Magnocellular- and parvocellular-pathway contributions to a novel visual illusion

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Magnocellular- and parvocellular-pathway processing in a novel visual illusion

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If viewed peripherally, a white disk presented in an intersection of gray alleys in a grid of black squares is not detected. Previous work showed that both retinal and cortical mechanisms contribute to this "blanking phenomenon" (McAnany & Levine, 2005). Here, we examine magnocellular (MC) and parvocellular (PC) pathway contributions to this novel form of visual disappearance. In these experiments, grids of black squares were continuously presented 15o above and below fixation on a 46 cd/m2 gray background (background and alley luminance was always equal); a white disk appeared in a randomly chosen intersection. Subjects were asked to identify which intersection (left, middle, right) contained the disk.

In one condition, the disk was presented as a 36 ms pulse, a presentation duration that favors the MC-pathway. Subjects identified the correct intersection with near-perfect accuracy in this condition. In a second condition, the disk was ramped on, held for 36 ms, and then ramped off (minimizing temporal transients, thus biasing processing toward the PC-pathway). Subjects' responses to the ramped stimulus were essentially random. A third condition was intended to saturate the MC-pathway by introducing a large luminance transient concurrent with the disk presentation (Leonova, Pokorny, Smith, 2003). To induce the luminance transient, the background and alley gray luminance before and after the pulsed disk presentation was 0.3 log above or below the 46 cd/m2 gray. Contrast threshold under this condition was significantly higher than when the disk was pulsed without a luminance change.

There are two possible explanations for these results. First, the MC-pathway may be solely responsible for detecting the disk; the disk cannot be detected when the MC-pathway is saturated or ineffective. Alternatively, either pathway can detect the disk, but the PC-pathway includes processing that causes blanking in the presence of the grid.

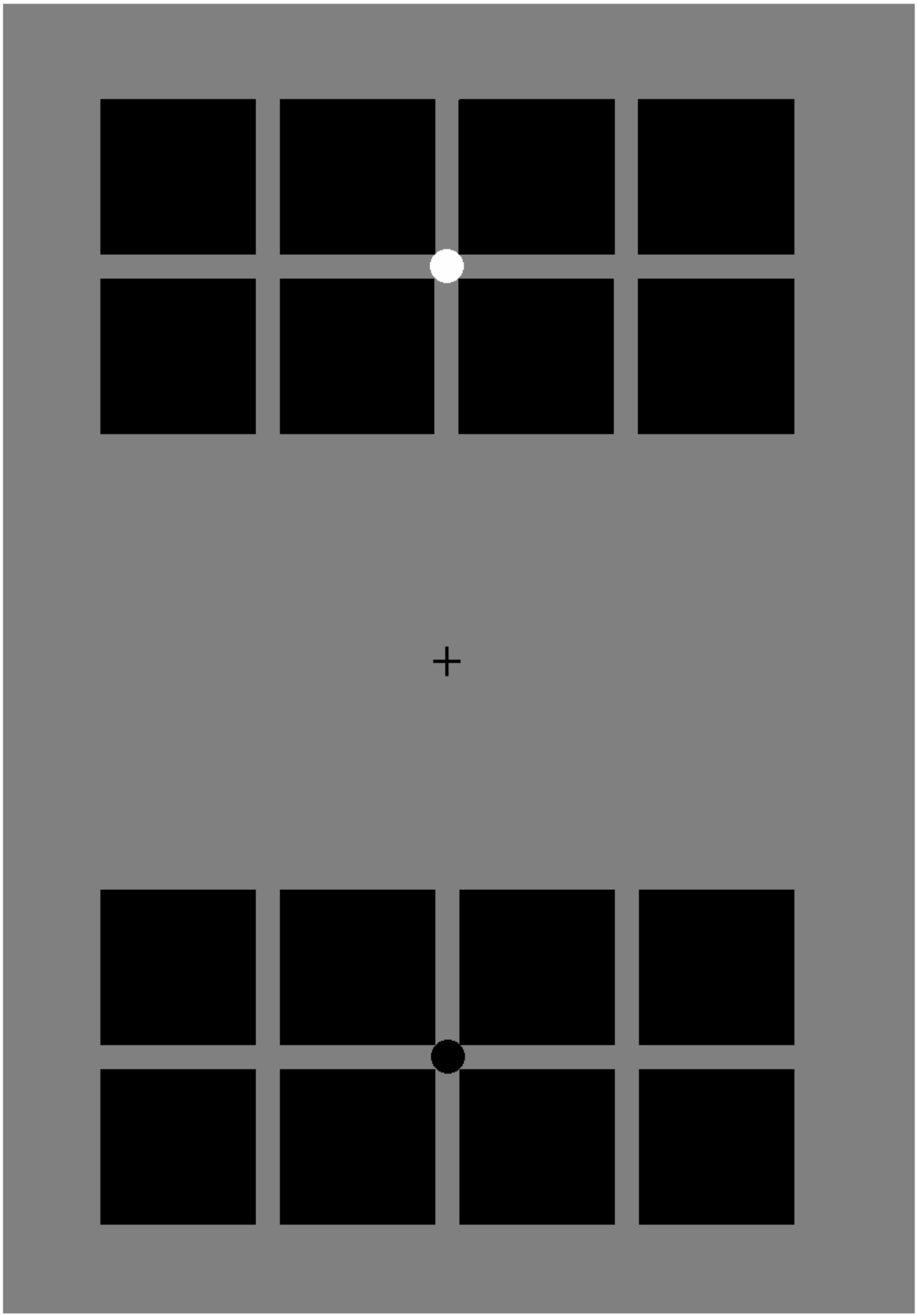


Figure 1

The Blanking Phenomenon

- A white disk presented at the intersection of gray alleys in a grid of black squares is not detected when viewed peripherally (at an eccentricity of approximately 10^{o} or greater) (McAnany & Levine, 2004)

- This "blanking phenomenon" is demonstrated in Figure 1
  - If the + (or the lower grid) is fixated, the white disk in the upper grid vanishes, as if falling into a scotoma

- The effect is not simply due to decreased resolution in the peripheral retina, as a dark disk is easily detected
  - If the + (or the upper grid) is fixated, the dark disk in the lower grid remains visible
- This novel form of “visual disappearance” has been shown to have contributions from both pre- and post-fusion sites in the visual system (McAnany & Levine, 2005)

- **PURPOSE:**

  The purpose of this study was to examine the visual pathway responsible for the generation of the blanking phenomenon

Methods

- The authors (males, 26 and 62 yr) served as subjects
- Stimuli were presented binocularly on a calibrated EIZO display monitor
- A 4x2 grid of black (0.1 cd/m^2) squares was presented continuously in both the upper and lower visual fields (squares were absent in control conditions)
- A single white disk appeared in one of three possible intersections (chosen at random) 15.5^o above or below fixation
- The subject was asked to determine which intersection contained the disk (3AFC)
- Programs were written in MATLAB using the psychophysics toolbox extensions (Brainard, 1997)

EXPERIMENT I

Steady- and Pulsed-Pedestal Thresholds

- Pokorny & Smith (1997) devised steady- and pulsed-pedestal psychophysical paradigms believed to bias visual processing toward the magnocellular (MC) and parvocellular (PC) pathways, respectively.
- Figure 2 depicts the sequence used in the steady- (Fig. 2A) and pulsed-pedestal paradigms (decrement: Fig. 2B; increment: Fig. 2C)
- The **steady-pedestal** paradigm biased processing toward the MC pathway because the test target was presented briefly
- The **pulsed-pedestal** paradigms biased processing toward the PC pathway because the abrupt change of the luminance pedestal drives the MC pathway toward saturation (Leonova, *et al*., 2003)

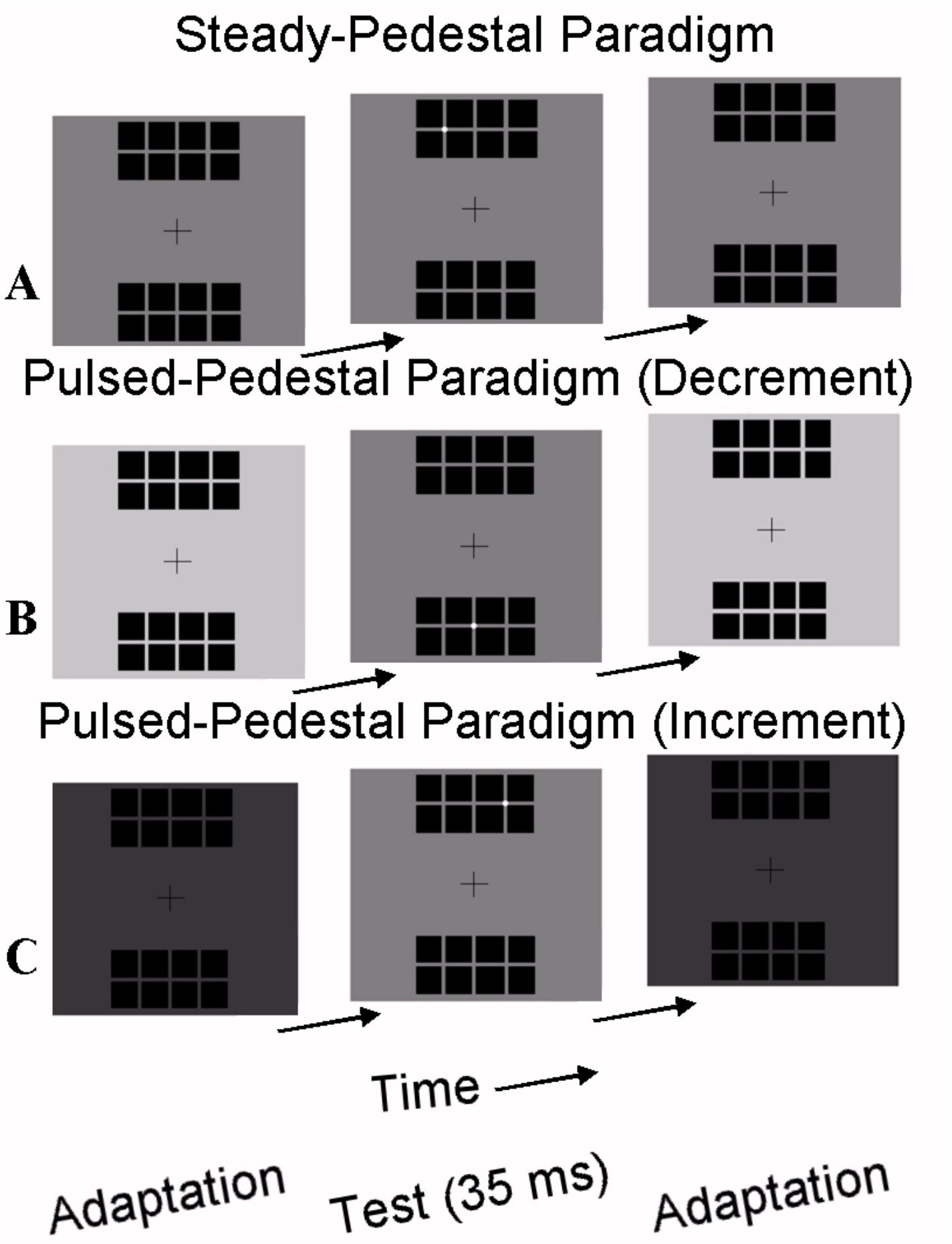

Steady-Pedestal Paradigm
A
Pulsed-Pedestal Paradigm (Decrement)
B
Pulsed-Pedestal Paradigm (Increment)
C
Time
Adaptation
Test (35 ms)
Adaptation

Figure 2

Stimulus Parameters

- **Test duration:** 35 ms
- **Luminance:** Pedestal, 47 cd/m^2
  - Decrement: Adapting field was 0.3 log greater than the pedestal
  - Increment: Adapting field was 0.3 log less than pedestal
  - Disk could range from 47 to 92 cd/m^2
- **Disk Threshold Determination:**
  - Disk threshold was determined using an adaptive staircase procedure following rules for accelerated stochastic approximation (Treutwein, 1995)
- **Definition of Contrast:**
  - Contrast was defined as:

$$C = (L_D - L_P)/L_P ,$$

where L_D was the disk luminance, and L_P is the pedestal luminance

EXPERIMENT I: RESULTS

Steady- and Pulsed-Pedestal Thresholds

- Figure 3 gives the results for the steady- and pulsed-pedestal paradigms tested with or without squares (error bars indicate 95% confidence intervals)

With Squares:

- Under the steady-pedestal paradigm, disk threshold was low and the blanking phenomenon was weak or absent
- Under the pulsed-pedestal paradigms, thresholds were high, indicating a strong effect of blanking
- Threshold was lower for the decrement than for the increment pulsed-pedestal paradigm

Without Squares:

- Thresholds were low under both paradigms
- Threshold was lower for the increment than for the decrement pulsed-pedestal paradigm

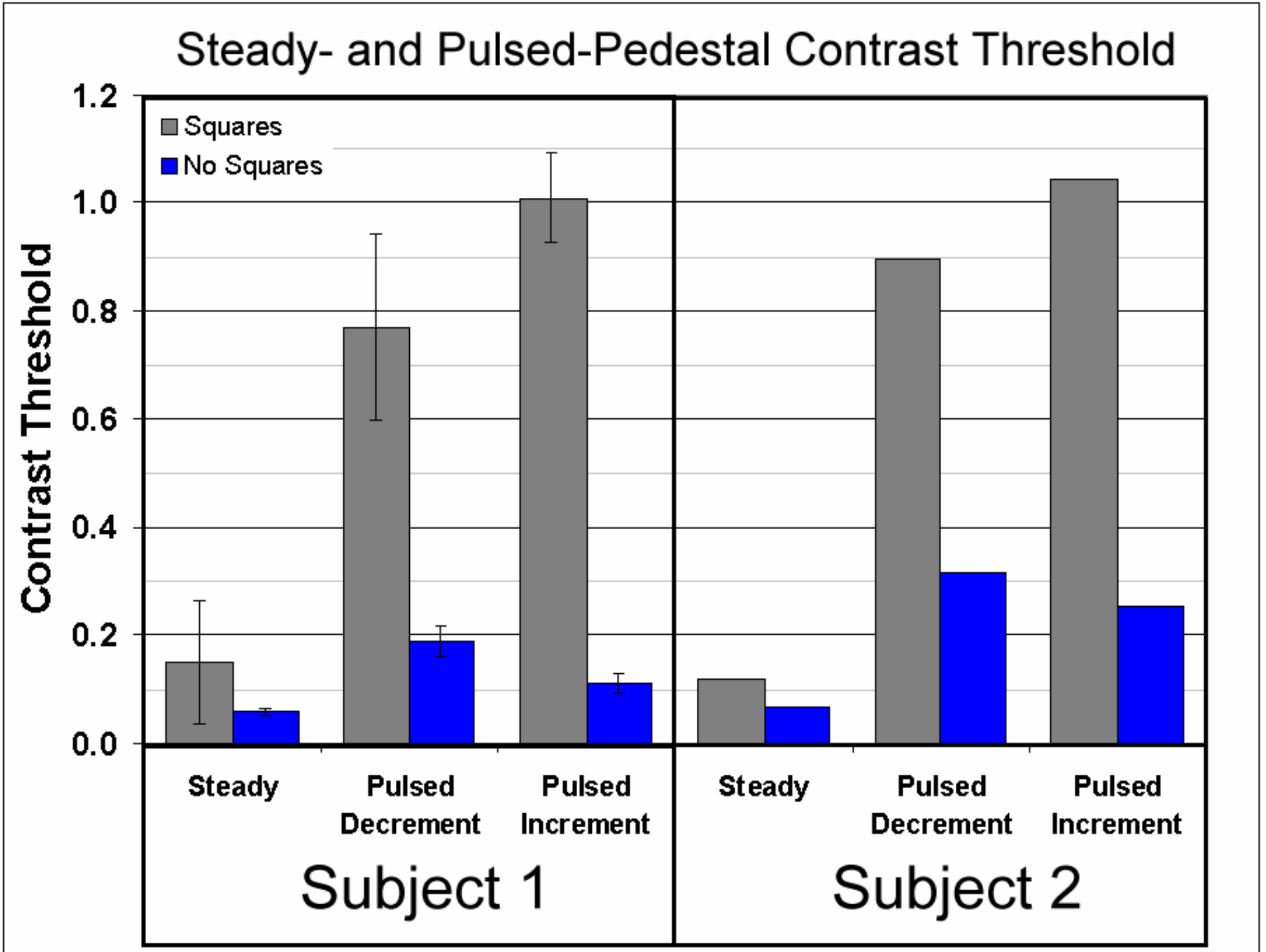

Steady- and Pulsed-Pedestal Contrast Threshold
Contrast Threshold
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Squares
No Squares
Steady
Pulsed Decrement
Pulsed Increment
Subject 1
Steady
Pulsed Decrement
Pulsed Increment
Subject 2

Figure 3

EXPERIMENT I: CONCLUSIONS

Steady- and Pulsed-Pedestal Thresholds

- When visual processing is biased toward the MC pathway (steady-pedestal), the illusion is very **WEAK** (or absent)

- However, when processing is biased toward the PC pathway (pulsed-pedestals), the illusion is very **STRONG**

- Results indicate:
  - a role for PC pathway processing in generating the Blanking Phenomenon
  - a role for MC pathway processing in disk detection given the lower threshold in the steady-pedestal than pulsed-pedestal paradigm no squares conditions

- Threshold differences between increments and decrements when squares are absent can be attributed to the gain due to the different levels of adaptation before the pulse
- Threshold differences between increments and decrements when squares are present may be due to the effect of gain on the relative contrast of the squares
  - In the decrement condition, the adaptation produces an effective reduction in the contrast of the squares (thereby reducing the strength of the illusion)
  - In the increment condition, the strength of the illusion may be enhanced due to an effective increase in square contrast

Origin of the Threshold Increase in the Pulsed-Pedestal Paradigms

- Are the threshold increases in the pulsed-pedestal paradigms simply due to the presence of squares?
- In Fig. 4 each ‘no squares’ bar has been expanded by the ratio of the ‘steady with squares’ to the ‘steady no squares’ conditions (the ratios were 2.46 & 1.75 for S1 and S2, respectively)
- The blue area of the bar at the bottom is the threshold without squares (replotted from Fig. 3)
- The blue and gray area represents threshold increase due to the squares (derived from the multiplication ratio)
- The yellow area of each bar indicates the threshold increase that is left unaccounted for; this is interpreted to be the magnitude of the blanking phenomenon in the pulsed-pedestal paradigms

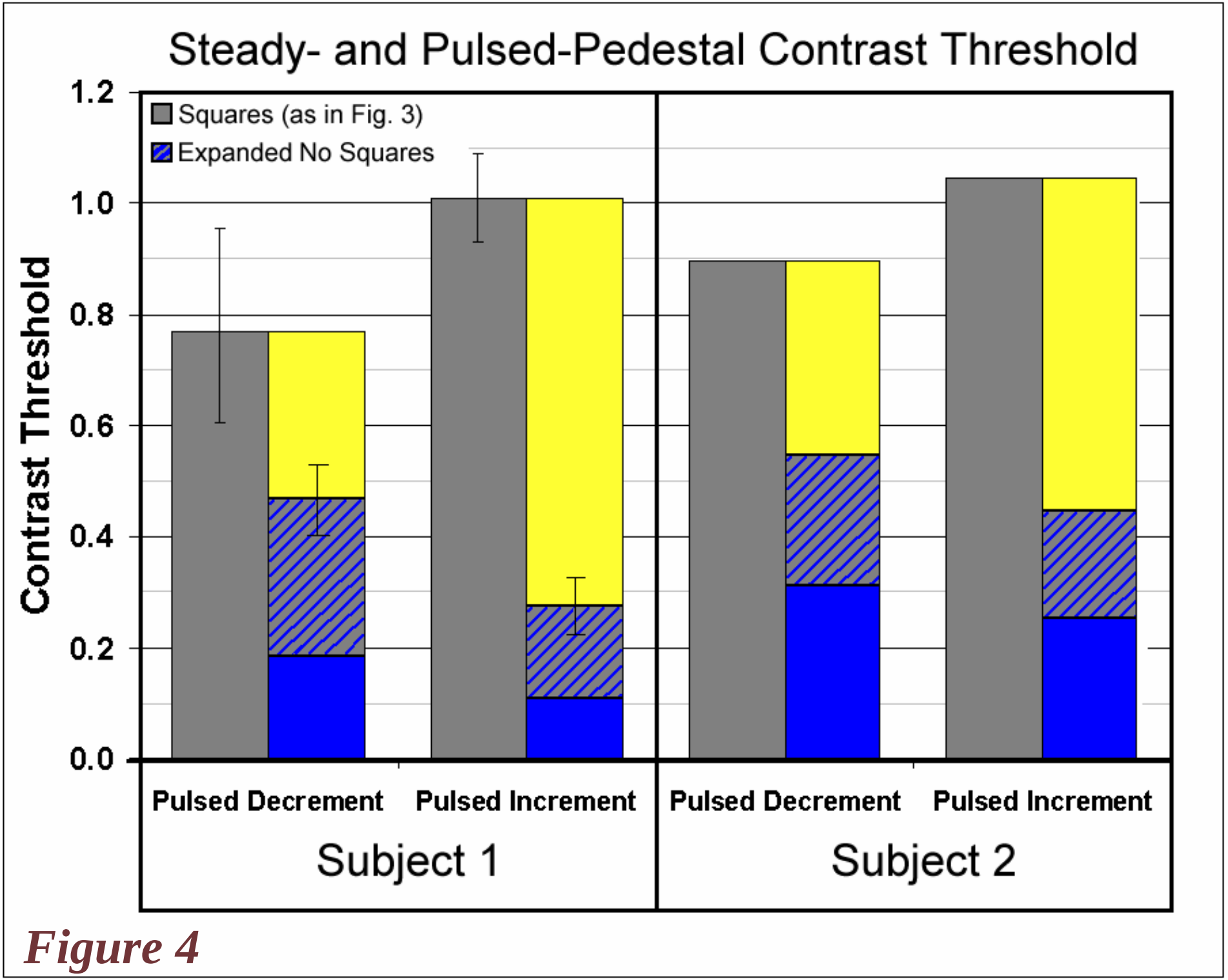
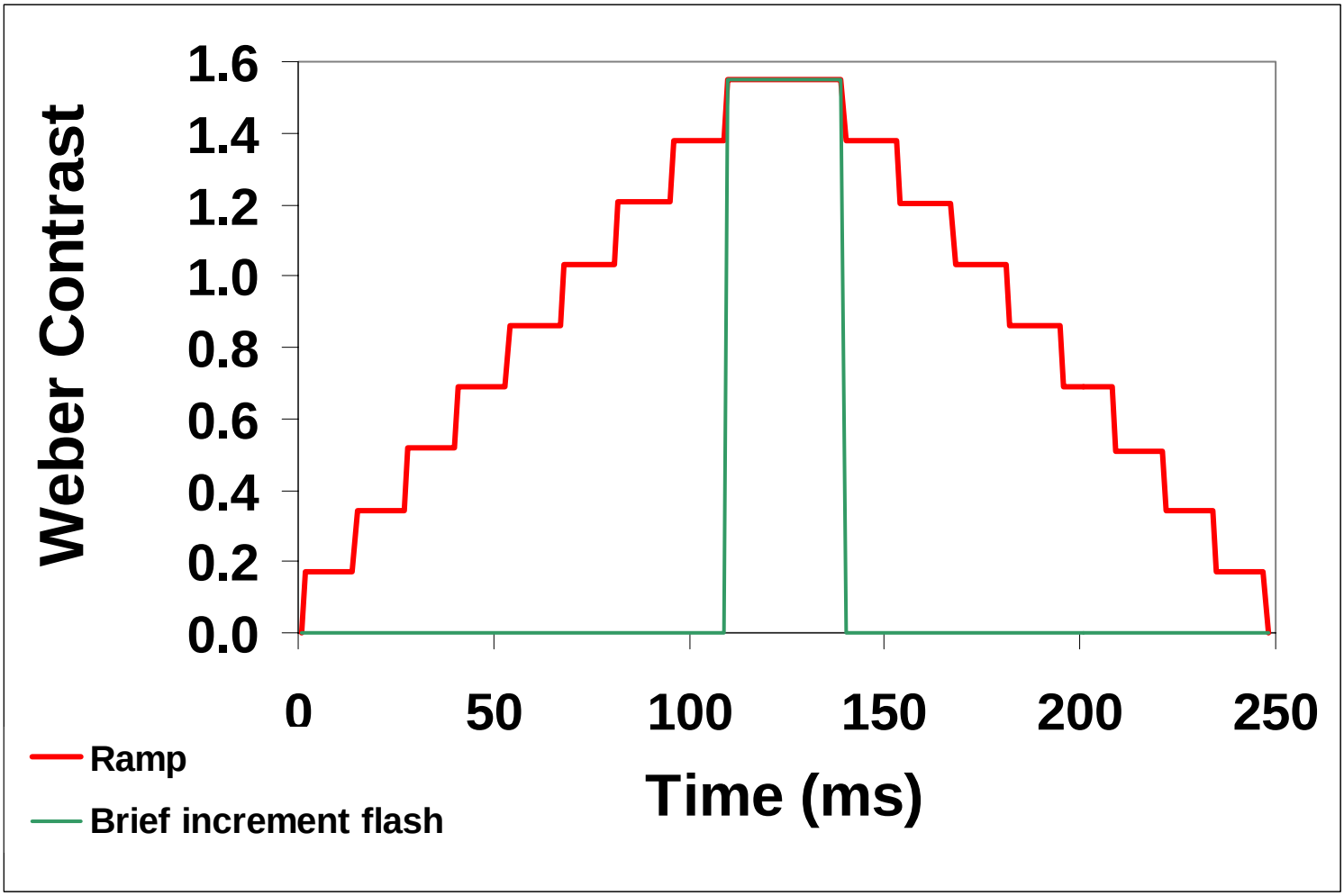

Steady- and Pulsed-Pedestal Contrast Threshold
Squares (as in Fig. 3)
Expanded No Squares
Contrast Threshold
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Pulsed Decrement
Pulsed Increment
Subject 1
Pulsed Decrement
Pulsed Increment
Subject 2

Figure 4

EXPERIMENT II

Ramp and Increment Flash Presentations

- The temporal presentation characteristics were altered to bias processing toward the MC or PC pathway
- Slowly ramping the disk on and off minimizes temporal transients and biases processing toward the PC pathway
- Presenting the disk as a brief increment biases processing toward the MC pathway
- Subjects identified which of three intersections contained the disk, which was presented at the maximum contrast. Percentage of correct responses was calculated



- Temporal presentations:

Ramp:

Disk contrast was increased from 0 to 1.55 (maximum value possible) in 9 steps (106 ms total), held for 35 ms at the maximum contrast, then decreased in 9 steps

Brief increment flash:

Disk contrast was increased from 0 to 1.55 in a single step, held for 35 ms at the maximum contrast, then decreased in one step

EXPERIMENT II: RESULTS

Ramp and Increment Flash Presentations

- Figure 5 gives the results for the ramp and increment flash presentations
  (error bars indicate 95 % confidence intervals)

- When the disk was ramped on and off, subjects performed just above chance

- When the disk was presented as an increment flash, subjects identified the correct intersection with near perfect accuracy

- These results are consistent with a role for the PC pathway in the blanking phenomenon

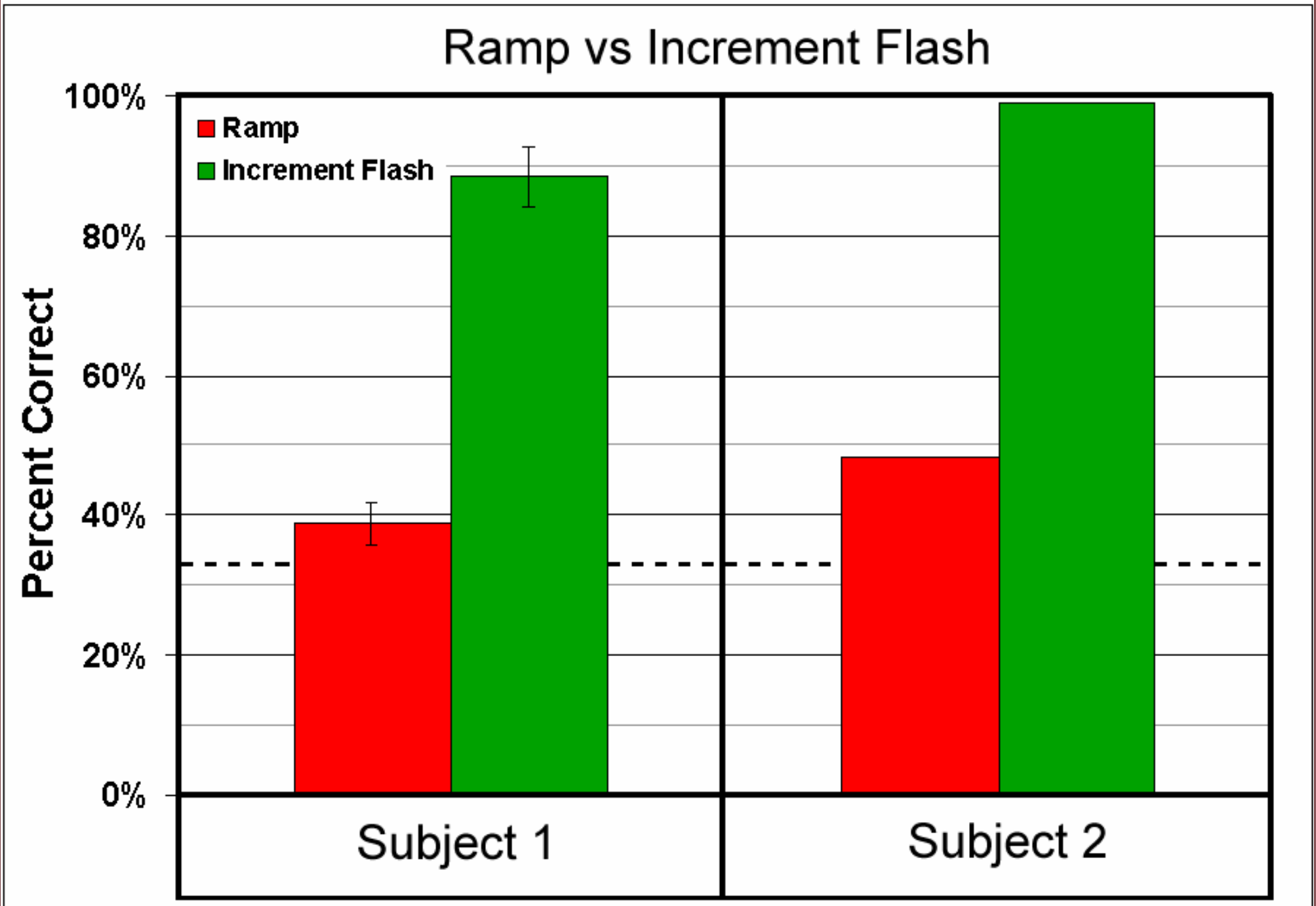

Ramp vs Increment Flash
100%
80%
60%
40%
20%
0%
Percent Correct
Ramp
Increment Flash
Subject 1
Subject 2

Figure 5

General Conclusions

- Both experiments indicate that the blanking phenomenon is absent when visual processing is biased toward the MC pathway, and present when processing is biased toward the PC pathway
- Two possible conclusions can be drawn from these results:

  (1) The MC pathway may mediate sensitivity for simple disk detection; the disk cannot be detected as readily when the MC-pathway is saturated and sensitivity is mediated by the PC pathway

  (2) The PC-pathway includes processing that causes blanking in the presence of the grid

  (The original simultaneous disk and grid presentations were much like the pulsed-pedestal paradigm where detection is mediated by the PC pathway)

References

- Brainard, D. (1997). The psychophysics toolbox, *Spatial Vision*, *10*, 433-436.
- Leonova, A., Pokorny, J., Smith, V.C. (2003). Spatial frequency processing in inferred PC- and MC pathways. *Vision Res.*, *43*, 2133-2139.
- McAnany, J. J. & Levine, M. W. (2004). The blanking phenomenon: a novel form of visual disappearance. *Vision Res.*, *44*, 993-1001.
- McAnany, J. J. & Levine, M. W. (2005). A psychoanatomical investigation of the blanking phenomenon . *Vision Res.*, *45*, 193-203.
- Pokorny, J. & Smith, V. C. (1997). Psychophysical signatures associated with magnocellular and parvocellular pathway contrast gain. *J. Opt. Soc. Am. A*, *14*, 2477-86.
- Treutwein, B. (1995). Adaptive psychophysical procedures. *Vision Res.*, *35*, 2503–2522.