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Perceptual Response to Visual Noise and Display Media

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Background

The present project was designed to follow up an earlier investigation in which we studied perceptual adaptation in response to the use of Night Vision Goggles, or image intensification (I^2) systems, such as those employed in the military. Our chief concern in the earlier studies was with the dynamic visual noise that is a byproduct of the I^2 technology: Under low light conditions, there is a great deal of "snow" or sporadic "twinkling" of pixels in the I^2 display which is more salient as the ambient light levels are lower. Because prolonged exposure to static visual noise produces strong adaptation responses (e.g., Durgin, 1993) we reasoned that the dynamic visual noise of I^2 displays might have a similar effect, which could have implications for their long term use. However, in the series of experiments reported last year, we found no evidence at all of such aftereffects following extended exposure to I^2 displays. This finding surprised us, and led us to propose the following studies:

1. <u>An investigation of dynamic visual noise and its capacity to produce aftereffects</u>. Because we had not established that dynamic noise would have the same effect as static noise, we believed it possible that it was the dynamic character of the noise in the I^2 displays that had blocked adaptation.

2. <u>An investigation of the perceptual consequences of characteristics of the display media</u>. Because the visual noise in an I^2 display is a characteristic of the display medium, rather than of the displayed object, we thought it possible that such characteristics of the medium are treated separately in perception.

These proposed studies led to some further investigations, which are also reported here, regarding the context-specific conditioning of perceptual response.

Overview of the Results

The results of three sets of studies will be described.

First, we found that dynamic visual noise produces adaptation of texture perception of the same magnitude as matched static visual noise. It cannot be that I^2 displays fail to produce texture adaptation because the display noise is dynamic.

Second, we determined that statistical properties of a displayed image may be attributed to either the image itself, or to a "medium" through which the image is viewed. We found that *judged image quality* could be enhanced for low resolution images, if a grid was placed over the image which produced an impression of looking "through" the grid at the image. This finding has important implications not only for optimism concerning I^2 displays, but also for improving image quality of low resolution images--such as enlargements of digitized images.

Third, we found that aftereffects of perceived texture density could be made contingent on display features such as the color of a frame surrounding the test region. One implication of this is that texture adaptation may not transfer between visually distinct contexts. This contextual nature of perceptual learning is of some importance for the use of unusual visual displays, for it offers the possibility of training the visual system to tune itself to specific visual contexts.

Texture Density Aftereffects from Dynamic Visual Noise

Prior investigation has shown that the perceived density of visual texture is subject to an aftereffect: After exposing a portion of the visual field to dense texture, textures presented in that region will appear less dense than when presented in an unadapted region. The basic effect is illustrated in Figure 1. The magnitude of the distortion is initially quite large (as much as 50% reduction in perceived density) but fades with time.

To test whether dynamic visual noise would produce a similar distortion, displays were constructed in which the number of texture elements remained constant, but some proportion were randomly replaced on each frame of the display. At any instant the texture is like that shown in Figure 1, but over time individual elements appear and disappear independently. As a result, two regions can be adapted with displays that are matched ass regards the number of elements, but differ in their motion.

We ran two experiments to test for aftereffects of perceived density in static displays resulting from adaptation to dynamic noise. In one experiment, a region was adapted to a dynamic noise "texture" and then assessed for perceived density. A strong aftereffect was

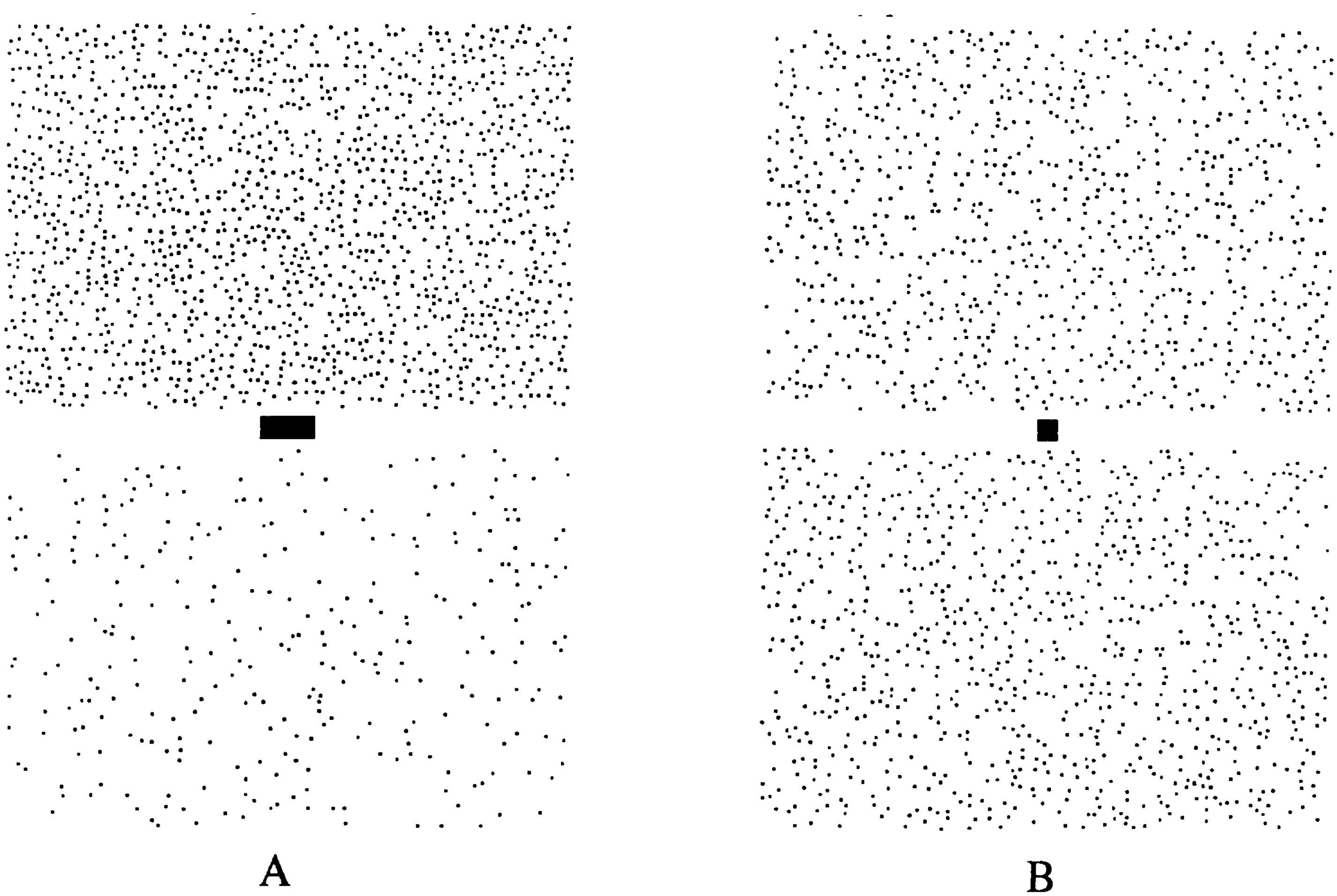

Figure 1. The aftereffect of texture density can be experienced with the figure above. If you direct your gaze to the fixation mark of Panel A for several seconds and then switch quickly to the fixation mark of Panel B, the upper field of Panel B will probably appear markedly less dense than the lower (it is actually the same field, rotated 180°). The same effect can be demonstrated when luminance is properly controlled.

found to result from dynamic noise, as illustrated in Figure 2. In a second experiment, we adapted one region to dynamic noise textures and a second region to a sequence of static textures which were frozen images of a single frame from the dynamic region. We found no reliable difference between perceived texture in the two regions, indicating that both kinds of stimuli are equally effective in producing aftereffects of texture density. These data are also shown in Figure 2.

We conclude that high contrast dynamic visual noise is an effective adapting stimulus for the generation of a texture density aftereffect. It therefore appears that the absence of adaptation effects from Night Vision Goggles cannot be explained by the dynamic quality of the visual noise in I^2 systems.

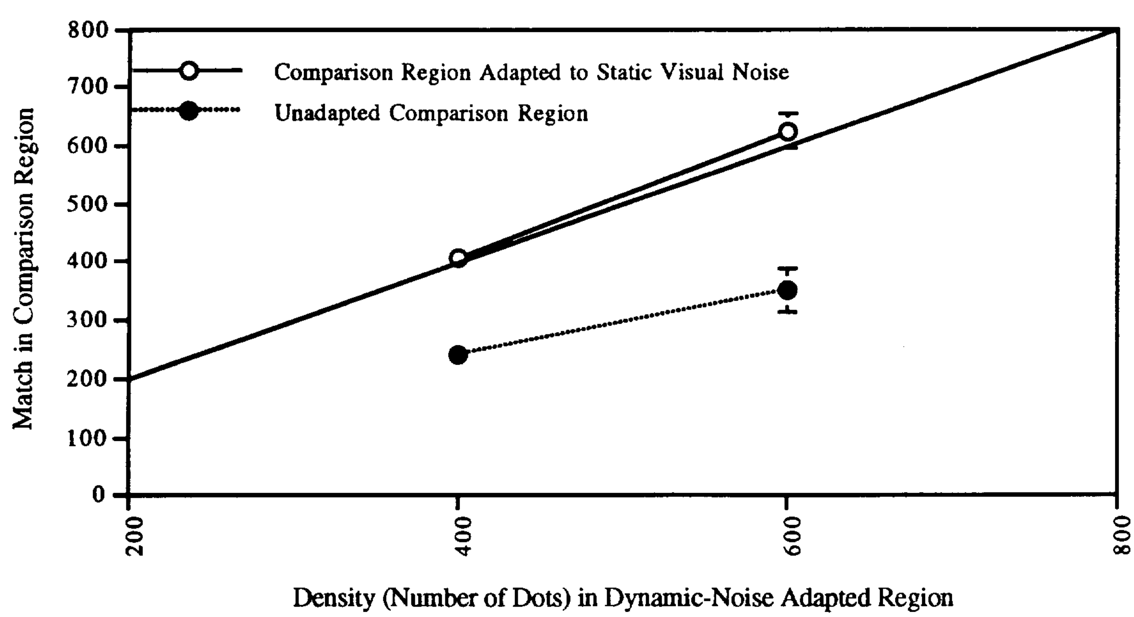

Figure 2. Matches of perceived texture density (established by a staircase method) between regions adapted to static and dynamic noise (open circles) indicate the two types of stimuli have equal adapting power. Matches between textures presented in an unadapted region and in a region adapted to dynamic noise (filled circles) indicate strong distortion due to dynamic noise adaptation.

Studies of Perceptual Response to Display Media

Images viewed through a medium or device may be degraded by the device. The perceptual separation of these display artifacts from the image itself is an interesting psychological process. In many cases the observer has a dual awareness of (1) the object under observation and (2) the means of observation. For example, night vision goggles, while enhancing what can actually be seen, provide a somewhat degraded image relative to normal viewing. The observer in such a context does not mistake the scintillation of pixels (dynamic visual noise) for real events, but comes to see as if through the noise. The noise appears as an aspect of the medium, rather than the world.

To investigate this important phenomena, we considered the problem of image resolution in enlarged images. To enlarge a digitized image requires only that the pixel size be enlarged -- either by employing a different monitor, or, in software, by using enlarged virtual pixels. Such enlarged images, have a distinctive "quantized" appearance, however. This phenomenon is illustrated on the left in Figure 3. Quantization, which removes detail information, adds high-frequency artifacts (the edges apparent between the virtual pixels). These artifactual edges may be removed by blurring the image (which is computationally expensive to be done in software). The effect of blurring can be observed by standing far enough from the image that the edges are no longer visible. At a large viewing distance (4 meters or so) the left image in Figure 3 will appear "normal". Indeed, at such a distance, it cannot be distinguished from a high resolution version of the same image, nor from a blurred version of the same image. In all cases, one will have the impression that the image is of perfect resolution; the loss of detail (which is not noticed) is attributed to the viewing circumstance -- the blur of distance. These facts are well known and have been demonstrated many times.

What has not been appreciated, however, is that the "false" sense of image quality that is engendered in viewing a quantized image from a distance can also be created using a very overt "medium". On the right in Figure 3 is shown the same quantized image with the

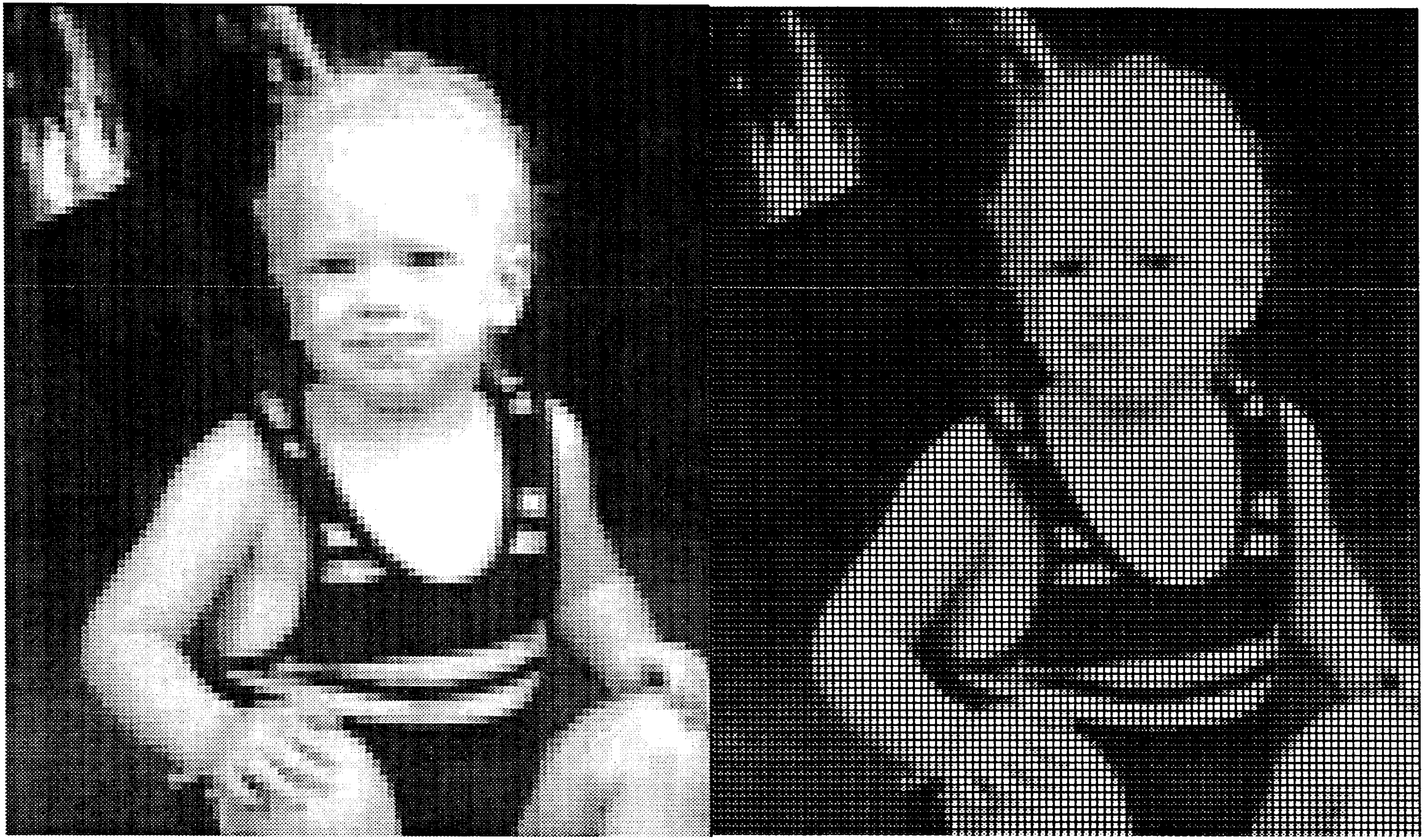

Figure 3. A "quantized" image resulting from enlarged virtual pixels in shown on the left. Quantization introduces high spatial frequency edges which reduce apparent image quality. On the right, the same quantized image has been overlaid with a grid which "covers" the artifactual edges. The image appears to be markedly improved in resolution. The best viewing distance for this effect is about 1 meter. At distances of 3 or more meters, the left image appears "improved" because reduced acuity removes the edges. What is unique about the grid is that it improves the image while *adding* high frequencies.

quantization masked by a grid. The true image information is not altered in any way, but it is clear that the artifactual edges, now masked by "real" edges of the grid, now segregate. At a medium viewing distance (such that the dither pattern used in printing the image is not salient) this image appears to be a high resolution image which is covered by a screen. Thus, a sense of enhanced image clarity can be obtained without blurring the image (computationally expensive) or moving the viewer to a greater distance (and thus reducing the size of the image on the retina).

In order to document this phenomena, we asked undergraduate observers to rate comparatively the image quality of several kinds of images. Our main goal was to compare a gridded high-resolution image with a gridded, quantized version of the same image. For comparison, we included blurred versions of the same images so that there were four kinds of images used and each was either viewed with or without a grid. Thus, in addition to then original high-resolution versions and the quantized version of each image, we created two blurred images in which the blurring either (1) removed detail equivalent to quantization (i.e. of the same spatial frequency as the quantization) or (2) removed even more detail (blurring over areas 1.5 times as large) than was lost by quantization.

The results were quite clear. The high resolution images were ranked highest whether gridded or ungridded. However, the relative ranking of the blurred and quantized images depended upon the presence of the grid. With the grid present, the quantized images were judged to be nearly as good as the high-resolution images, but the blurred images were judged to be much less clear. In the ungridded test, however, the quantized images were judged to be of terrible quality and both blurred images were rated higher than was the quantized image. (In both conditions the relative ranking of the two blurred images was appropriate to their level of blur.) In short, the use of a grid enhances image quality for quantized images such that they are preferred to a blurred image containing the equivalent amount of detail.

Contingent Aftereffects of Visual Texture Density

Recently there has been renewed interest in whether perception can become conditioned (e.g., Siegel, Allan, & Eissenberg, 1992). For example, it is plausible that the visual system readjusts itself for reading, whenever a page of text is presented, because the kind of visual information required for reading is different than for normal viewing. An important property of display media is that they can present a distinct viewing context. If the visual system can adapt itself to particular viewing contexts and retain several learned adaptation "sets", then switching between NVGs and normal viewing may be aided by context-specific visual learning.

Over the past year, we have been investigating the contingent adaptation of texture perception. This work has been presented at the annual meeting of the Association for Research in Vision and Ophthalmology, and that report is appended. In essence we find that aftereffects of the perceived density of texture can be made contingent upon a visual context, specified in this case by the color of the surrounding frame.

The basic paradigm we have used is to adapt people to (a series of) stimuli in which textures appear to the left and right of a fixation mark. Whenever the frame surrounding the textures is red, the left texture, for example, will be denser than the right. When the frame is green, the relative densities will be switched so that the denser texture is (in this case) on the right. Following such adaptation, we find that the context specified by the red frame will induce a perceptual response equivalent to exposure to a dense texture on the left. In other words, in the context of a red frame, an aftereffect of density is found which corresponds to the relative density of textures paired with the red frame during adaptation. The opposite aftereffect is found for the green frame.

It should be noted that this is somewhat different from simple classical conditioning in that the response evoked is an adaptation response rather than the perception of a greater density where it was presented before. If sound is used to cue the location of the denser side, the more traditional effect is found: the side originally paired as denser with the cueing pitch will now appear denser when the pitch is presented again. Therefore, while the contingent effect of sound may be called a classically conditioned response, the effect of the frame is best understood as a conditioned recalibration of vision. Such context-specific recalibrations could play an important role in normal perception.

Conclusions

We have shown that dynamic visual noise can produce adaptation of texture density. However, the presence of noise in a viewing medium may be compensated by (1) perceptual segregation of image and media properties or (2) visual learning contingent upon context.

The latter two findings are of great significance for the understanding of how the human visual system may accommodate itself to novel types of visual displays. The perceptual segregation of image and medium, for example, points to a principle as important as the distinction between figure and ground. It is possible that the perceptual attribution of image properties to the medium through which the image is viewed plays an important role in normal perception. This in turn may help to understand why people do as well as they do with degraded visual signals.

Moreover, while learning theory might predict in some general way that the perceiver will learn to adapt to his viewing environment, we have uncovered evidence of very specific adaptation responses that appear to be cued by extraneous visual features which serve as contexts. A better understanding of such context-cued recalibration could have an important role to play in the designing the user-end of specialized displays such as NVGs. Contingent aftereffects such as we have demonstrated are tantamount to the training of the visual system.

References

Durgin, F. H. (1993). Texture density adaptation and the perceived numerosity and distribution of texture. Manuscript submitted for publication.

Siegel, S., Allan, L. G., & Eissenberg, T. (1992). The associative basis of contingent color aftereffects. Journal of Experimental Psychology: General, 121, 79-94.

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Publications

Durgin, F. H. (1993). Texture density adaptation and the perceived numerosity and distribution of texture. Manuscript submitted for publication.

Durgin, F. H. (1993). Texture density aftereffect contingent on color of frame. Investigative Ophthalmology & Visual Science, 34, (4) 785.

Durgin, F. H., Proffitt, D. R., Olson, T. J., & Reinke, K. S. (1993). Comparing depth from disparity to depth from motion. Manuscript submitted for publication.

Texture Density Aftereffect Contingent on Color of Frame

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Summary

A novel contingent aftereffect is reported. In two experiments, it is shown that the perceived relative density of texture in two regions can be made contingent upon the color of the background (frame) surrounding those regions. In the first experiment, the effect was found with black and white scatter-dot textures. The phenomenon was replicated in a second experiment using luminance-balanced-dot textures.

Contingent aftereffects have been found for many visual dimensions. Contingent aftereffects of color are probably the best known (e.g., the McCollough Effect), but motion aftereffects, for example, have been made contingent on color, texture, and binocular disparity of the inducing stimuli, as well as aspects of the surrounding region, and even direction of gaze (Anstis & Harris, 1974; Favreau, Emerson, & Corballis, 1972; Mayhew, 1973; Mayhew & Anstis, 1972; Potts & Harris, 1975; Walker, 1972).

While the ubiquity of contingent aftereffects does not rule out the possibility that they are due to the adaptation of double-duty "detector" neurons (such as the color/orientation-sensitive neurons that are known to exist), frame effects pose the added complication of large receptive fields for these double-duty detectors. Thus frame effects are more suggestive of models of adaptation in which networks of neurons rather than individual "detector" cells are affected.

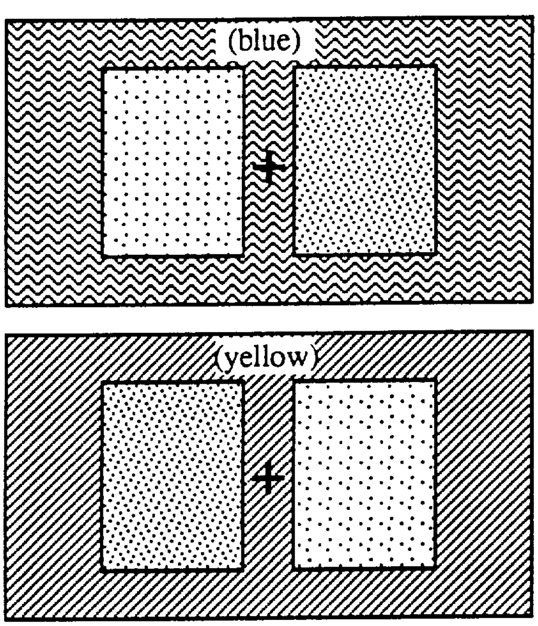

Figure A1. A schematic illustration of a pair of adaptation stimuli used in Experiment 1. The density/color correlation illustrated here was reversed for half the subjects. The randomly scattered dots were white.

A color aftereffect contingent on the lightness of the surrounding frame has recently been reported (Siegel, Allan, & Eissenberg, 1992). The present studies were undertaken to determine whether an aftereffect of texture density (see Figure 1, above) could be made contingent on aspects of the surrounding frame. Frame color was selected for study.

Experiment 1

Purpose

The first experiment was a demonstration that the perceived relative density of texture in two regions can be made contingent on information specified in a frame surrounding the two regions.

Black and white textures were presented within frames of yellow or light blue. Color of frame was correlated with relative density during adaptation. Density matches were then measured in the context of each frame color.

Method

Twelve UVA undergraduates served as subjects.

The apparatus was a Sun 3/60 with color monitor.

<u>Adaptation</u>

While fixating a central mark, subjects were exposed to 500 adaptation stimuli in which the relative density of two fields was correlated with the color of the surrounding frame. A pair of such stimuli illustrating the correlation of color and density are schematically depicted in Figure A1. The colors used in the frames were bright yellow and a light (sky) blue.

Each texture field subtended a region approximately 4° x 5.33°(240 x 320 pixels), and was 1° from the center of the fixation mark. New randomized textures were used on each adaptation exposure. The dense textures contained 1200 dots, the sparse textures, 96. Texture elements were white squares (2 x 2 pixels) scattered randomly (except that overlapping or abutting dots were excluded) against a black background. Exposure time was 200 msec. The screen was black apart from the fixation mark during the ~800 msec ISI.

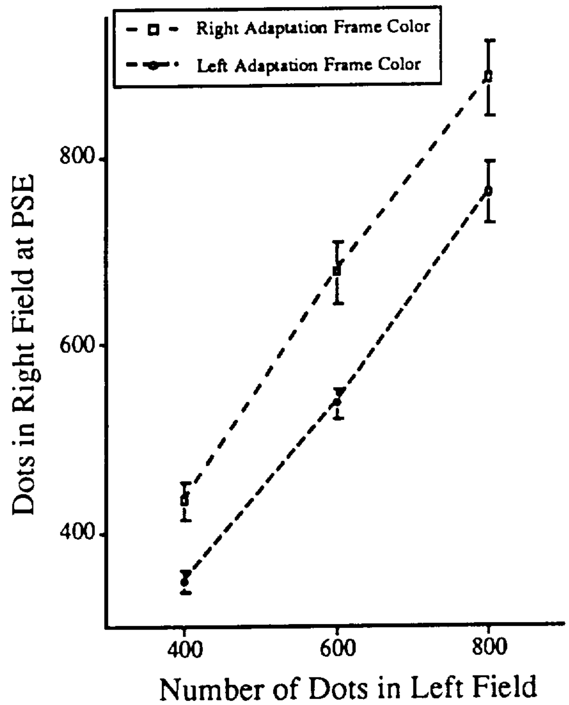

Figure A2. The results of Experiment 1. Mean PSEs following adaptation indicate that more dots are required in right field when the frame color was that associated with high density on the right. This is consistent with a negative aftereffect of density which is contingent on color of frame.

Measurement

Following adaptation a staircase method was used to assess points of subjective equality (PSE) at three levels of density in the presence of each frame color. The left field was held constant in density, and the right field varied so that the PSEs in the two frame conditions could be directly compared. Subjects made forced choice comparisons on each trial. They were to choose the field that appeared denser.

Because the right field was variable, a contingent effect would be evidenced if the frame color associated with more dots on the right during adaptation also required more dots to be on the right during measurement for the fields to appear equal. Fewer dots should be required on the right when the other frame color was present.

Results and Discussion

A contingent aftereffect of texture density was found. Mean PSEs after adaptation are plotted in Figure 2. A repeated measures ANOVA revealed a highly reliable main effect of frame color, $F(1,11) = 22.8$, $p < .001$. The right fields did require more dots in the presence of the right-associated frame color, but fewer dots in the context of the left-associated frame color. Mean distortion was about 10% in each direction.

A strong contingent aftereffect has therefore been demonstrated in which perceived density of texture depends upon both (1) the color of the surrounding frame and (2) the spatial position of the texture. The effect is suggestive of classical conditioning, where frame color is the CS and local texture adaptation the CR.

Because the texture density was confounded with texture brightness, and the frame colors were not equiluminant, it is possible that the effect found has little to do with density itself or with color. A second experiment was therefore performed to ensure that the effect could be found when luminance was balanced.

Experiment 2

Purpose

The second experiment controlled for luminance of the textures and brightness of the frames.

Textures were composed of randomly scattered luminance-balanced dots. The colored frames were set to five brightness levels of roughly equiluminant reds and greens during adaptation to decorrelate hue and brightness. During measurement, the darkest and lightest frames of each color were used.

Method

Eighteen UVA undergraduates served as subjects.

The apparatus was the same as Experiment 1.

Stimuli modifications

Adaptation proceeded as in Experiment 1, but with modified stimuli.

Textures. The texture elements were balanced dots, white 2 x 2 pixel squares surrounded by 1-pixel-wide black annuli which were presented against a grey background with the same average luminance as the dots. To increase texture visibility, viewing distance was decreased, increasing all visual angles by roughly 50%. In addition, stimulus durations were increased to 500 msec. The screen was the grey of the background during the ISI.

Frame colors. During adaptation, there were five brightnesses of green and red in the frame. The darkest shades were roughly 75% the luminance of the brightest. Near-equiluminance of the different hues was established by a minimum motion technique with other subjects prior to the main experiment.

Measurement

The procedure was the same as Experiment 1 except that eight PSEs were measured (2 frame hues x 2 frame luminances x 2 texture densities).

Results and Discussion

The finding of Experiment 1 was replicated. Mean PSEs after adaptation are plotted in Figure A3. A repeated measures ANOVA revealed a highly reliable main effect of frame $F(1,17) = 22.9$, $p < .001$. There was no reliable effect of frame lightness.

There was a main effect of density in the absolute size of the distortion $F(1,17) = 5.49$, $p < .05$, but not in its relative size (analysis of log differences). This suggests a multiplicative distortion of texture, which is consistent with a simple density aftereffect.

Thus, the effect is found when texture density and color of frame are decorrelated with luminance.

Conclusions

The relative density of texture in two regions of the visual field may be made contingent upon a context, which is here defined as information provided in other parts of the visual field (color of frame).

This effect is consistent with a classical conditioning account in which frame color is the conditioned stimulus and local texture adaptation is the conditioned response.

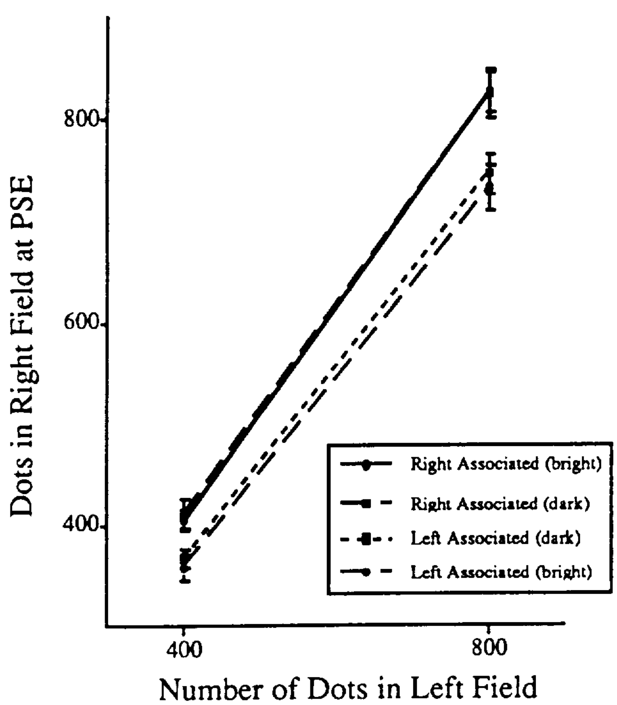

Figure A3. The results of Experiment 2. As before, mean PSEs following adaptation indicate that more dots are required in right field when the frame color was that associated with high density on the right. Thus the effect persists even when luminance differences are eliminated in textures and frames.

References

Anstis, S. M., & Harris, J. P. (1974). Motion aftereffects contingent on binocular disparity. Perception, *3*, 153-168.

Durgin, F. H., & Proffitt, D. R. (November, 1991). The detection of texture density: Evidence from adaptation. Presented at the annual meeting of the Psychonomic Society, San Francisco.

Favreau, O. E., Emerson, V., & Corballis, M. (1972). Motion Perception: A color-contingent aftereffect. Science, *176*, 78-79.

Mayhew, J. E. W. (1973). Aftereffects of movement contingent on direction of gaze. Vision Research, *13*, 1789-1795.

Mayhew, J. E. W., & Anstis, S. M. (1972). Movement aftereffects contingent on color, intensity, and pattern. Perception & Psychophysics, *27*, 531-536.

Potts, M. J., & Harris, J. (1975). Movement aftereffects contingent on the pattern or color of a stationary surround. Vision Research, *15*, 1225-1230.

Siegel, S., Allan, L. G., & Eissenberg, T. (1992). The associative basis of contingent color aftereffects. Journal of Experimental Psychology: General, *121*, 79-94.

Walker, J. (1972). A texture-contingent visual motion aftereffect. Psychonomic Science, *28*, 563-570.

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