that visual persistence exists in processes that follow motion analysis, agreeing with the claims of Coltheart (1980), Adelson and Jonides (1980), Long (1985a) and others. Since motion-defined figures require motion analysis and since no retinal units are direction-

ally selective in primates (Grüsser & Grüsser-Cornehils, 1973), the persistence of the motion figures cannot be attributed to retinal mechanisms. In addition, since dot motion during the ISI had little effect on the visual persistence of the motion figures (Expt 2), it is unlikely that either motion aftereffects or any other persistence at the level of motion analysis is the source of the visual persistence for motion figures found in our experiments.

We cannot, however, determine whether the visual persistence of motion figures is mediated solely by processes specific to the analysis of motion or by form analysis processes that are common for luminance and motion figures. The difference of persistence duration between motion figures and luminance figures implies that different mechanisms contribute to visual persistence for motion and luminance figures to some extent. There may be, nevertheless, a common mechanism underlying part of the visual persistence for motion and luminance figures.

As Haber (1983) argues, the persistence of a static image may not be of much use as visual storage but may in fact interfere with visual perception by temporally blurring images together (see also Breitmeyer, 1976, 1980). However, briefly preserved images might serve a role in retaining information which is briefly occluded by another object or by an eye blink. Whatever the case, the results of our experiments can be regarded as revealing the temporal resolution for motion-defined forms. Since motion-defined stimuli have longer persistence than luminance-defined stimuli, we would expect that the ability to detect rapid changes in motion-defined stimuli would be less than for luminance-defined stimuli. The temporal characteristics for motion- and luminance-defined figures have been compared previously by Regan and Beverley (1984). These authors reported that the duration of temporal summation is longer for motion figures than for luminance figures. Our finding of a more gradual decay of persistence for motion than for luminance figures agrees with their results.

In summary, we find that the visual persistence for motion-defined forms is longer than that for luminance-defined forms. The persistence for motion-defined forms must rely on mechanisms located beyond the retina and did not appear to be mediated by motion aftereffects.

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