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Summary of Awarded Presentation

Orientation processing underlies pattern randomness perception

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Humans can easily discriminate between randomly spaced and regularly spaced visual patterns. Herein we demonstrate that observers can adapt to the randomness of two-dimensional visual patterns. Pattern adaptations with varying levels of physical randomness caused an aftereffect in which the perceived randomness decreased (increased) following an adaptation to a pattern with high (low) physical randomness (Experiment 1). Adaptations to 22.5°-rotated patterns did not cause an aftereffect in the non-rotated test patterns (Experiment 2). Additionally, contrast polarity did not affect an aftereffect (Experiment 3). These results indicate that the perception of visual pattern randomness is governed by second-order orientation processing, which is insensitive to luminance contrast.

Key words: vision, texture perception, perceptual adaptation, pattern randomness

Humans can easily discriminate between random and regular visual patterns. Two plausible mechanisms to discriminate visual pattern randomness have been proposed. The first mechanism is that the extraction of higher-order image statistics underlies pattern randomness perception. Specifically, the visual system may detect the positional variation of elements in a pattern, and uses this variation to estimate pattern randomness. The second mechanism is that low-level visual processing, such as orientation processing, is responsible for pattern randomness perception because positional variation also alters the pattern of the orientation signals.

Herein we devise experiments to distinguish between these two mechanisms. First, we examined whether the visual system can adapt to pattern randomness (Experiment 1). Next, we employed adaptor patterns rotated by 22.5° to verify whether adaptations to specific orientation bands are the source of the aftereffect because the mechanism to detect positional variation, if present, is insensitive to any orientation manipulation between test and adaptor patterns. Finally, we tested whether the congruency of the luminance polarity between adaptor and test stimuli influences the aftereffect (Experiment 3) to confirm the contribution of second-order orientation processing, which is generally insensitive to the polarity.

Methods

Experiment 1. Six (Exp. 1), four (Exp. 2), and five (Exp. 3) observers participated. The viewing distance was 45 cm. The stimuli consisted of a fixation point, two adaptor stimuli, and two test stimuli. All stimuli were displayed on a gray background. The fixation point was a small red circle at the center of the display. Each adaptor and test stimulus consisted of two-dimensional dot patterns, which were 16 by 16 black dots with a radius of 0.05°, presented left and right of the fixation with an eccentricity of 9.80°. The position of each dot was determined based on a continuous uniform probability density function with mean μ and range ω in x and y dimensions; a larger ω denoted a more physically random pattern. The adaptor stimuli consisted of patterns with low, middle, and high physical randomness (ω=0.10, 0.39, and 0.69°, respectively). The test stimuli were composed of patterns with seven levels of physical randomness (ω=0.10–0.69°).

Observers were asked to maintain their gaze on the fixation point. Each trial was initiated when the observer pressed the spacebar, and then the adaptor stimuli were presented for 5.0 s (Fig. 1a). After a 0.4-s blank screen, the two test stimuli were presented for 0.3 s. Then the observers were asked which of the test stimuli was perceived to be more random. The experiment was manipulated by the Psi method to estimate the point of subjective equality (PSE) of the perceived randomness. A larger PSE represented a larger perceived randomness. The measurements were terminated after 150 trials.

Experiments 2 and 3. These experiments were similar to Experiment 1, except that variables for adaptor rotation (0° or 22.5°; Exp. 2) and congruency of contrast polarity between the adaptors and test stimuli were introduced (Exp. 3). Adaptor stimuli consisted of patterns with low and high or middle physical randomness; here a larger PSE denoted a larger pat-

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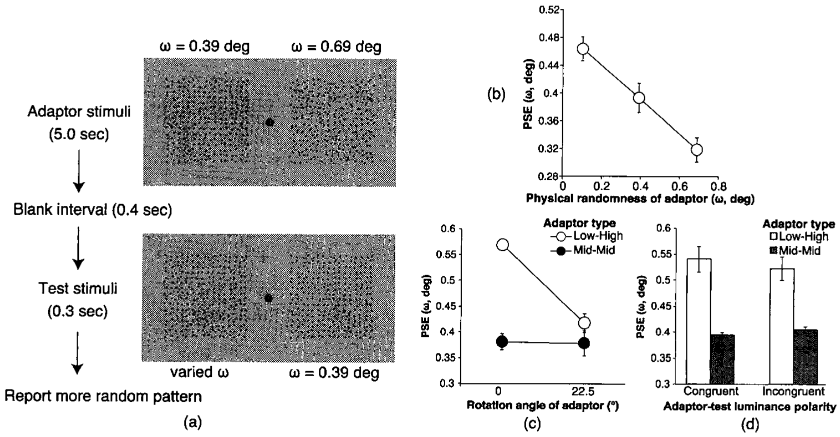

Figure 1. (a) Example of stimuli in Experiment 1. Results of experiments (b) 1 , (c) 2, and (d) 3. Error bars denote S.E.M.

tern randomness aftereffect.

Results

Experiment 1. A one-way repeated measures ANOVA of the perceived randomness with physical randomness of the adaptor as a factor showed a significant main effect, $F(2, 10)=12.60$, $p<.002$ (Fig. 1b). Multiple comparisons indicated that adaptation to high-randomness patterns caused a significant decrease in the perceived randomness, $p<.04$, and *vice versa*, $p<.05$.

Experiment 2. A two-way repeated measures ANOVA with rotation and adaptor type as factors showed a significant interaction, $F(1, 3)=55.90$, $p<.005$ (Fig. 1c). A significant aftereffect was induced by the unrotated rather than the rotated adaptor in the low-high condition, $F(1, 6)=86.65$, $p<.0002$.

Experiment 3. A two-way repeated measures ANOVA with contrast polarity and adaptor type as factors showed only a significant main effect for the adaptor type, $F(1, 4)=33.34$, $p<.005$ (Fig. 1d).

Discussion

The results indicate that the visual system can adapt to pattern randomness. Moreover, adaptation may occur during second-order orientation processing, but not while detecting the positional variation of the elements. Finally, orientation processing, which causes the aftereffect, is unaffected by contrast polarity. Thus, the human visual system may heuristically construct the experience of pattern randomness by assessing the pattern of second-order orientation signals.

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