The perceptual fate of letters in two kinds of apparent movement displays

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Two experiments investigated the importance of figural relationships among stimulus elements in the determination of the kind of motion perceived in bistable apparent-movement displays. Stimulus frames containing the words MITE and ITEM were constructed in such a way that the letters I, T, and E appeared in corresponding locations while the M was in disparate locations between frames. When the frames were alternated with a 20-msec ISI, observers maintained local figural identity in their percepts of apparent movement. However, when the frames were alternated with an 80-msec ISI, observers reported apparent movement of the entire groups of letters and thereby ignored figural relationships in their percepts of apparent movement. In a second experiment, it was found that figural nonidentity between elements of successive frames always resulted in apparent movement of a perceptual group or "blob" regardless of ISI. It is suggested that short-range apparent-movement percepts rely strongly upon figural identity among corresponding stimulus elements, whereas long-range apparent-movement percepts do not.

Despite over 70 years of intensive study, the precise role of the figural relationship between successively presented stimuli in the production of apparent movement is not known. Many studies have led to the conclusion that figural identity is not a necessary condition for the production of good apparent movement (e.g., Kolers & Pomerantz, 1971; Navon, 1976; Orlansky, 1940). A number of other experiments have resulted in the conclusion that alternating stimuli must be meaningfully related (in both figural and interpretative aspects) for good apparent movement to be seen between them (e.g., DeSilva, 1926; Jeeves & Bruner, 1956; Toch & Ittelson, 1956; Warren, 1977).

In a somewhat different paradigm, Pantle and Picciano (1976) and Petersik and Pantle (1979; see also, Braddick, 1974) have demonstrated that the alternation of the same two stimulus frames can give rise to two very different apparent-movement percepts, depending upon, among other things, the duration of the interstimulus interval (ISI) between the frames. The two types of apparent movement observed are sufficiently different to suggest that form information regarding stimulus elements within the frames is processed differently in the two cases. The authors argued that two different perceptual processes underlie the two kinds of apparent movement, and that in studies of apparent movement it is valuable to distinguish between local form information (e.g., details) and global form information.

Until relatively recently (cf. Anstis, 1979), researchers have not considered the difference between these two apparent-movement processes in the design of their experiments, and it is likely that experimental results and interpretations have been confounded by them. It is the purpose of the present paper to make an initial demonstration of how local form information and the apparent-movement processes interact as a function of ISI.

Two Apparent-Movement Processes

Pantle and Picciano (1976) and Petersik and Pantle (1979) alternated stimulus frames similar to those first studied by Ternus (1926/1938). Each frame contained three regularly spaced dots in a horizontal row. In one frame, the three dots were shifted one complete unit to the right so that the two leftmost dots in that frame were in the same position as the two rightmost dots in the first frame. When these frames were alternated with a short ISI (generally less than about 40-50 msec), observers reported the two center dots as remaining stationary while a third dot shifted back and forth around them (element movement); that is, local form identity seemed to be preserved in the overlapping dots. When the frames were alternated with a longer ISI (preferably 60 msec or longer), observers reported seeing a group of dots shift back and forth as a whole (group movement). Here, identical forms (the dots) paired with one another over greater distances.

Petersik and Pantle (1979) interpreted element movement to be the product of a short-range apparent-movement process, probably the same one

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described by Braddick (1974). With the Ternus stimuli, the short-range process was favored by complete overlap or only small shifts of the center dots, short ISIs, and complete or near figural identity of the overlapping dots (for example, when the dots of one frame are replaced with vertical line segments and the dots in the second frame with horizontals, element movement cannot be obtained; Pantle & Petersik, 1980; cf. Braddick & Adlard, 1978). Thus, form identity and proximity in both space and time were seen as crucial for this kind of apparent movement. When the functioning of the short-range process was disrupted by any of a number of stimulus or observer manipulations, a second, long-range process (cf. Braddick, 1974) evidently was favored. The long-range process was ordinarily stimulated by longer ISIs, and neither figural identity (Pantle & Petersik, 1980) nor close proximity were considered crucial to its operation. In some instances, it behaved like a "default" mechanism, operating when stimulus manipulations prevented the operation of the short-range process.

It is important to note that there were thought to be nearly no form requirements for the long-range process. In some respects, it creates a global form, or blob, in its grouping of alternately presented stimulus elements. In the following sections of this report it will be shown how stimulus conditions that favor either the short- or long-range process also affect the perceptual fate of stimulus forms in apparent movement and how local form information might reciprocally influence the type of apparent movement seen.

Form Information in Group and Element Movement

In the original experiments by Pantle and Picciano (1976) and Petersik and Pantle (1979), figurally identical dots were used in the stimulus frames. As pointed out by Ternus (1926/1938), dots in these arrangements can be "mapped" onto one another to produce either group movement or element movement with equal *a priori* probability. For the present experiment, we sought a stimulus display that would preserve the basic design of the group/element movement display and yet would not consist of figurally identical elements in each position. Hence, a two-frame display was created in which one frame contained the word MITE and the second frame contained the word ITEM. The words in the two frames were arranged so that the letters I, T, and E appeared in corresponding locations. This meant that the letter M appeared on the left in the first frame and had no corresponding partner in the second. Similarly, the letter M appeared on the right in the second frame and had no partner in the first. The question we asked was whether observers of these alternating frames would preserve the form identity of the letters and consistently report the I, T, and E as stationary, regardless of ISI, or whether local form would be ig-

nored so that the two words (or something?) would be seen as shifting back and forth as wholes. If the earlier description of the short- and long-range processes is correct, namely that local form identity mediates pairings between frames with the short-range process but is ignored with the long-range process, then the former prediction should obtain with short ISIs and the latter with long ISIs.

EXPERIMENT 1

Method

Subjects. Twenty-four undergraduate students (7 male, 17 female) volunteered to participate in the experiment. None of the subjects were aware of the purpose of the experiment or were experienced with the group/element movement display. Data from none of the subjects were discarded.

Stimuli and Apparatus. Each frame of a display was presented through one channel of a three-channel tachistoscope (Scientific Prototype, Model GB). Frames were viewed from a distance of 153 cm and subtended a visual angle of 4.8 deg vertically and 6.6 deg horizontally. The luminance of the white background of each frame was 4.1 cd/m², and the luminance of the dark letters was 0.7 cd/m².

The letters were printed in India ink. The letters on each stimulus frame were printed in block capital form; the stroke width of each was 9 min visual angle, and the average width of the letters was 34 min. The vertical extent of each letter subtended 31 min. The edge-to-edge separation between letters subtended 13.5 min.

Procedure. Upon arriving for the experiment, each subject was seated in a light-tight booth attached to the tachistoscope and was allowed to dark adapt for 5 min. Each subject was instructed that two stimulus displays were to be presented and that the subject's task was simply to report what was seen. Each subject was to view the screen globally, looking straight ahead but attending to the entire screen. It was stressed that the subject's perceptual reports were to be based upon what was *seen* and not upon what the subject *thought* might be happening. At this point, a tape recorder was placed inside the booth with the subject so that all responses would be permanently recorded.

By the flip of a coin, it was determined whether the subject would be exposed to the alternation of the stimulus frames with an ISI of 20 msec first or to one of 80 msec first. Each stimulus frame was presented for a duration of 200 msec. The ISI was dark. While the first display was being presented, the subject had an unlimited period of time to report his or her "best visual impression" of what was perceived. If the response did not include any statement to the effect that something was perceived as moving or that something was seen as remaining stationary, the experimenter asked for more detail. After completion of the first response, there was a rest period of approximately 2 min duration, followed by presentation of the second display.

If any subject was not able to describe what was presented, or if the description could not be interpreted by the experimenter, following the descriptions of both stimulus displays, the stimulus displays were re-presented in close succession, each for a period of approximately 20 sec. Next the subject was asked to describe the similarities and the differences between them. This procedure was adopted for 6 of the 24 subjects.

Scoring. The tapes were subsequently analyzed by three raters, the author and two college-aged individuals from the local community. For each description of a stimulus, if the subject reported that three or more letters appeared to move, the subject's response was to be called "group movement." On the other hand, if two or more letters were reported as stationary, the subject's response was to be called "element movement." After each rater had scored the tapes, the ratings were recorded along with the corresponding ISIs for each report.

The raters agreed regarding the rating to be applied to 47 of the 48 (24 subjects $\times$ 2 ISIs) reports. In order to arrive at one final set of results, the 48th report was assigned the rating upon which two of the three raters agreed.

Results

The frequency of obtained reports of group and element movement for both the 20- and 80-msec ISIs, along with their expected frequencies, are shown in Table 1. As can be seen, a majority of responses at the 20-msec ISI indicated that the subjects preserved the local identity of the overlapping letters; that is, they reported element movement in which the I, T, and E were perceived as remaining stationary while the M shifted from end to end. However, when the ISI was 80 msec, a value generally unfavorable to the short-range process associated with element movement, the subjects reported a majority of group-movement responses. In this case, the M from frame 1 typically is seen as moving into the position of the T in frame 2, etc. That this was the case was revealed in the spontaneous comments of the subjects (see below). This type of percept suggests that local figural identity is unimportant in determining group movement; rather, the collection of stimulus elements is seen in motion. A chi-square analysis showed these distributions of responses to be significantly different from what might be expected on the basis of chance [$\chi^2(1) = 25.18$, $p < .001$].

The group movement of the words MITE and ITEM is paradoxical in the sense that the individual letters in motion must perceptually change their identities to complete the movement of the group. That subjects indeed perceived something like this with the 80-msec ISI is shown in the following spontaneous comments: "It appears that the entire words are moving—all the letters"; "All of the letters are moving relative to the boundaries of the screen"; and "The whole word is moving from left to right, but 'item' is showing up on the right." One subject seemed to be unaware that she was viewing two words: "It's the same word moving back and forth across the screen." Another subject was clearly aware of the paradoxical nature of group movement and resolved it in the following way: After having reported element movement with the 20-msec ISI,

upon viewing the frames with the 80-msec ISI, she said, "The M is still switching from the front of the word to the back of the word, but the other three letters in between—the I, T, and E—are shifting too." It is obvious that the figural identity of letters was coded at some point during an 80-msec trial, since most subjects correctly reported the two words. Nonetheless, the local form identity appears at least irrelevant to the generation of the movement signal.

The present experiment has demonstrated that, in the types of stimulus frames we used, local form identity is preserved at short ISIs and disregarded at long ISIs. However, since figural identity itself was not manipulated between frames, it is impossible from this experiment to determine the dependency of group and element movement upon interframe figural identity. If the interpretation of the short- and long-range processes presented in the introduction is correct, we would expect that figural nonidentity between frames would prevent that operation of the short-range process and would therefore result in a majority of group-movement responses due to the "default" operation of the long-range process. With this prediction in mind, we repeated Experiment 1 with stimuli that did not possess identical form information in any part of frames 1 and 2.

EXPERIMENT 2

Method

Subjects. The subjects for this experiment were 12 volunteer undergraduate students. None were aware of the purpose of the experiment and none had served in Experiment 1.

Stimuli and Apparatus. The stimuli and apparatus were the same as in Experiment 1, with the exception that the stimulus frame containing the letters ITEM was replaced by a frame containing the letters AVHW. For this pair of frames, the letters A, V, and H occupied the same spatial positions as the letters, I, T, and E, respectively.

Procedure and Scoring. The procedure and scoring were identical to those used in Experiment 1.

Results

With the exception of one subject, all subjects reported seeing movement that can be categorized as "group movement" by the criteria established in Experiment 1 at both the 20- and 80-msec ISIs. The subject who was the exception reported element movement at the 20-msec ISI and group movement at the 80-msec ISI.

Most subjects did not spontaneously report seeing any of the letters in the spatially overlapping positions change identity until they were instructed to focus their attention upon one of them. Under such instructions, an individual "element" in a given spatial position seemed to remain stationary and change its identity as the frames alternated (e.g., "I" turned into "A"). When this percept occurred, the remaining letters appeared mostly to continue to move as a group (although such movement is surely paradoxical,

Table 1
Frequencies of Group and Element Movement Reports
for 20- and 80-msec ISIs

Movement Response	ISI				Total
	20		80		
	Observed	Expected	Observed	Expected	
Element	23	14.5	6	14.5	29
Group	1	9.5	18	9.5	19
Total	24		24		48

given that one element in the middle seemed to remain stationary).

DISCUSSION

The present experiments have demonstrated that when figurally identical letters are present in corresponding locations of two stimulus frames, the local figural identity predominates at the shorter ISI (20 msec) so that letters of the first frame are perceptually paired with their figurally identical partners in the second frame. When figurally identical partners are not available in corresponding locations of both frames, the local identity of the letters is ignored for the purposes of generating a movement signal, and the collections of letters are treated as perceptual wholes (which are then seen in group movement), even at the shorter ISI.

On the other hand, with a longer ISI (80 msec), the local identity of the various letters is ignored, regardless of the design of the stimulus frames, and group movement is nearly always seen. This perceptual irrelevance of the local identity of the stimulus elements is apparently due to the fact that when stimulus conditions in general favor the operation of the long-range apparent-movement process, the motion signal is generated with regard to global forms, collections of elements, or blobs (the low spatial-frequency tuning of the long-range process in a similar apparent-movement paradigm has been demonstrated by Pantle, 1982). This interpretation is supported by the results of Ramachandran, Ginsburg, and Anstis (1983), who showed that the apparent-movement signal is directed to stimuli with similar low-spatial-frequency content rather than to stimuli with similarity of oriented edges when both alternatives are available in an apparent-movement display. It is noteworthy that the experiment of Ramachandran et al. was conducted with stimulus separations greater than the putative limit of the short-range process (i.e., 15 min; see Braddick, 1974). Based on present findings, along with those of Braddick (1974), Pantle and Petersik (1980), and Petersik, Pufahl, and Krasnoff (1983), we might expect that with smaller separations the short-range process would mediate the apparent-movement signal with the stimuli of Ramachandran et al., so that movement between similarly oriented edges would be observed.

Although local form information may be irrelevant to the generation of the group-movement signal, that form information may nonetheless be recovered through the operation of a nonmovement perceptual process. The conflict between the group-movement signal and some other form signal may account for the "plastic deformations" noted by Berbaum, Lenal, and Rosenbaum (1981) and others (e.g., Kolers, 1972) when apparent movement occurs over relatively

large distances (i.e., when the long-range process operates).

In group movement, it is the collection of elements (letters) that moves as a whole. This occurs despite the fact that there is no obvious ecological transformation that maps the word "mite" onto the word "item" or the letters "avhw" onto the word "mite." The conclusion to be drawn from these experiments and others like them (Braddick, 1974; Pantle & Petersik, 1980; Pantle & Picciano, 1976; Petersik, Boring, & McDill, 1982; and Petersik & Pantle, 1979) is that when other stimulus conditions (e.g., a short ISI) favor the operation of the short-range process in apparent movement, local form information determines the apparent motion. On the other hand, group movement favored by other stimulus conditions essentially determines the perceptual fate of local form information.

CONCLUSION

After conducting a study of apparent movement that almost certainly depended upon the long-range process, Kolers (1972) concluded that "the visual system responds to locations of stimulation and infers or creates changes of figure to resolve that disparity" (p. 57). The present experiments demonstrate that under proper spatiotemporal conditions (i.e., small spatial and temporal separations of the stimuli) the visual system responds to local form information as well, and selects an appropriate apparent-movement process—the short-range process, if the form information is congruent between frames and the long-range process if it is not—to disambiguate positional disparities.

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