REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED
FINAL 01 Oct 91 TO 30 Sep 94

4. TITLE AND SUBTITLE
INTERMEDIATE LEVELS OF VISUAL PROCESSING

5. FUNDING NUMBERS
F49620-92-J-0016
61102F
2313/AS

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AFOSR-TR 95 0110

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10. SPONSORING/MONITORING AGENCY REPORT NUMBER

19950306 032

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

We completed a comprehensive theoretical account of visual surface representation based on a new understanding of many of our recently reported perceptual phenomena. In particular, we determined the degree to which the "generic view principle" can explain these new findings and also extended its domain to a large number of perceptual phenomena (Shimojo and Nakayama, 1992). We apply the generic sampling principle which indicates that the visual system acts as if it were viewing surface layouts from generic, not accidental vantage points. Through the observer's experience of optical sampling, which can be characterized geometrically, the visual system makes associative connections between images and surfaces, passively internalizing the conditional probabilities of image sampling from surfaces. In turn, this enables the visual system to determine which surface a given image most strongly predicts. Thus, visual surface perception can be considered as inverse ecological optics based on learning through ecological optics. Because of its neglect of prior probabilities and higher level knowledge, visual surface perception deviates from strict Bayesian notions of inference.

14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
(U)	(U)	(U)	(U)

AFOSR 95 0110

AFOSR Final Technical Report
Intermediate Levels of Visual Processing

Ken Nakayama

Grant # F49620-92-J-0016
Award period: 10/1/1991-10/31/1994

Our major research accomplishments over the past grant period are summarized below:

1. We completed a comprehensive theoretical account of visual surface representation based on a new understanding of many of our recently reported perceptual phenomena. In particular, we determined the degree to which the "generic view principle" can explain these new findings and also extended its domain to a large number of perceptual phenomena (Shimojo and Nakayama, 1992). We apply the generic sampling principle which indicates that the visual system acts as if it were viewing surface layouts from generic, not accidental vantage points. Through the observer's experience of optical sampling, which can be characterized geometrically, the visual system makes associative connections between images and surfaces, passively internalizing the conditional probabilities of image sampling from surfaces. In turn, this enables the visual system to determine which surface a given image most strongly predicts. Thus, visual surface perception can be considered as inverse ecological optics based on learning through ecological optics. Because of its neglect of prior probabilities and higher level knowledge, visual surface perception deviates from strict Bayesian notions of inference.

2. We demonstrated that tasks which were thought to be mediated by the outputs of receptive field mechanisms were actually mediated at a more intermediate level, at surface representation. Heretofore, visual search, visual texture segregation, and motion perception were thought to be determined by image properties. Experimental studies of visual search indicated that the conspicuity of an odd target was not determined by image features, but by amodally completed surface shape (He and Nakayama, 1992). Studies on visual texture segregation also indicated that the emergence of a defined texture region was dictated not by the image shape, but surface shape (He and Nakayama, 1993). Finally, with respect to apparent motion, the correspondence between tokens is not based on image properties, but again on surface properties.

3. We demonstrated two entirely new and we believe, related, phenomena regarding the consequences of surface encoding. First, we demonstrated that apparent motion correspondence is preferentially made between tokens which reside on the same surface. Thus it appears that motion is surface-bound (He and Nakayama, 1994). Second, we show that attention cannot be efficiently

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allocated to arbitrary depths and extents in space, but is linked to perceived surfaces. In visual search experiments, we show that we cannot easily focus attention across iso-disparity or iso-depth loci unless they are part of a well-formed surface. Yet we can easily spread our attention selectively across well-formed surfaces which span extreme variations of stereoscopic depth. In cueing experiments, we show that selective attention is weakened if targets and distractors either form a single implicit plane receding in space or simply rest on such a common plane. We conclude that attentional deployment is not "content-free", but spreads over perceived surfaces (He and Nakayama, unpublished). Of interest is the fact that the two phenomena are very likely to be related. Thus, the obvious conclusion is that visual motion is bound to surfaces as a consequence of the surface-bound nature of visual attention.

4. We have uncovered a new and unexpected short-term memory effect, the priming of pop-out or attentional deployment. We examined a visual search task in which observers respond to the high-acuity aspect of a pop-out target (shape of an odd-colored diamond, vernier offset of an odd spatial frequency patch). Repetition of the attention-driving feature (color, spatial frequency) in this task primes the pop-out; repetition of the high acuity shape/response aspect does not. Priming of pop-out is due to a decaying memory trace of the attention-focusing feature laid down with each trial. The trace exerts a diminishing effect over the following 5-8 trials (~30 seconds) and its influence over this time is cumulative. Observers cannot willfully overcome the priming, suggesting it is passive and autonomous. Both target facilitation and distractor inhibition are evident, the former having a greater effect. The phenomenon shows complete binocular transfer (Maljkovic and Nakayama, 1994). A similar effect can also be seen if we consider repeating positions. Here, repetition of the same target position leads to faster discriminations, but the appearance of the target at positions occupied by a previous distractor slow down the attentional deployment. Additional studies indicate that the position and feature priming are independent. Furthermore, and even more surprising, the priming is linear. That is, we can predict the changes in reaction time of any complex sequence of previous trials simply by assuming superposition of the additive effects of position and feature priming. (Maljkovic and Nakayama, unpublished dissertation).

The research mentioned above on pop-out culminated in Vera Maljkovich's dissertation, which has been appended.

Publications completed during the grant period.

Nakayama, K. and Shimojo. S. (1992) Experiencing and perceiving visual surfaces. **Science 257**: 1357-1363.

He, Z. J. and Nakayama, K. (1992) Surfaces vs. features in visual search. **Nature 359**: 231-233.

Mackeben, M. and Nakayama, K. (1993) Express attentional shifts. **Vision Research 33:** 85-90.

He, Z.J. and Nakayama, K. (1994) Apparent motion determined by surface layout not by disparity or 3-dimensional distance. **Nature 367**: 173-175.

He, Z.J. and Nakayama, K. (1994) Perceiving textures: beyond filtering. **Vision Research 34:** 151-162.

He, Z.J. and Nakayama, K. (1994) Surface shape not features determines apparent motion correspondence. **Vision Research 34,** 2125-2136.

Verghese, P. and Nakayama, K. (1994) Stimulus discriminability and visual search. **Vision Research**, **34,** 2453-2468.

Anderson, B.L. and Nakayama, K. (1994) Towards a general theory of stereoscopic processing: Matching, occlusion and fusion **Psychological Review 101,** 414-445.

Maljkovic, V. and Nakayama, K. (1994) Priming of pop-out: I. Role of features, **Memory and Cognition 22,** 657-672.

Ph.D. Dissertation

Maljkovic, Vera (1994) Priming of popout: evidence for implicit short-term memory of feature and position. Unpublished doctoral dissertation, Harvard University.