Visual dissociation of digitized photographs

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Visual dissociation occurs when a visual marker from one display in a rapidly presented sequence (e.g., 9 items/sec) is perceived as having occurred in a temporally adjacent display. Three experiments that evaluated the application of computer graphics techniques to study this phenomenon with digitized color photographs are reported. The primary concern was that visible phosphor persistence might artificially increase the frequency of integration errors. In Experiment 1, visible phosphor persistence was assessed using a multiple-repetition subtraction test to determine which stimulus conditions did not yield reportable persistence. On the basis of these results, visual dissociation performance when the same color photographs were presented using mechanical 16-mm projection (as in previous research) and when they were presented on a computer monitor were compared in Experiments 2 and 3. The results supported computer application, in that computer presentation yielded the same pattern of errors and accuracy levels as did research using mechanical projection.

The purpose of our research was to determine whether a computer graphics system could be used to conduct research on visual dissociation when digitized color photographs served as stimuli. Visual dissociation research requires rapid serial visual presentation (RSVP; e.g., 9 pictures/second). Subjects search each sequence for a picture that contains a specified feature. Until now, research of this type has been conducted using single-frame photography and 16-mm data analyzer projectors (e.g., Intraut, 1985, 1989; Potter, 1976). Our primary concern was whether visible phosphor persistence on the monitor would limit the usefulness of computer application in this research area. Various forms of visible persistence and iconic representation have been clearly established (e.g., Burt 1960; Colheath, 1980; Dijkstra & Dunsmuir, 1988; Farrell, 1984; Farrell, Pavel, & Speiling, 1990; Loftus, Dunsmuir, & Gehrig, 1992, Neisser, 1967). The danger is in confounding the effects of phosphor persistence on the screen with persistence in the visual/cognitive system (see Irvin, Yantis, & Jonides, 1983). Jonides, Irvin, & Yantis, 1985; Rayner & Pollatshak, 1985).

Three approaches were taken. First, a shutter test was conducted to determine whether we could detect visible phosphor persistence with our stimuli. Second, in an attempt to eliminate or minimize persistence, we tested the effectiveness of following each picture with a white "bleaching" field for one noninterlaced video frame. The third approach involved direct comparisons of subjects' performance when the same pictorial sequences were presented mechanically, using a 16-mm data analyzer projector, and when they were presented on a color monitor.

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Visual Dissociation

Visual dissociation (also referred to as "temporal migration") is a perceptual error that occurs when stimuli are presented in rapid succession (e.g., 9-20 items/sec) in the same spatial location (e.g., Gathercole & Broadbent, 1984; Intraut, 1985, 1989; Lawrence, 1971; McLean, Broadbent, & Broadbent, 1983). The task typically requires the subject to view a rapidly presented stream of stimuli (usually alphanumeric symbols or words) and to report the stimuli containing a specified target characteristic. The phenomenon occurs when subjects confusively report the target characteristic as occurring on the stimulus but, on a temporally adjacent item. For example, using color photographs of objects and a presentation rate of 9 items/sec, Intraut (1985, 1989) showed that a black frame that surrounded one picture in a 1-picture sequence was frequently and confidently reported as being on the immediately preceding or immediately following picture in the sequence.

Intraut (1989) proposed a model of the early stages of picture processing that provides a possible explanation of this phenomenon. A central component of the model is a very short-term visual/conceptual store (Arons & Phillips, 1980; Potter, 1976). Integration of features and comprehension of the display take place at this stage of processing. There is evidence to suggest that under conditions of rapid continuous presentation (faster than 3 items/sec), more than one picture at a time may be held in this very short-term store (Intraut, 1984, 1989). It is under conditions of simultaneous processing that temporal migration errors are likely to occur.

According to this view, migration of a component occurs when display integration time is long relative to presentation rate. When this is the case, integration of the components of one display is not complete at the time that the next display enters the store. Longer integration times would be expected for displays that were more complex or had unfamiliar attributes. Thus, to obtain the same

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level of frame migration across different types of stimuli, a presentation rate used for stimuli that are relatively easy to identify must be faster than that used for stimuli that are relatively difficult—for example, numbers as compared with colored objects (Intraub, 1985) and letters as compared with words (Gathercole & Broadbent, 1984).

Finally, the direction of migration (preceding or following a picture) is apparently determined to some degree by the speed of target detection (Intraub, 1989). When the target is detected rapidly, it is more likely to become integrated with the previous picture (~1 error). When it is detected a little more slowly, it is more likely to become integrated with the next new picture that enters the store (~1 error). Intraub (1989) reported that reaction times to target detection were significantly faster on trials in which subjects had made a high-confidence -1 error than they were on ones, in which they had made a high-confidence +1 error. The difference in detection-time was about 20 msec.

Applications of Computer Technology

The importance of computer technology to research on picture perception is not limited to the obvious benefits of eliminating the tedious task of single-frame photography. It allows a more fine-grained manipulation of presentation rate than does mechanical projection, and computer graphics technology allows digitized photographs to be edited in ways that are difficult to accomplish with photography alone.

There are several potential problems facing researchers who use computer graphics technology to conduct research requiring precise tachistoscopic presentations, particularly with complex stimuli that can take a relatively long time to generate on tape. Computer graphics are likely to become more complex in the video computer, they can be presented in any order, and each can be presented for as little as a single noninterlaced video frame. A primary concern for us was the possibility of visible phosphor persistence, which raises an obvious problem—that is, determining whether the subject’s error in reporting the conjunctive of visual events reflects integration errors within the human visual system or integrated composites of stimuli within the computer display (see Irwin et al., 1983; Jonides et al., 1983; Rayner & Pollack, 1983).

EXPERIMENT 1

The purpose of Experiment 1 was to determine whether (1) subjects could detect the presence of a stimulus picture on the basis solely of phosphor persistence, and (2) visible phosphor persistence could be eliminated by introducing a white “blanking” field for one noninterlaced video frame following each picture. To address the first question, the digitized photographs were alternated with a blank field (either gray or black). Subjects viewed the screen monocularly, through the aperture of an electronic shutter. The shutter was closed when the stimulus was presented and opened when the blank field was presented. In this way, if visible phosphor persistence existed, the subjects would be able to distinguish trials in which a picture preceded the blank field from trials in which it did not. Rapid alternation of the stimulus and the field in each sequence was used to enhance the likelihood of detecting faint persistence of the stimulus, which might not be obvious if a single brief presentation of stimulus and blank were shown. A third condition, presented after the primary conditions were completed, alternated the stimulus with another picture under the same stimulus conditions described above, in order to determine whether picture composites could be detected due to visible phosphor persistence.

To address the second question, the same procedure was followed except that the last video frame of the stimulus presentation was replaced by a bright white field (a “blanking” field). It was hoped that this would eliminate visible persistence of the stimulus, by charging the phosphor across the entire display.

Method

Subjects. The subjects were 6 student volunteers (undergraduate and graduate students) from the University of Delaware. Each was paid $4.50 for participation. Several worked in our lab and were especially motivated to scrutinize the visual display and report everything they could see.

Stimuli. The stimuli were colored negative photographs of objects that were cut out and photographed in the center of a gray background to create a set of 25-min slides (described in Intraub, 1985). The slides were prepared using a Kodak Carousel projector, and the images were captured with a Jena Vector Corporation (JVC) CCD color video camera attached to the graphic display (described in the section on equipment). Image resolution was 378 x 243 pixels x 16 bits of color. This allows 65,536 different colors, making up for the relatively low spatial resolution and producing a high-quality image. Subjects of the images were presented to a television set of the 16-mm film sequences used by Intraub (1983, 1985).

The centrally positioned pictures ranged in size, with the smallest containing about 14% of the gray background and the largest—viewing 49%. The actual pictures were an arm, a suitcase, a white cat, a mouse, a Peking duck, a plane, a tractor, a flag, a hot air balloon, a projector, and a sock. Luminance of the stimuli was determined by using a photometer at six different locations on each object (in the case of a particularly small object and a particularly large object, three and nine locations were measured, respectively). For field luminance, several measurements were taken, distributed around the field. The mean luminance for color objects in the computer display was 17.1 L. Luminance of the gray field was 17.1 L. Luminance of the white “blanking” field was 24.8 L. A small lamp dimmed illumination the subject’s keyboard, it had no measurable effect on display luminance.

Apparatus. Displays were presented on a Mitsubishi (Model D9A14AX) color monitor, capable of displaying noninterlaced images. These were presented using an IBM-compatible (386/25-MHz) computer, equipped with a Trinitron AT/34 4-MHz graphics board. The visual angle subtended by the computer display was approximately 4.9° x 9.6°.
C programming was used in conjunction with Truetime Stage 2.0 (a programming tool enabling a library of C commands that drives the various features of the AT&T Viva board). The computer was pro-
grammed to drive a Unilistic electronic shutter (Model 2212) with
a Unilistic stainable (probes) shutter in flight. The subject's eye
and delay times were recorded at 3.5 and 4.5, respectively. Subjects
viewed the screen with one eye, through the shutter. To ensure
that the subjects were viewing the shutter monocularly, an opaque
eyebrown was attached to the shutter so that if the other eye opened,
view of the display was possible. The subject was constructed out of
dark cardboard that was cut to fit around the shutter and cover the
non-

viewing eye.

Measuring timing. To test if actual display duration corre-
sponded to the duration we specified in our software, we used
a stopwatch to time these. The task was to open and close the at
least once.

The stopwatch was placed at the aperture of the shutter (where
the subject's eye would normally be positioned) and the same pro-
cedure was followed. These tests did indeed reveal a timing prob-
lem that was corrected prior to running the experiment.

Design. There were four presentation conditions with 12 se-
quences in each. These were mixed randomly in a repeated mea-
sures design. Each stimulus picture was presented in all four con-
ditions. In the two standard conditions, stimulus pictures were
alternated with black fields (either a gray field that was similar to
the gray background of the pictures, or a black field). In the
blackfield condition, the last video frame of each picture was re-
placed with a white blackfield, prior to presentation of the gray
or black field.

These 48 sequences were intermixed with another 48 sequences
that served as "catch trials." The catch trials were identical to the
four conditions just described (i.e., gray field or black field, standard
presentation or "bleaching" field), except that stimulus pictures
were replaced with blank fields. The stimulus picture and interspersing
field was presented instead (e.g., a gray field replaced the stimu-
lus when the alternating field was gray). These conditions
allowed us to obtain a measure of detection response times when
no stimulus was actually presented.

The experiment ended at the time of the experiment proper. Twelve sequences were constructed in which a
picture of a stimulus picture was presented with another picture.
Each picture was placed in the middle of the sequence, and two objects (e.g.,
a horizontal object was varied with a more vertically oriented ob-
ject). The catch trials were to be used on the last video frame of each picture comprising
on the background of gray. Six of these se-
quence of 200 ms.

The subjects viewed the stimulus with the stimulus, they were
told that the two pictures were presented in the same location.

The subjects were asked to report the sequence for each trial by
naming each stimulus picture. This was their cu to focus attention on the
fixation point. The sequence of 200 ms was then presented with a
500-1000 ms delay and the 1000 ms sequence. The imperative was
to see if you can identify each of these pictures. The subjects were
informed that the experimental task required

The results of Experiment 1 indicated that visible phos-
pheresis persistence was evident for our stimuli only when
bleached by a black field. The implication of this finding
was that visible phosphorescence would there-
fore not pose problems for studying temporal migration if we used the stimuli and gray fields that did not yield visible traces in the cluster test. Experiments 2 directly tested this assumption using behavioral measures rather than a subjective report procedure. We directly compared performance on Intraub's (1985) same-migration task when the sequences were presented using a 16-mm projector and when they were presented using two types of computer displays (standard projection and presentation with the interpersed 'bleaching' field used in Experiment 1). Experiments involving alphanumerical stimuli have often been conducted using computer displays, both in visual discrimination experiments, such as those described previously, and in related multiple-task VSP experiments (Intraub & Broadbent, 1987; Karnescher, 1991; Karnescher & Porter, 1991; Raymond, Shapiro, & Arnell, 1992; Reeves & Sperring, 1986; Sperring & Reeves, 1980; Weichselgartner & Sperring, 1987). In contrast, research involving color photographs has relied on single-frame cinematography and mechanical projection (e.g., Intraub, 1983, 1989; Porter, 1976). Photographs of objects and scenes can vary greatly from one stimulus to the next, so that objects don't always overlap the same spatial area—that is, a part of an object may be followed sometimes by a blank area in the next picture and sometimes by a filled area. With alphanumerical stimuli, one has the option of presenting black stimuli on white backgrounds, thus minimizing persistence of a feature of the filter. Effects of visible phosphor persistence would be expected to be more pronounced for color photographs than for alphanumerical stimuli, and might alter performance on a visual dissociation task. The rationale for Experiment 2 was as follows. If there is visible phosphor persistence, then we should observe a greater frequency of migration errors with the computer displays than with the cinematic display, because in addition to mental integration errors, there would be actual stimulus components appearing briefly on the screen. Furthermore, in addition to the frequency of errors, if the two types of presentation techniques are equivalent, the pattern of errors should also be the same.

Intraub (1985) observed a striking bias for reporting the large trace around the immediately preceding picture in the sequence rather than the immediately following picture. This was in contrast to the pattern typically obtained with alphanumerical stimuli, in which migration occurs more frequently following the first pictures in the sequence (e.g., Gathercole & Broadbent, 1984; Intraub, 1985; Experiment 4; Lawton, 1971; McLean et al., 1983; Weichselgartner & Sperring, 1987). There are several theoretical interpretations of why different migration patterns might occur. These raise interesting questions for future experiments on visual dissociation that are beyond the scope of this paper. The important issue for the present research is whether or not the unusual pattern of migration for large-frame detection would replicate. We expected this pattern to replicate when mechanical projection was used, the question was whether it would also replicate in the computer conditions.

Both computer conditions were tested because we were concerned that the repetitive flashing of the "bleaching" field, while providing an additional safeguard against phosphor persistence, might interfere with task performance. The flashing could induce visual masking or provide a distraction, thus breaking the observer's concentration.

Method

The subjects were 40 male and female undergraduates who had elected to participate in the departmental subject pool. Apparatus. The projector system used for the two computer conditions was the same as that used in Experiments 1 and 4. Visual 'instrumentation' consisted of a color data projector used to project the 'bleaching' field. In the color film apparatus, the projector was located in a projection box, and images were rear-projected on a screen in the room with the computer. All subjects were therefore seated in the same room. They faced either the rear-projection screen or the color monitor. The visual angle subtended by both types of displays was approximately 6° X 8°.

Stimuli. The stimuli were the same 12 color magazine photographs of objects used in Experiment 1 (4 different sets of 12 objects were used in the practice sequence that preceded the actual experiment). The stimuli and the pictorial material were the same across all 4 sequences of one picture in the practice test.

As described in Experiment 1, the computer images appeared subjectively to be of the same quality as projected images. luminance, perceptual task material, and the subjects to rest, with the exception of one picture in the practice test.

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Design. All 12 pictures served as target picture (the one with the black frame), twice, except for the mustard and the glass. The picture with the target picture only once and the glass was the target three times. The reason for this discrepancy was a printing error carried over from Intraub (1985). It was carried over to present the trial for accuracy of recognition. The instructions were used correctly in a response. The sequence for the target picture was equally distributed across Experiments 2, 4, and 5. The pictures that flashed a given target picture were reversed the second time that target picture was presented. The same 24 sequences were presented using the computer display without the 'bleaching' field, the computer display with the 'bleaching' field, and the projector. Twenty subjects participated in each condition. Presentation rate in the projector condition was 1 frame/sec, while the computer displays presented the same rate in the two computer conditions. 117 msec. In the 'bleaching' field, a new video frame associated with the stimulus was replaced by a blank field. In the video frames of the association, the field. Stimulus onset asynchrony was therefore the same in both computer conditions.

Procedure. The subjects were tested individually. They were familiarized with the pictures and their names following the same method as Experiment 1. As in Intraub (1985), to familiarize them with the black frame, the pictures were presented again, this time with the frame around each one. Again, the subjects were told that the frame was present or absent, and that one type of sequence to use them to focus attention on the fixation point was to the blank field. For 2 rows of 3 series would then flash on the screen, followed by a 1-msec delay and the sequence. The subjects were instructed to provide confidence ratings for each sequence (very sure, not sure, or unsure). This procedure was carried out for the practice picture and the practice sequence. The instruction was the same for the 24-item picture set and the 24-experimental sequences.
Results and Discussion
The subjects' confidence ratings in each condition were similar to those obtained in Intraub's (1985) experiments and are presented in Table 1. The subjects failed to respond on 1.3% or fewer of the trials in each condition ("misses"). As in the previous research, all analyses were conducted on high-confidence trials (those with ratings of sure or pretty sure). The percentage of high-confidence responses that were correct (hits) and those that were incorrect at each serial position are shown in Table 2.

All three conditions replicated the pattern of results reported by Intraub (1985). The subjects made numerous high-confidence migration errors, usually reporting the immediately preceding or immediately following picture as the one with the frame (−1 and +1 pictures, respectively). In all conditions, fewer than 8% of all high-confidence error responses fell outside this window.

The important comparisons were between the standard computer condition (no "bleaching" field) and the projector condition, and the two computer conditions. Nonorthogonal planned comparisons conducted on the proportion of correct target detections (hit rate) revealed no significant difference between the standard computer condition and the projector condition [F(1,17) = 1.19]. Although there appeared to be an increase in accuracy when the "bleaching" field was added to the computer display, this difference between the two computer conditions did not reach significance [F(1,17) = 2.43, MSE = 550.20, p < .13].

Similar to Intraub's (1985, 1989) previous research, there was a bias for reporting the immediately preceding picture in the sequence. Wilcoxon tests showed this bias to be significant (at p < .01) in each condition (T = 7, n = 19, T = 0, n = 17, T = 9, n = 16; in the projector, computer, and computer with "bleaching" field conditions, respectively). To consider the degree of bias, difference scores were obtained for the three conditions by subtracting the proportion of errors to later pictures in the sequence from the proportion of errors to the preceding pictures. The mean difference scores are shown in Table 3. Nonorthogonal planned comparisons showed that the size of the difference score (i.e., the size of the bias to report earlier pictures) did not change as the standard computer condition was compared with the projector condition (F < 1) or when it was compared with the computer condition in which the "bleaching" field was present (F(1,57) = 1.88).

The pattern of temporal migration was unaffected by presentation mode. Subjects did not make more errors when viewing the display on the monitor than they did with the projection screen, and the pattern of results (i.e., a bias toward reporting preceding pictures) was upheld.

The addition of a briefly flashed white "bleaching" field clearly did not result in a performance decrement; if anything, subjects in this condition tended to be slightly more accurate in target detection. If future research shows this difference to be reliable, possible reasons might be that (1) the interpolated flashes may heighten awareness, or (2) the white field may be interpreted by the visual system as a new event (or may act as a mask) so that it reduces integration errors between temporally adjacent pictures in the visual/conceptual short-term store. What can be determined from the current experiment, however, is that the addition of the "bleaching" field does not hurt performance or change the general pattern of errors in a visual dissociation task.

EXPERIMENT 3
Experiment 2 followed up the findings of Experiment 2, using three different rates of presentation (100, 117, and 133 msec per picture). This presentation does not allow for very fine-grained differences in presentation rate. Computer presentation, however, allowed us to readily compare performance at presentation rates in which the stimulus onset asynchrony could be changed in 17-msec increments. According to the visual integration model described earlier, frame migration is influenced by the processing time needed to integrate the components of a display and the speed at which the pictures are presented. Therefore, according to this model and, in fact, to most models that would attribute the effect to on-line processes (rather than to a response error occurring in memory following presentation), these subjectively similar-looking presentation rates should yield a greater frequency of high-confidence migration errors as presentation rate is increased.

Method

Subjects. The subjects were 32 undergraduate volunteers from the same population as in Experiment 2.

Stimuli and Apparatus. The same apparatus and the same sequences of digitized color photographs were used as in Experiment 2.

Design and Procedure. The subjects were randomly assigned to one of three conditions: slow (133 msec/picture), medium (117 msec/pic-
Although the results of the shutter test were encouraging, subjective report alone would not be sufficient to allay concerns about this aspect of computer presentation. Experiments 2 and 3 were performed to determine whether subjects' behavioral data would converge on the same conclusions. In Experiment 2, a direct comparison was made between subjects' performance on a visual discrimination task with photographs using mechanical projection (cinematography, as in Intravaia, 1985) and computer presentation. Intravaia's research was replicated, and the same pattern of errors and similar levels of accuracy and confidence were obtained in the projector and computer conditions. In no instance did the computer presentation yield lower accuracy, as would be expected of visible phosphor persistence causing fleeting stimulus composites on the screen.

Experiments 1 and 2 also showed that once the stimulus set had been screened using the shutter test, the addition of a white "blanching" field following each picture did not alter the general pattern of results or cause poor performance. If anything, subjects were more accurate with the interspersed field. This tendency toward less migration might indicate that the visual system interprets the flash as a new visual event, thus limiting integration errors between pictures. This issue in itself raises interesting questions for future research, but unless one is directly testing these possibilities, care should be taken in introducing the "blanching" field when conducting visual dissociation experiments. However, in experiments requiring single tachistoscopic exposures of pictures, the interspersed field would be useful as an additional safeguard against phosphor persistence.

Finally, using cinematographic presentation, computer presentation allowed us to alter presentation rate in terms of very small increments (one video frame, 16.676 msec), and to study the effect of these small changes on temporal migration—changes that might not be subjectively noticeable but that would be expected to affect visual integration. Experiment 3 showed that, relative to the baseline rate of 117 msec per picture, an increase or decrease of one video frame did not affect subjects' confidence ratings but did significantly affect the frequency of temporal migration errors. Whereas the baseline rate was associated with 60% correct detections, a decrease of 17 msec yielded only 42% correct and an increase of 17 msec yielded 72% correct.

In conclusion, the results indicate that computer technology may be used to conduct research on visual perception that requires rapid, successive presentation of digital images.
tized color photographs. Specifically, this seems to be the case for visual dissociation research, which would be contaminated by displays with visible phosphor persistence. The application of computer graphics technology to research on picture perception will allow for much more refined tests of visual integration, including the ability to alter photographs of scenes to study the possible effect on scene structure on temporal motion (see Intraub, 1985). Hopefully, it will foster more research on complex pictorial stimuli.

REFERENCES


NOTES

1. Initial testing revealed a timing problem that involved two different

2. One concerned an underemphasized character of the Set

3. The purpose of this part is to show the viewing time of the process. This com-

4. Design is included, within its process, a visual blank blast command (VPBLAST), which was not documented. Our programmer then had included a separate VPBLAST command. Thus, two successive com-

5. The term refers to the effect of visual persistence, known as the aper-

6. A similar view is presented in a future version of the program. So, the execution order (discount-

7. The presence of the two processes is real in a reversal of execution order of two commands, creating the shutter to open and close the frame too soon. This consistent error was compensated for by re-ordering the code.

2. This type of project has the same charm as a typical 16-bit pro-

3. The program has to allow for easily modifiable scenes as well as a wide-range of speeds, without compromising humanness. This type of project was typically used in rapid visual presentation research and re-

4. The maximum animation before computer technology was available. (Manuscript received December 29, 1994; revision accepted for publication June 1, 1995.)

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