The Blanking Phenomenon and its Psychoanatomical Implications

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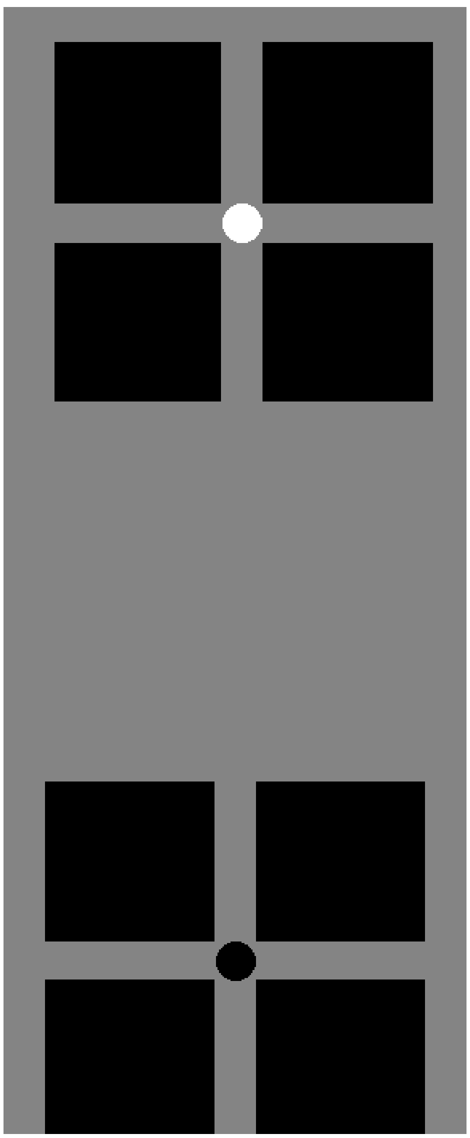


Introduction

At VSS 2002, we introduced a novel visual effect: "The Blanking Phenomenon"
When the black disk in the pattern to the left is fixated, the light disk disappears

- Only disks lighter than the background alley-gray disappear
- The disk must be presented extra-foveally (at least 15-20 deg. from fixation)
- Grid and disk must be presented concurrently
- The disk must fall within an intersection

It is often possible to determine the origins of visual phenomena by the use of dichoptic presentation

- If the phenomenon is present when segregated across eyes, it must be generated after the point of fusion
- If the phenomenon is not present, it must occur before the point of fusion

General Methods

Stimuli

1. A grid consisting of 2 rows of 4 squares was presented 20.75 degrees from fixation (Fig. 1). A disk appeared with equal probability in one of the three

intersections. The subject's task was to determine which intersection contained the disk (3AFC)

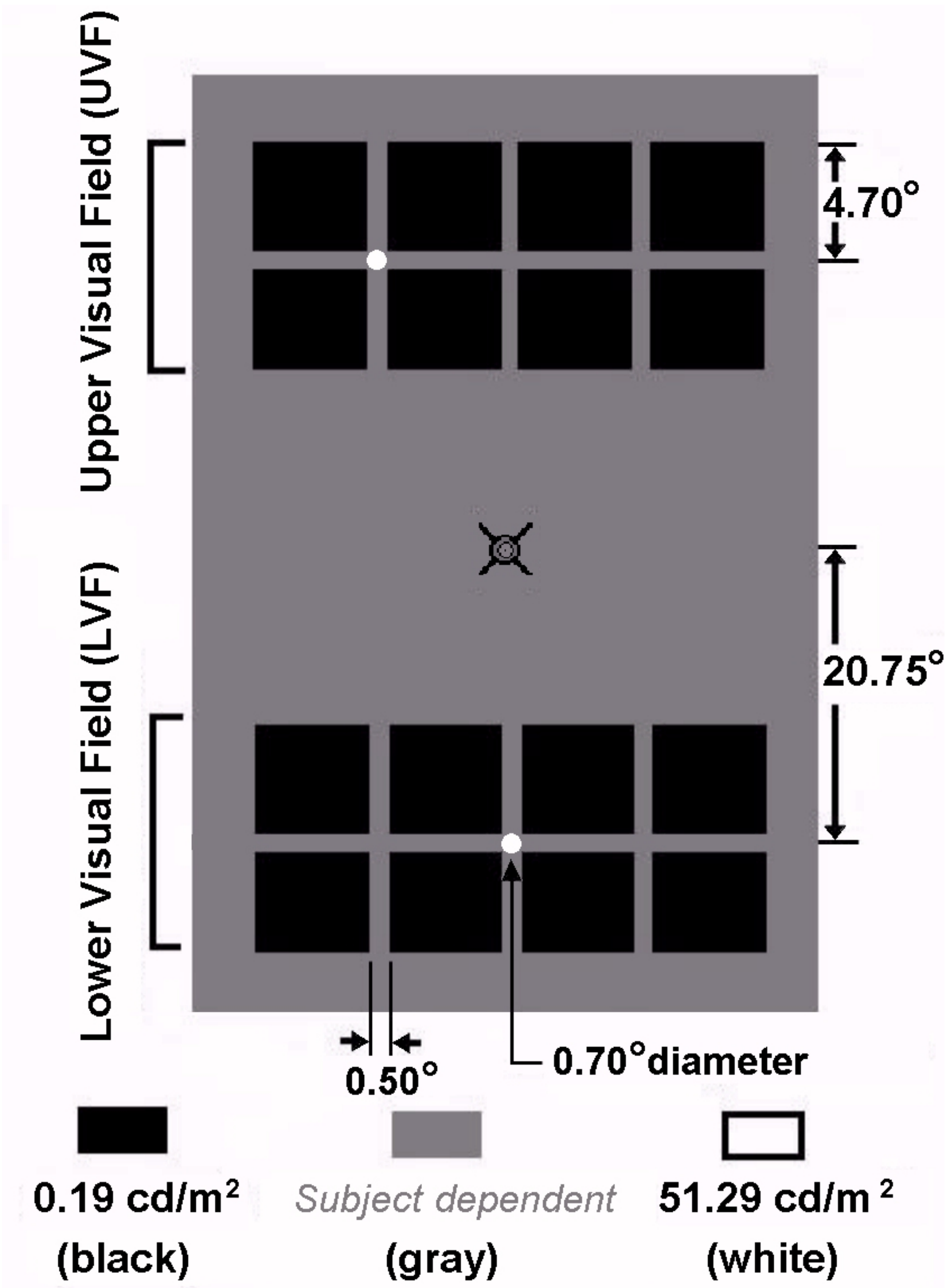
2. The squares could be either black (0.19 cd/m2) or white (51.29 cd/m2). The squares were always presented on the same background alley-gray
3. The absolute contrast of the disk at threshold was measured

Contrast was defined as the absolute value of Weber contrast:

$$\text{Contrast} = | (L_{threshold} - L_{alley\text{-}gray}) / L_{alley\text{-}gray} |$$

Background alley-gray was set appropriately for each subject

4. Alley-gray was determined by finding the gray level that resulted in equal thresholds for light disks with white squares and dark disks with black squares



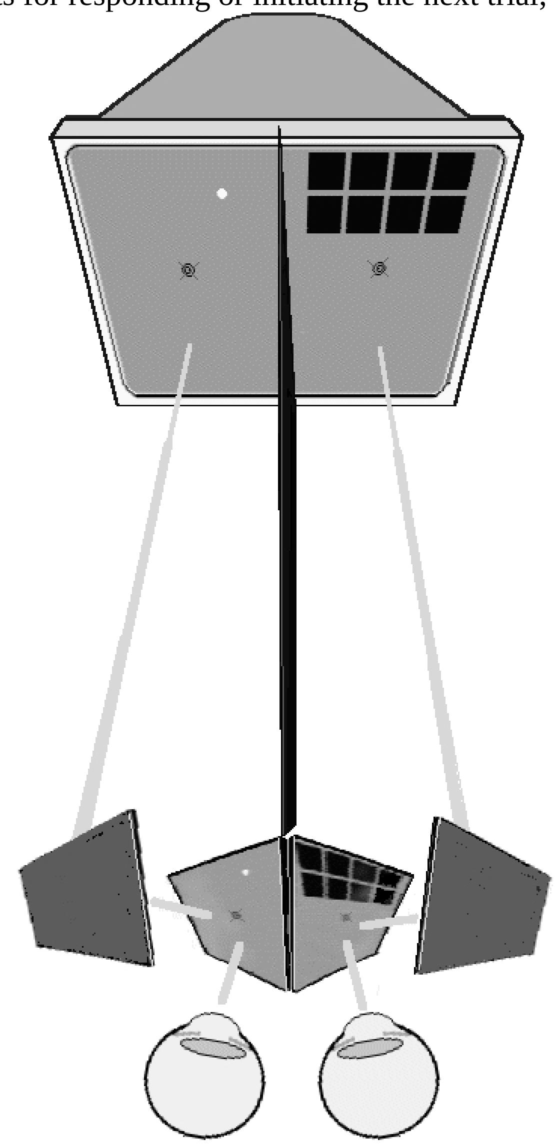
Stimulus Presentation

Stereoscopic presentation

- A stereoscope was created with a set of first-surface mirrors (Fig. 2)
- A horopter correction was made for each subject -- subjects aligned vertical and horizontal verniers at each possible test location, and a correction was applied for each stimulus presentation according to the location of the disk.

General stimulus presentation paradigm:

- Subjects fixated on a target appearing in 3D (view figure 2A as a direct-view stereogram)
- The subject initiated each trial with a key press
- The stimulus was presented briefly (either 222 or 278 ms) and replaced by a field of background alley-gray
- To discourage inappropriate fixation, the stimulus was presented with equal probability in the upper and lower visual field. The subject indicated his or her answer by key press. There were no time constraints for responding or initiating the next trial; no feedback was given



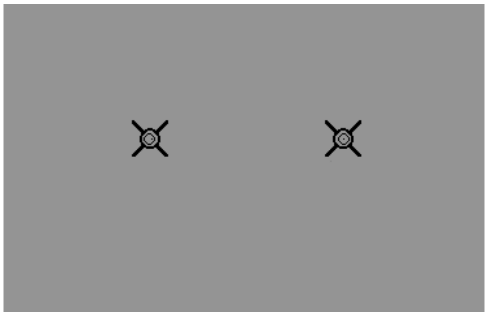


Figure 2A: *Stereogram of the fixation points*

Subjects

1. Data were collected from three subjects: two males ages 23 and 59, and one female age 24
2. All subjects had normal or corrected-to-normal vision

Psychophysical methods

A fixed-step staircase (FSS) — an adaptive procedure that quickly and accurately determines threshold — was used to find the disk contrast threshold in each condition

1. Each FSS began with a preliminary search for the general threshold range
2. Four FSSs were interleaved to provide data on stimuli appearing above and below fixation. The part of the stimulus that each eye received was determined randomly
3. FSS decision rules:
    - Two consecutive correct responses decreased the absolute value of the contrast by one unit
    - Each incorrect response increased the absolute value of the contrast by two units

4. FSSs were terminated when each of the 4 staircases achieved at least 16 reversals of direction
5. The average of the last 6 reversals was taken as threshold in each FSS
6. Threshold values from a minimum of two staircases were obtained from each subject for each condition

Experiment I (Dichoptic presentation)

Methods for Experiment I (Figure 3 A & B)

1. **Cortical and retinal contributions to the blanking phenomenon were assessed by presenting a light disk to one eye and a grid of black squares to the other eye (Fig. 3A)**
    - On each trial, the grid was equally likely to appear in the left or right eye
2. **In a separate experiment, a black outline-grid was introduced in the disk eye to facilitate alignment of the disk and grid (Fig. 3B)**
    - The outline was selected because it did not itself induce blanking
3. **Neither eye alone received a stimulus that would induce the blanking phenomenon. Thus, if the blanking phenomenon were observed in these dichoptic arrangements, it can be inferred that the effect is post-fusion**
4. **Control conditions consisted of disks presented in the absence of squares**

The stimuli in Figure 3 are set up as direct-viewing stereograms. Fuse the two frames to get a reasonable idea of what the subjects saw.

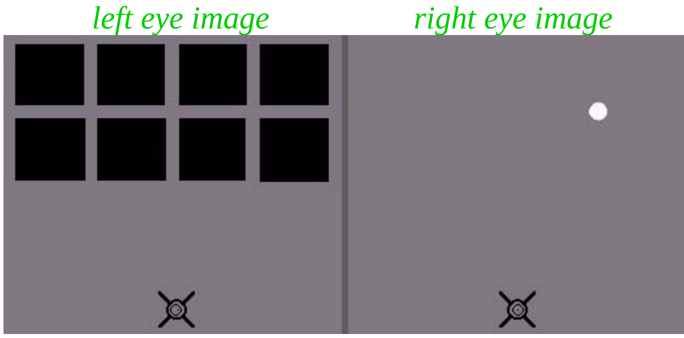


Figure 3A: *Dichoptic stimuli*

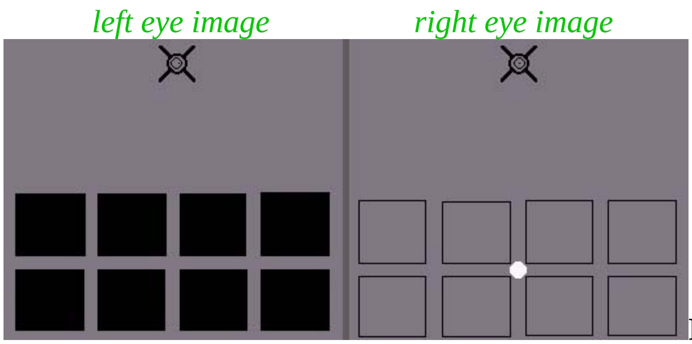


Figure 3B: *Dichoptic stimuli with outline grid in other eye to facilitate alignment*

Results of Experiment I (Figure 4)

1. **Contrast threshold was only slightly higher in the dichoptic arrangement lacking the alignment grid than in the control condition (disks presented without squares)**
    - However, observers subjectively reported poor alignment of the grid and disk

2. **Contrast threshold was significantly higher in the dichoptic arrangement with the alignment grid than in the control condition or unaligned dichoptic condition**

3. **Contrast threshold of the dichoptic stimuli with the outline alignment grid was significantly lower than the threshold obtained when each eye received both the grid and a disk**

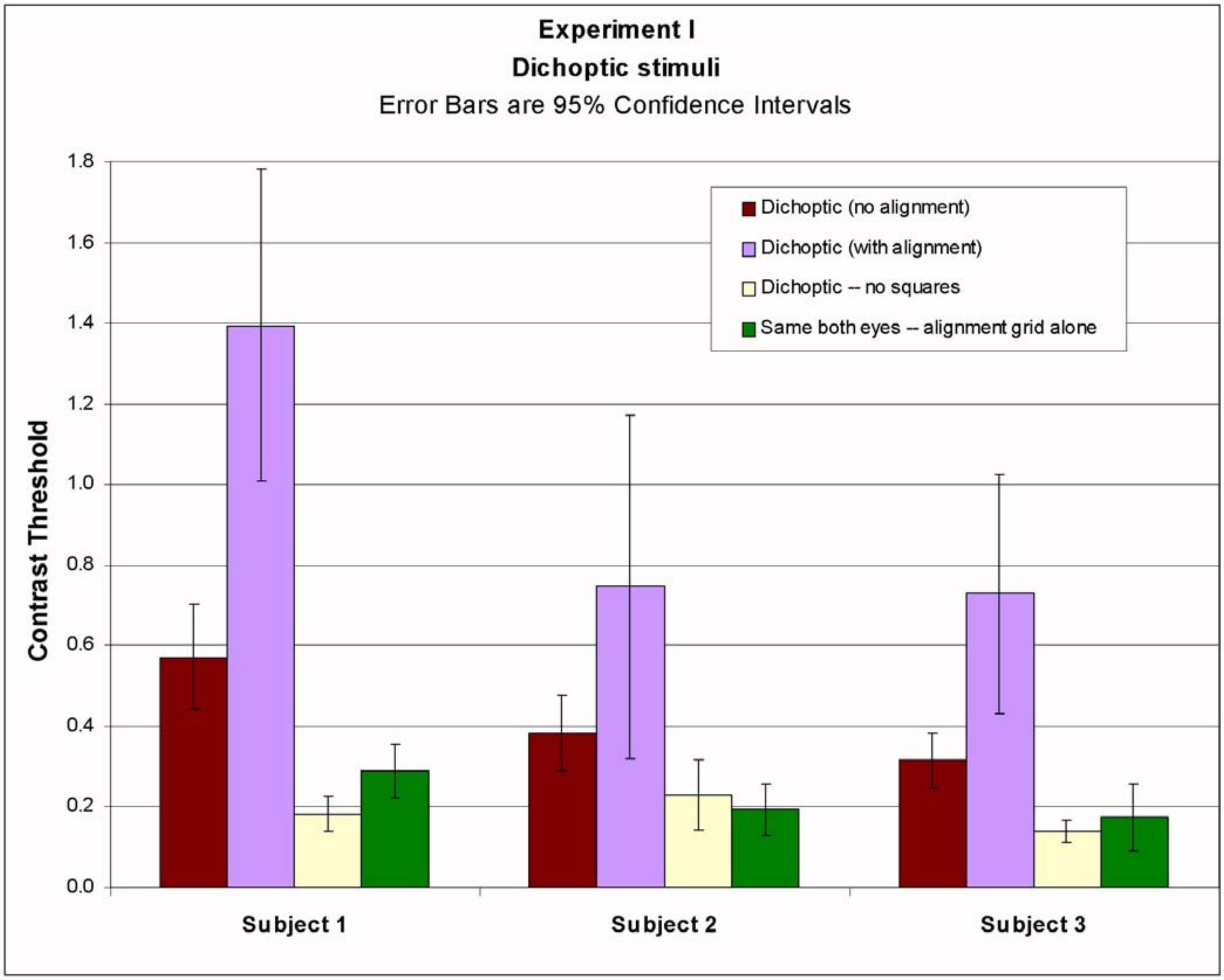


Figure 4

Conclusions of Experiment I

1. The dichoptic arrangement lacking the alignment grid is confounded by the possible misalignment of the disk and grid
2. The blanking phenomenon is present (but diminished) in the dichoptic arrangement with the alignment grid; a cortical contribution is implicated

Experiment II (Complementary images in each eye)

Methods of Experiment II (Figure 3 C & D)

1. **Cortical and retinal contributions to the blanking phenomenon were also assessed by presenting a grid and disk to each eye**

- **A grid of white squares and a light disk were presented to one eye and black squares and a dark disk to the other eye ("Same Contrast," Figure 3C)**
- **A grid of white squares and a dark disk were presented to one eye and black squares and a light disk to the other eye ("Opposite Contrast," Figure 3D)**
    - ✓ On each trial, the white squares were equally likely to appear in the left or right eye
    - ✓ These grids are easily aligned

2. **Control conditions consisted of light/dark disks presented in the absence of squares**

3. **To the cortex, the "opposite" and "same" contrast conditions are effectively identical (a black/white grid, light/dark disk)**
   4. If threshold in the same and opposite contrast conditions is different, a pre-fusion locus is implicated

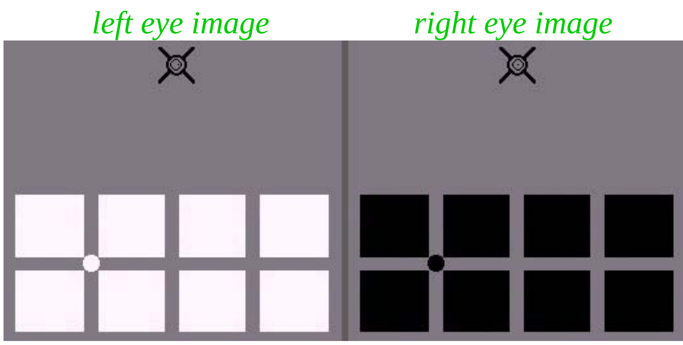


Figure 3C: *Complementary images neither of which should produce effective blanking*

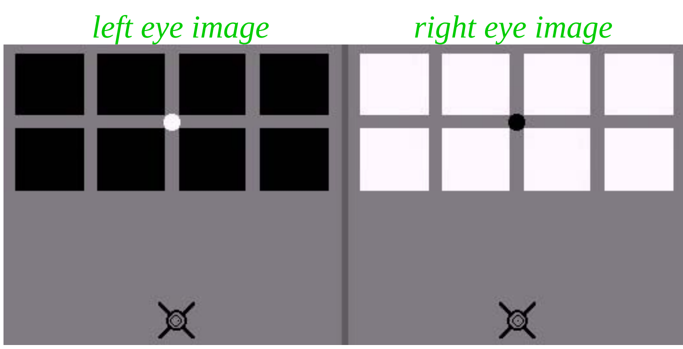


Figure 3D: *Complementary images either of which should produce blanking*

Results of Experiment II (Figure 5)

1. **Contrast threshold of the same contrast condition was significantly lower than the opposite contrast condition**

2. **The blanking phenomenon was present in the opposite contrast condition but less evident in the same contrast condition**

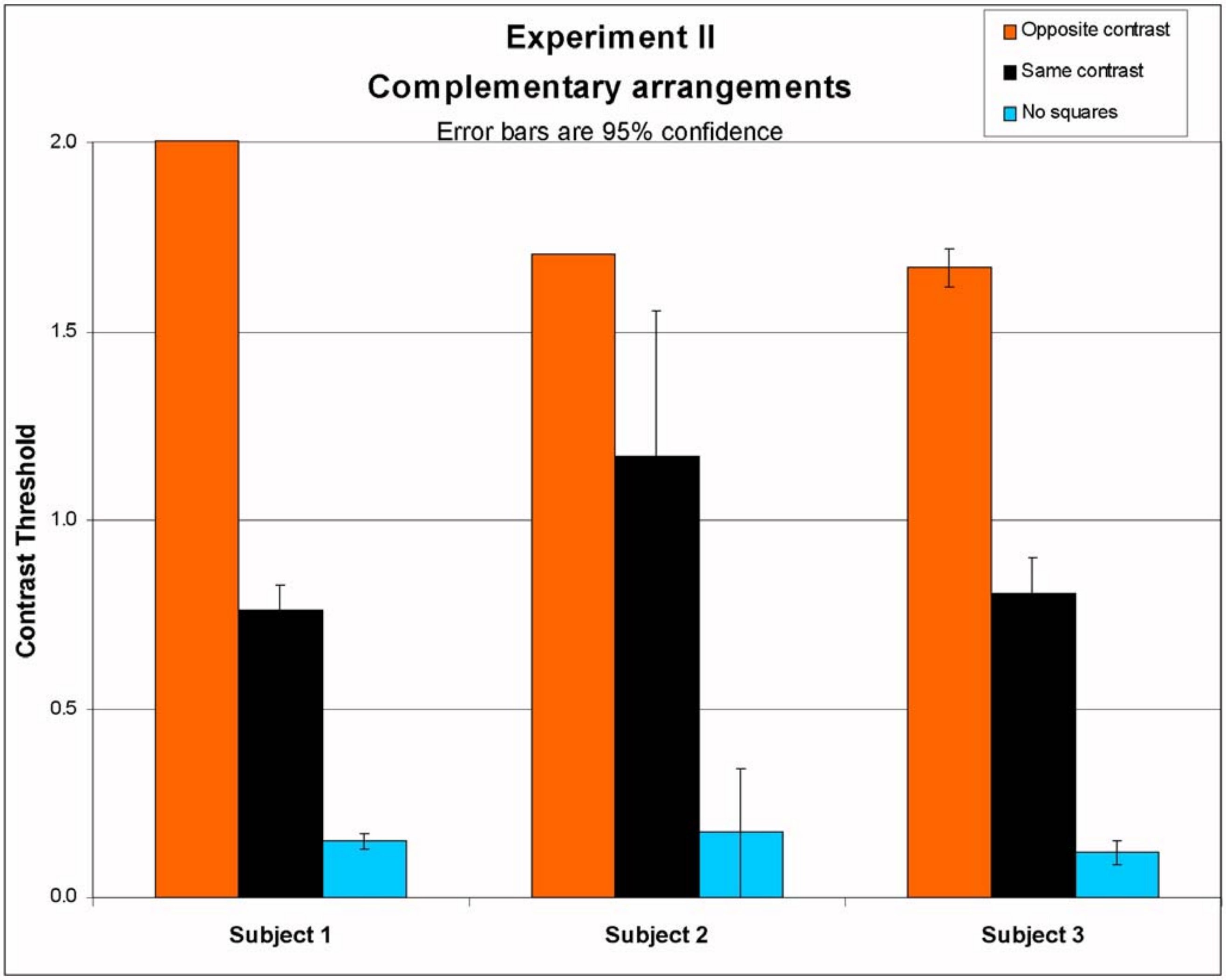


Figure 5

Conclusions of Experiment II

1. **The absence of blanking in the same contrast condition and its presence in the opposite contrast condition implies that blanking has a pre-fusion locus (likely retina or LGN)**
2. ***The possibility that binocular rivalry has confounded this result has been examined and rejected***
   - *The stimulus presentation was less than 300 ms; the onset of binocular rivalry is substantially longer*
   - *The 3D fixation point guaranteed proper fusion and absence of rivalry until the stimulus appeared*
   - *Observers subjectively reported a stable coherent percept*
   - *Recall that in Experiment I, the dichoptic condition with an alignment grid had a significantly higher threshold than the dichoptic condition lacking the alignment grid. This is contrary to the expectations if binocular rivalry were present. The eye with the alignment grid and disk would be more likely to dominate (decreasing threshold) compared to the disk in the simple dichoptic condition*

- *Binocular rivalry should result in an unstable staircase. Staircases obtained from conditions that induced different levels of rivalry are depicted in figure 6. (A) black squares and a dark disk presented in one eye and a background alley-gray field in the other. (B) dichoptic condition without the outline grid. (C) an example of a staircase (with black squares and a dark disk appearing in both eyes) in which rivalry was simulated by replacing the subject's response with a random response on half of the trials*

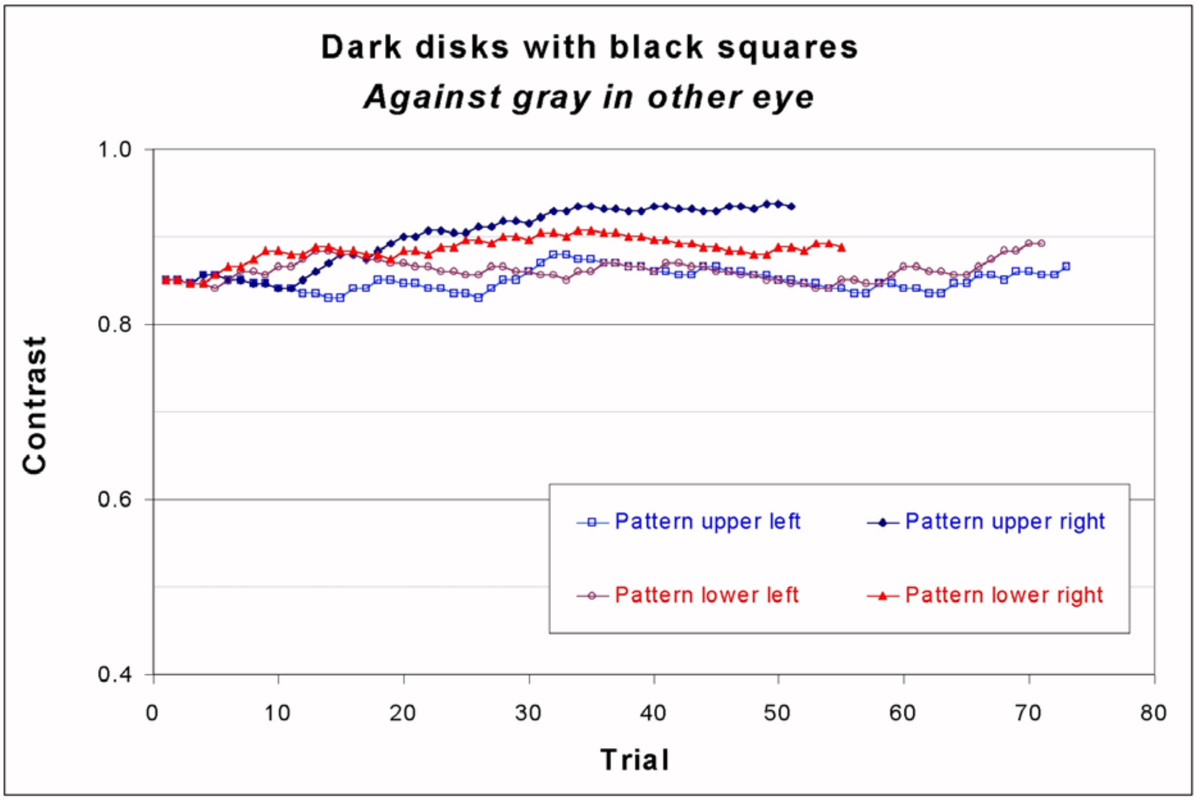


Figure 6A: *FSS from a situation that could produce rivalry*

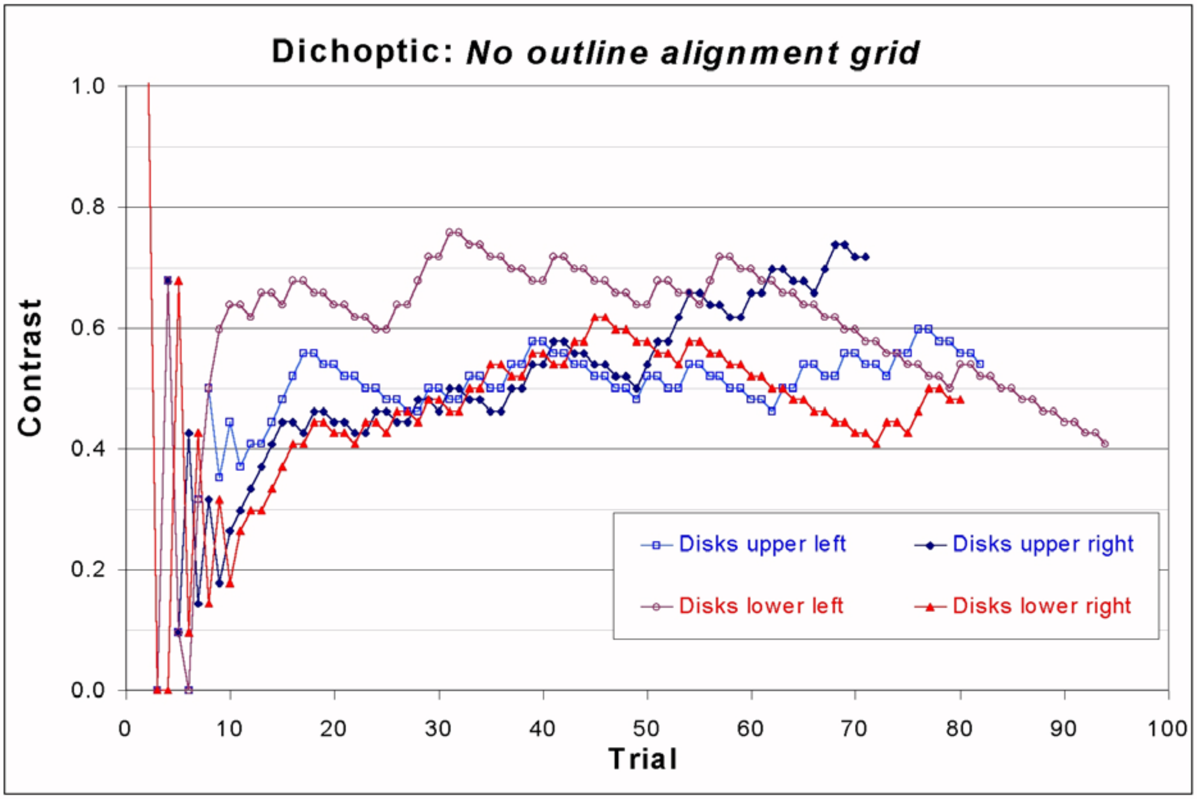


Figure 6B: *FSS from a situation that could produce rivalry*

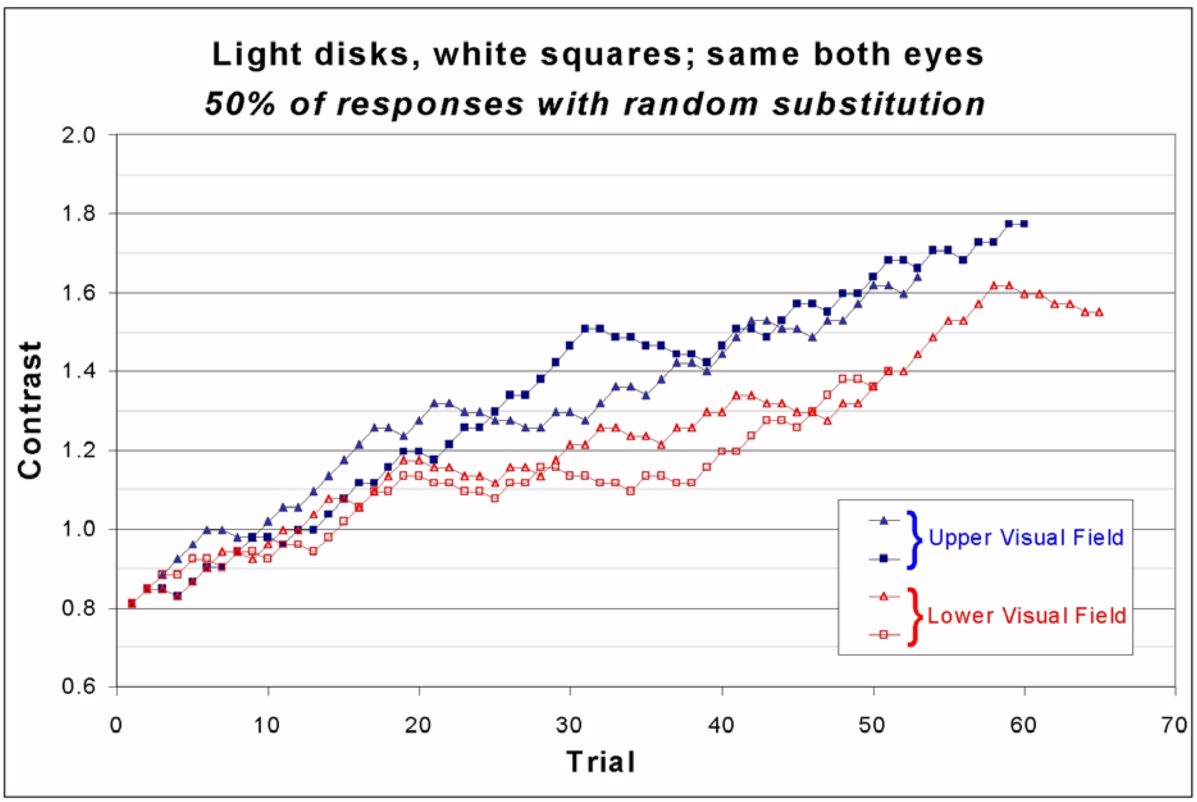


Figure 6C: *Rivalry simulated in an FSS by randomly altering half the responses*

Experiment III (Offset *vs* Disparity)

Methods of Experiment III (Figure 3 E & F)

1. **Experiment III was designed to bolster the results of the first two experiments**
2. **In Experiment III, light disks were shifted in opposite directions by the same amount in both eyes to induce disparity ("Disparity Condition," Fig. 3E)**
    - The disk appeared to be centered in the intersection but in a different plane than the squares (3D, in front of or behind)
3. **Alternatively, light disks were shifted (by the same amount as in the disparity condition) in the same direction in both eyes ("Offset Condition," Fig. 3F)**
    - The disk appeared in the same plane as the grid, but it was at the edge of the intersection
4. **In both the offset and disparity conditions, neither eye received a stimulus that should induce strong blanking; if blanking is present in the disparity condition, a cortical contribution must be present**

left eye image *right eye image*

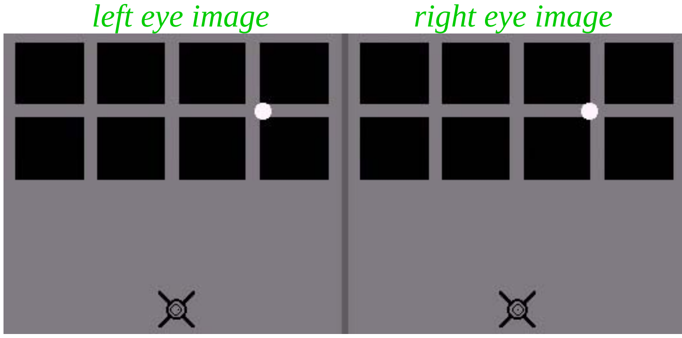


Figure 3E: Disk appears in a different plane than the squares

left eye image *right eye image*

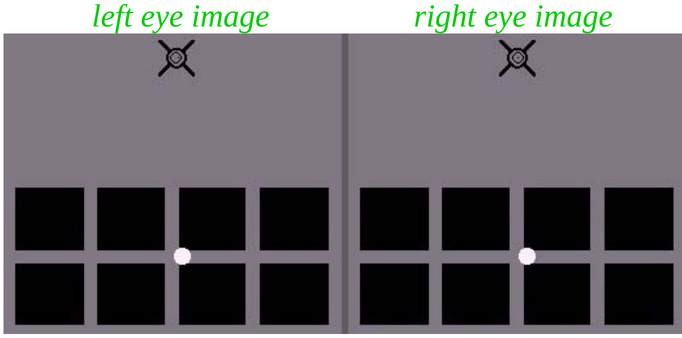


Figure 3F: Disk offset from center of intersection (same in both eyes)

Results of Experiment III (Figure 7)

1. **Disk contrast threshold in the disparity condition was significantly higher than the contrast threshold in the offset condition**
2. **However, contrast threshold in the disparity condition was lower than the contrast threshold of the light disk with black squares presented to both eyes with no offset**

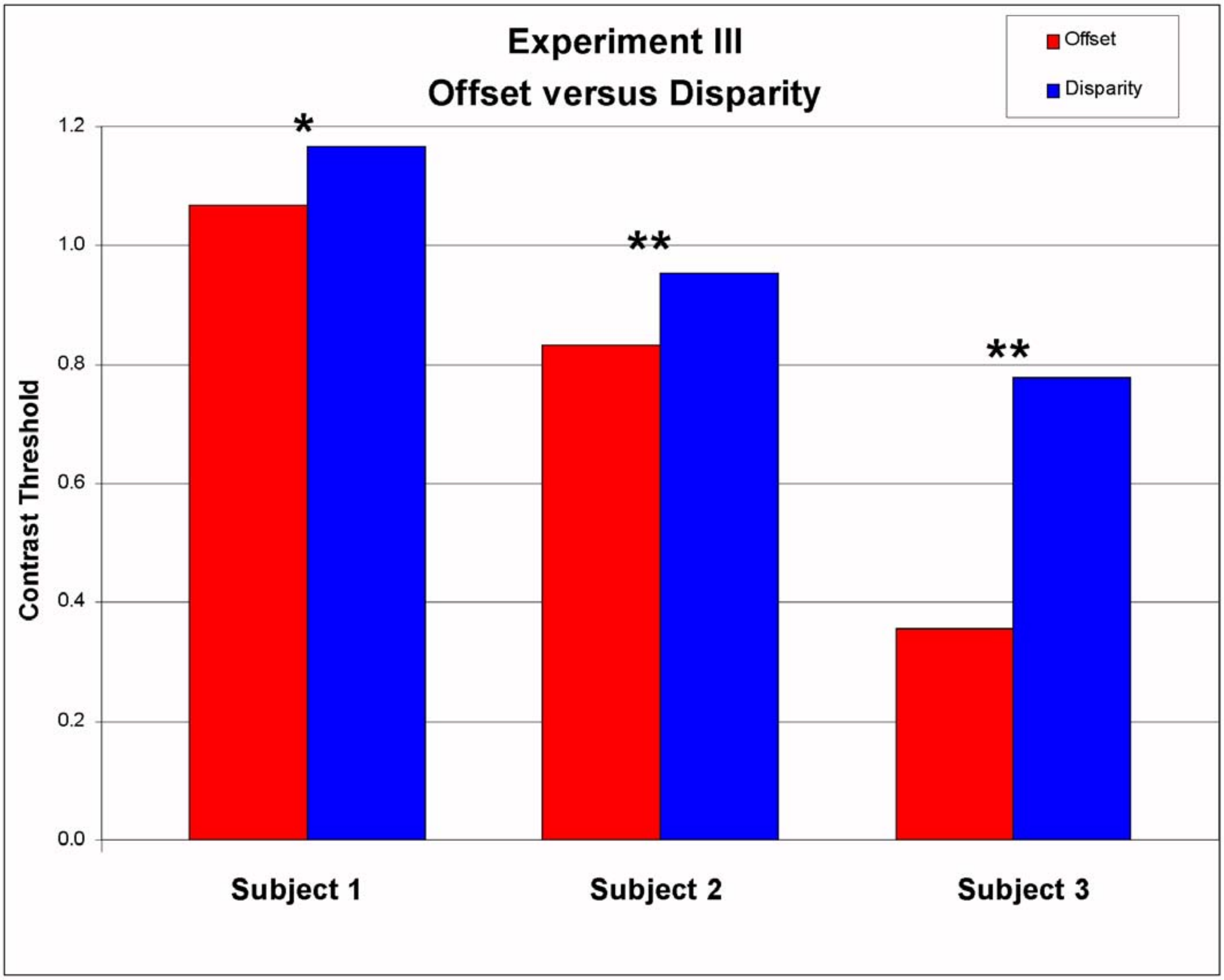


Figure 7

Conclusions of Experiment III

1. **If the disk appears centered in the intersection but in a different plane, blanking is present but reduced (as compared to the same stimulus appearing without disparity)**

2. **Results implicate a post-fusion (likely cortical) contribution to the blanking phenomenon**

Discussion

The blanking phenomenon appears to have both pre-fusion (retinal or LGN) and post-fusion (cortical) components

A "dual stage" theory can be invoked to explain the processing that results in the blanking phenomenon

- Lateral inhibition constitutes stage one. Light disks falling in intersections created by black squares receive approximately twice as much inhibition as disks falling entirely within an alley. This enhanced inhibition increases threshold and promotes blanking
- Cortical processing constitutes the second stage

Summary

	Blanking Present?	Inferred Locus
Experiment I	If aligned: YES (weak)	Cortex involved
Experiment II	Same Contrast: NO Opposite Contrast: Yes	Retina involved
Experiment III	Disparity: Yes Displacement: Weaker	Cortex involved