Contour Integration in the Peripheral Field of Normal and Low Vision Observers

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ABSTRACT

Purpose: Reports by Hess and Dakin (1997 & 1999) suggest that neural processing in the peripheral field is different from the central field. They reported that normal vision (NV) subjects using their periphery (beyond 10°) were unable to detect paths of alternating phase (AP) gabors embedded within randomly positioned gabors but could detect same phase (SP) paths. If true, this has implications for understanding the visual perception of people who have central field loss (CFL). This study 1) attempts to replicate Hess and Dakin's results; 2) measures the degradation in pathway detection in the periphery using smaller (2°) increments in eccentricity (0° path angle, SP & AP); and 3) measures the contour path detection of CFL patients with large scotomas.

Methods: Four NV subjects and two CFL patients (scotoma radii 13°-15°) identified the path stimulus in a temporal 2AFC experiment. A third CFL patient (17.5° scotoma radius) traced out the pathways on the monitor. An eye tracking system was used to ensure proper eccentric fixation by the NV subjects. A scanning laser ophthalmoscope was used to assess eye movements of the CFL patients.

Results: Three young NV subjects detected AP paths at 20° (71%, 67%, 65% correct, $p<0.01$). An 85-year old NV subject could not perform the AP task at 20°. Path detection decreased monotonically as a function of eccentricity (6°-24°) for both AP and SP stimuli. CFL patients performed similarly to NV subjects at the same eccentricities. NV and CFL subjects verbally reported seeing SP and AP paths when presented at eccentricities beyond 10°.

Conclusions: Contrary to Hess and Dakin, NV observers could detect AP paths beyond 10°. As with most visual functions, contour path detection declined steadily with eccentricity, with the more difficult task (AP) declining faster. The results for the NV observers could not be explained by poor fixation. We did not find improved performance in the CFL patients compared to NV subjects. If CFL patients had performed better, this might suggest cortical reorganization or neural adaptation. Therefore, we found no evidence of cortical reorganization or neural adaptation using this paradigm.

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BACKGROUND

Hess and Dakin (1997 & 1999) reported that normal vision (NV) subjects using their peripheral vision (beyond 10°) performed at chance levels when detecting paths of alternating phase (AP) gabors embedded within randomly positioned gabors but could detect same phase (SP) paths.

We asked:

Exp. 1 – Can we replicate Hess and Dakin's results?

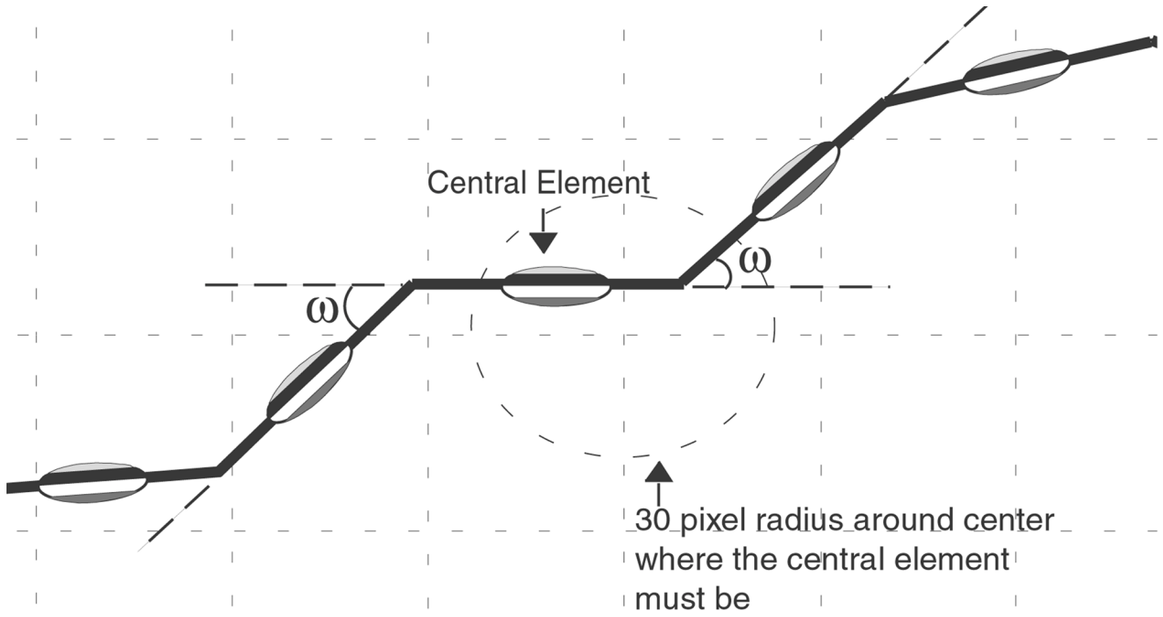
Exp. 2 – Using smaller (2°) increments in eccentricity, can we more accurately determine when pathway detection is lost?

Exp. 3 – Can people with large central scotomas perform better at the task than NV subjects, thereby providing evidence of cortical reorganization or neural adaptation?

General Methods

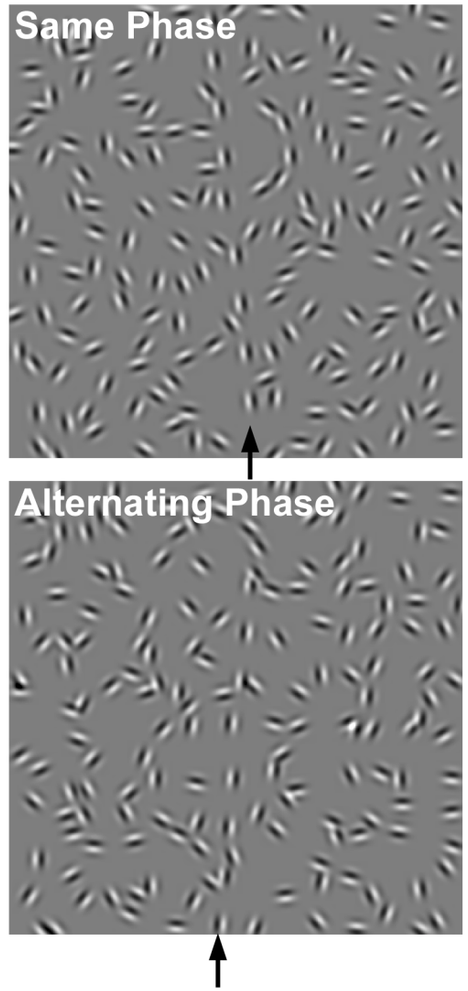
- Parameters were set to replicate Hess and Dakin (1997, 1999)
- 4 NV subjects aged 18 to 85; 100cm viewing distance
- 3 subjects with central field loss (CFL) with large central scotomas aged 47 to 58; variable viewing distances
- Temporal 2AFC procedure – 1 of 2 intervals contained the path stimulus
- Monocular task (dominant eye for NV subjects)
- NV subjects fixated on targets for eccentric viewing conditions
- SLO used to determine CFL subjects' eccentric fixation (preferred retinal locus: PRL)

STIMULUS



$$g(x, y, \theta) = 1 + c \cdot \sin(2\pi f\,(x \sin\theta + y \cos\theta) + \psi) \cdot e^{-(x^2+y^2)/(2\sigma^2)}$$

(x,y): distance from element center
θ: the orientation of the element
c: Michelson contrast (90%)
***f*: period**
ψ: sine phase relative to the element center (0° or 180°)
σ: the standard deviation (0.4*f*)
ω: path angle



- Driven by HP Apollo; monitor resolution was 1280 X 1024
- Monitor was 22.1° X 17.1° at 100cm view
- The stimulus subtended a visual angle of 10.3° X 10.3° from 100 cm

EXP. 1 – REPLICATION OF HESS AND DAKIN (1997, 1999)

Subjects: NV; 2 younger (RK & BP) and 1 older (HD); aged 18, 25,and 85

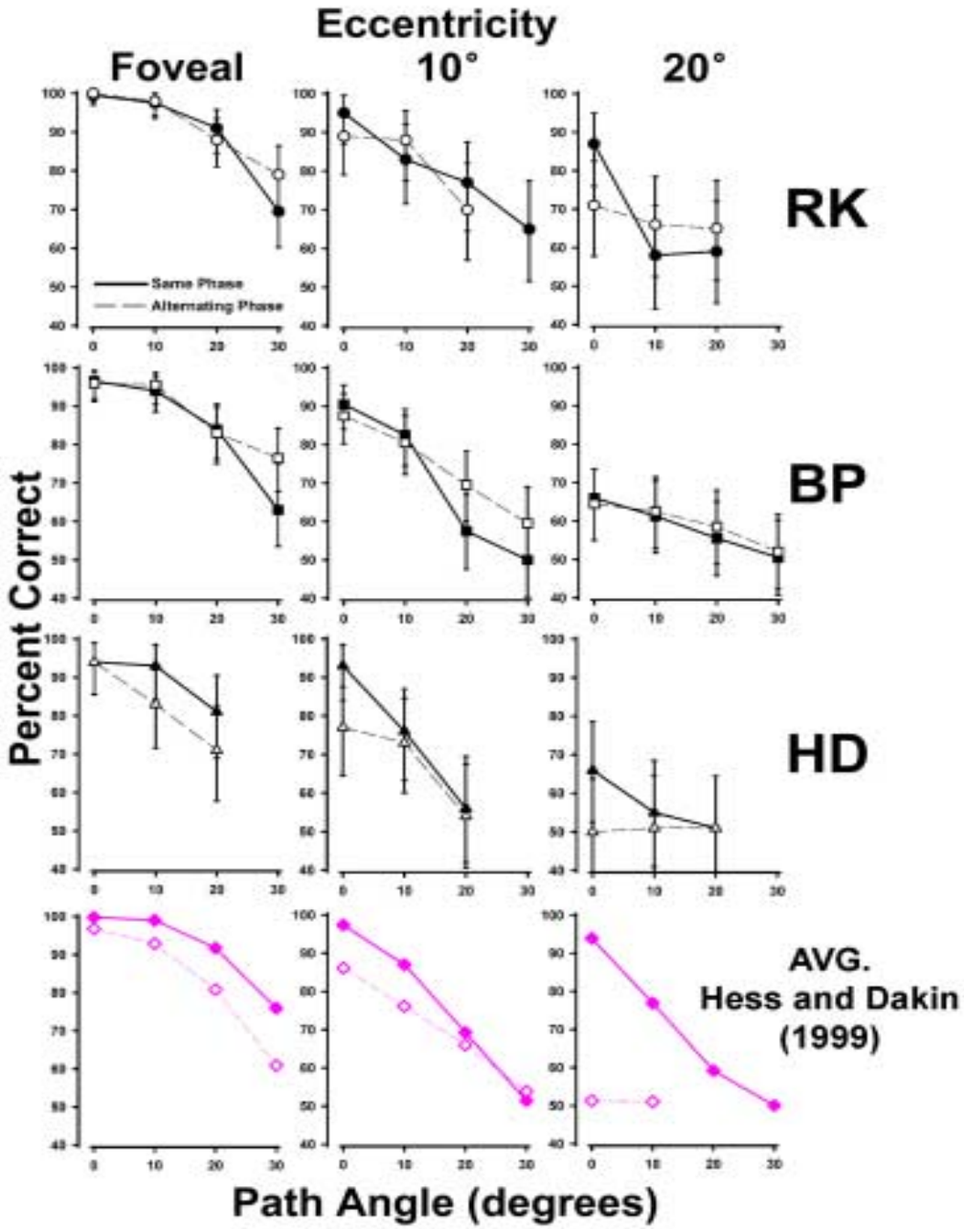
Conditions:

- 3 independent variables:
  a. Phase: Same Phase (SP) or Alternating Phase (AP)
  b. Path angle (ω): 0°, 10°, 20, or 30°
  c. Eccentricity: foveal (0°), 10°, and 20°
     - defined as degrees of visual angle from point of fixation to the center of the stimulus array

Methods:

- all subjects presented 100 to 300 trials for each condition
- started with easiest task first (smaller path angle, SP, lower ecc.)

EXP. 1 RESULTS



Error bars are 95% confidence interval

- Subjects RK and BP could detect paths beyond 10°, AP condition; verbally reported seeing paths "pop out"
- Subject HD could not detect paths beyond 10° eccentricity – could be due to his inability to fixate at 20° (85 years old)
- Replicated Hess and Dakin for SP conditions
- **Failed to replicate Hess and Dakin at AP, 20° ecc. condition**

EXP. 2 – DETECTION OF PATHS AS A FUNCTION OF ECCENTRICITY

Subjects: 3 Normal vision subjects (RK, BP, AN)

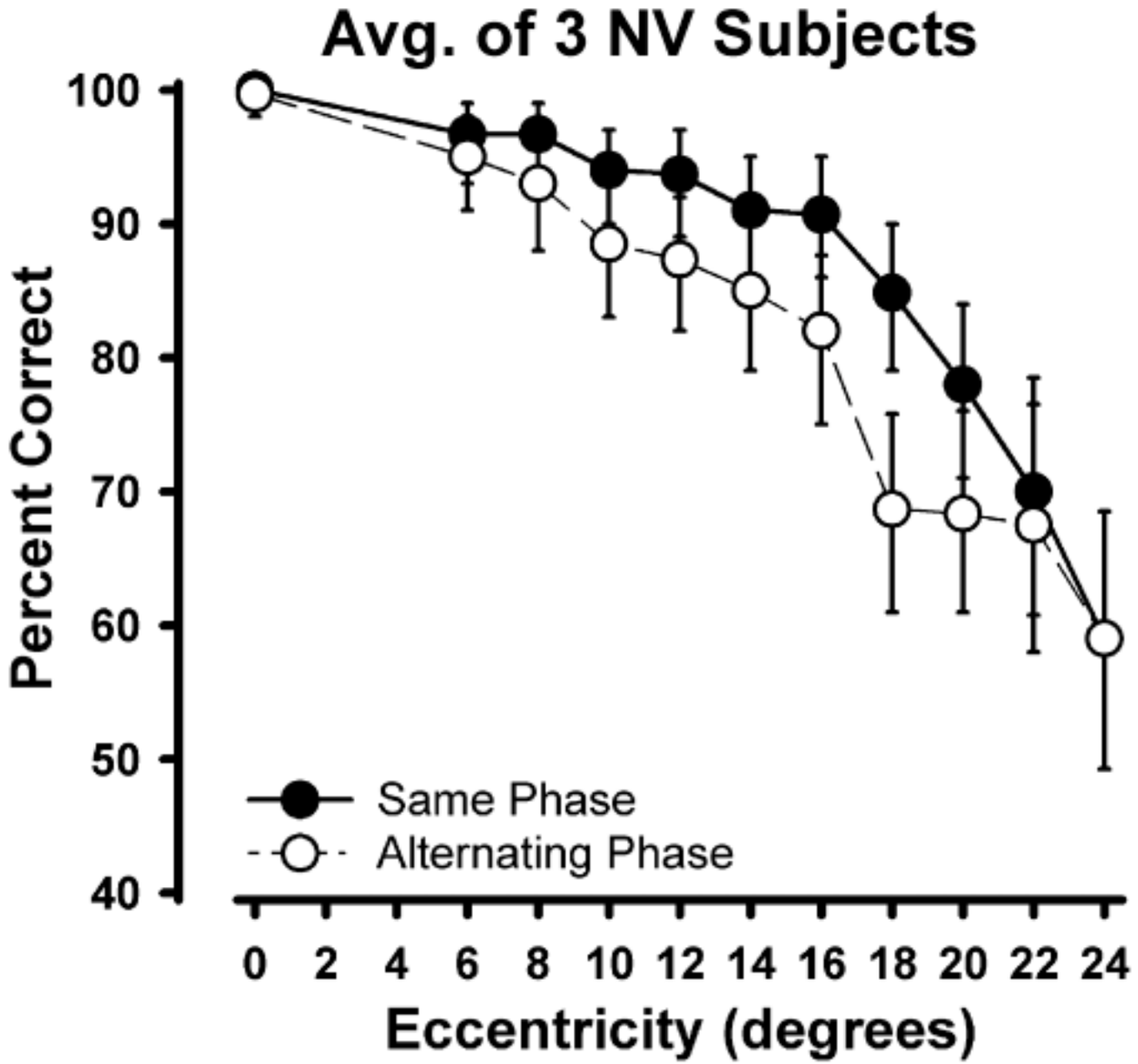
Conditions:

- 0° Path Angle; SP and AP
- Eccentricities tested: 0°, 6°, 8°, 10°, 12°, 14°, 16°, 18°, 20°, 22°, 24°

Methods:

- Order of conditions randomized (from 0° to 20° ecc.)
- Larger ecc. beyond 20° tested in sequential order, starting with easiest condition first
- Checked good fixation using eye tracking system in control experiment

EXP. 2 RESULTS



Error bars are 95% confidence interval

- No sudden drop in the ability to detect the AP paths beyond 10°
- 0° path angle pathways were seen beyond 20° for both the SP and AP conditions
- Contour path detection, as with most visual functions, declines steadily with eccentricity

EXP. 3A – CONTOUR INTEGRATION IN CFL PATIENTS

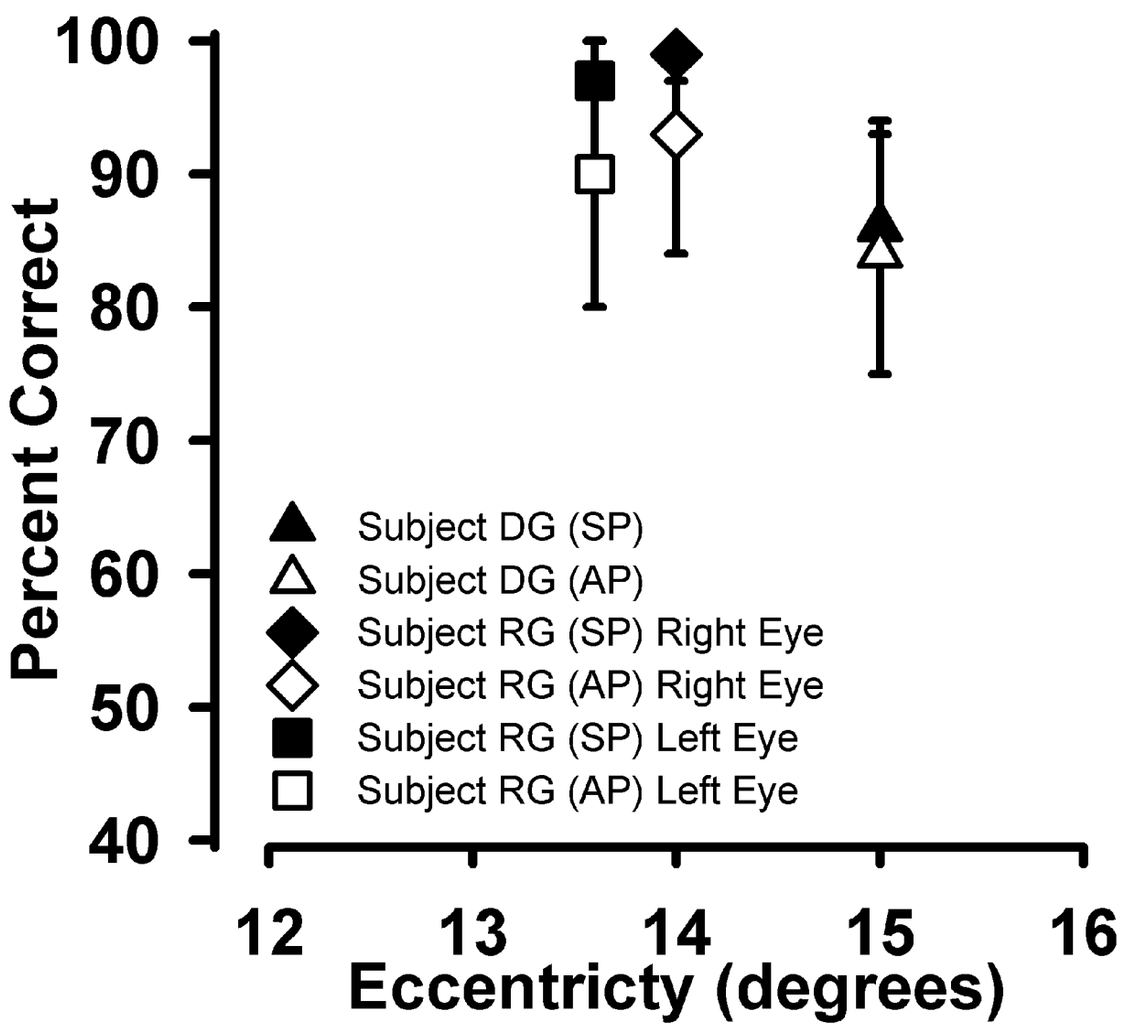
Subjects: 3 CFL patients with large central scotomas (DG, RG, DS)

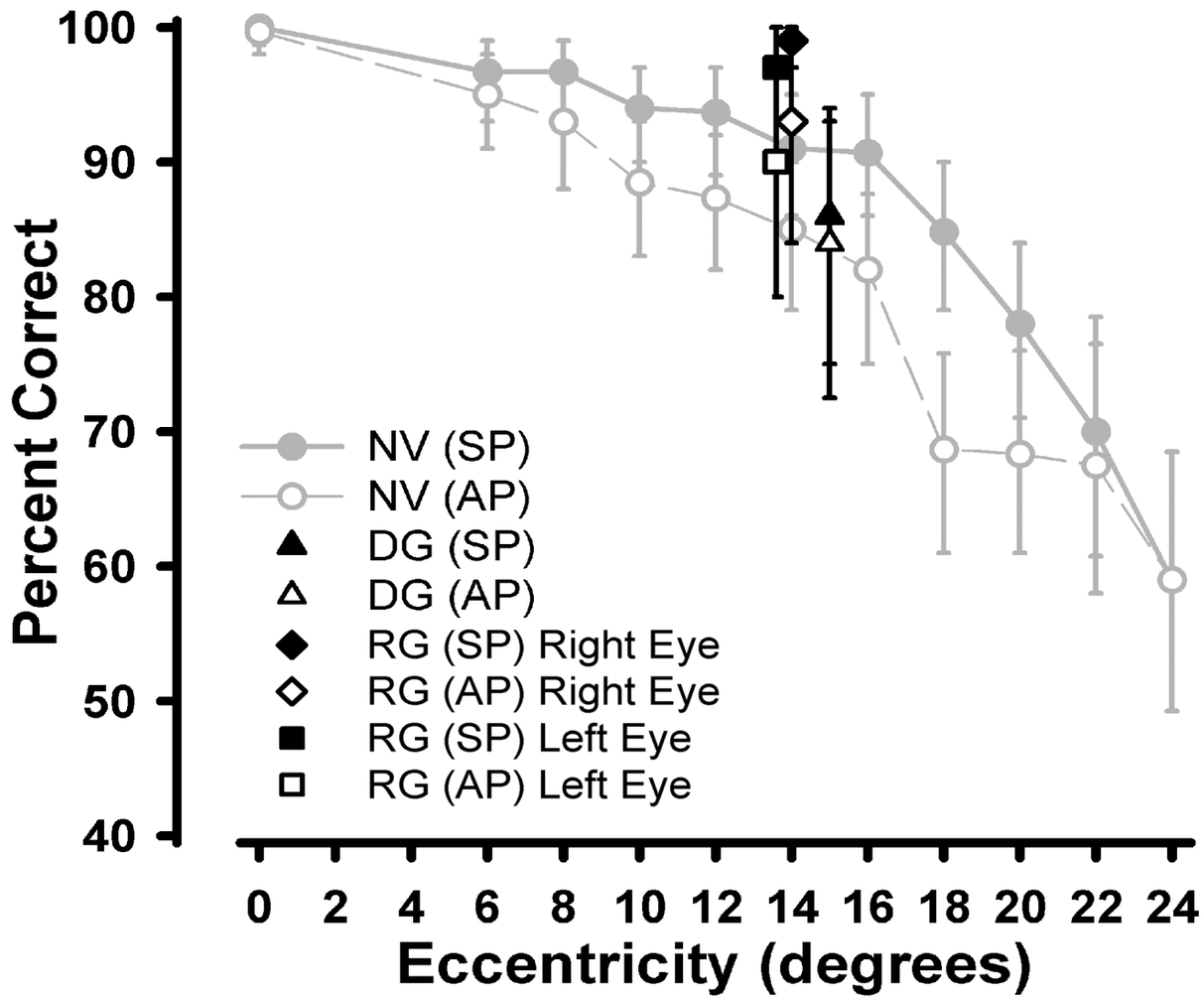
Conditions: 0° Path Angle; SP and AP

Methods:

- 2AFC; Monocular task
- Subjects were allowed to scan images
- Sat at viewing distance comfortable for them
- Subject DS participated in alternative task (see Exp. 3B)
- Longer presentation time (4 seconds instead of 2)
- Preferred retinal locus (PRL) determined by SLO
- DG had a 20cm view; RG had a 50cm view

EXP. 3A RESULTS





Error bars are 95% confidence interval.

EXP. 3B – CONTOUR INTEGRATION IN CFL PATIENTS

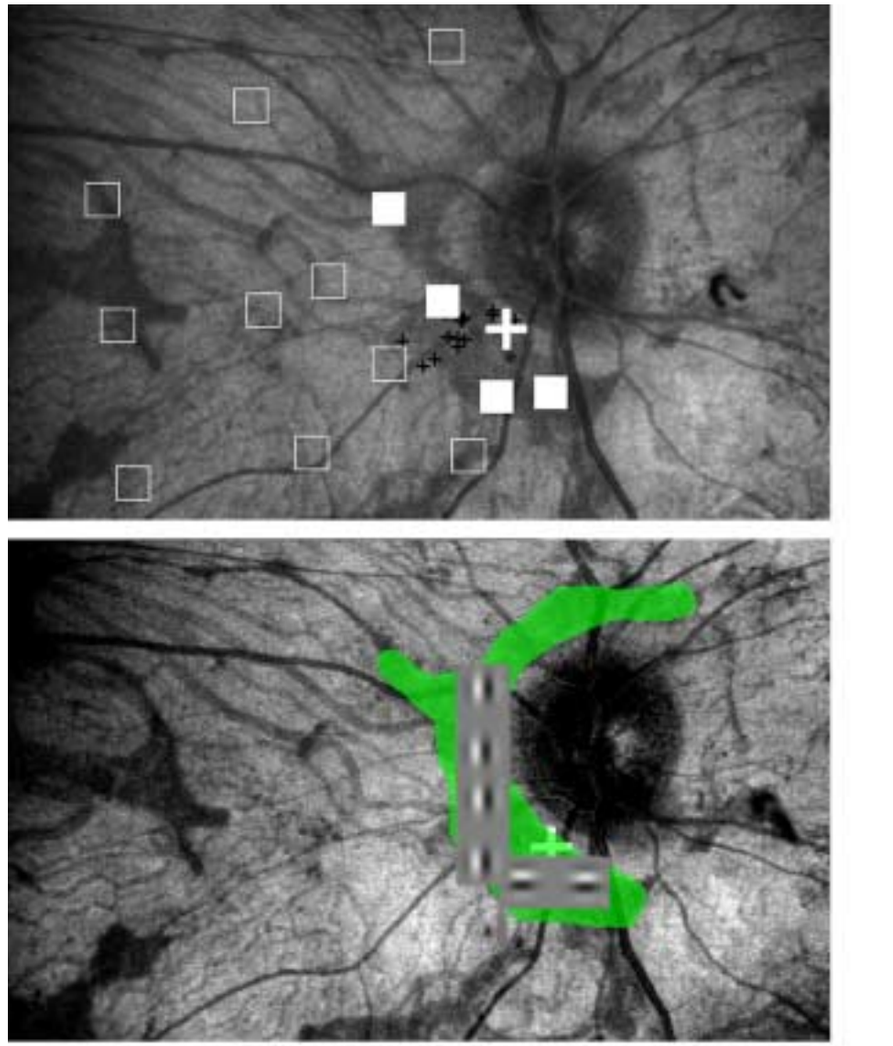
Purpose: 1 CFL subject (DS) performed an alternative task; 17.5° PRL

Task: Point or trace out the pathway on the screen with finger

Conditions: 0° Path Angle; SP and AP (50 images for each condition)

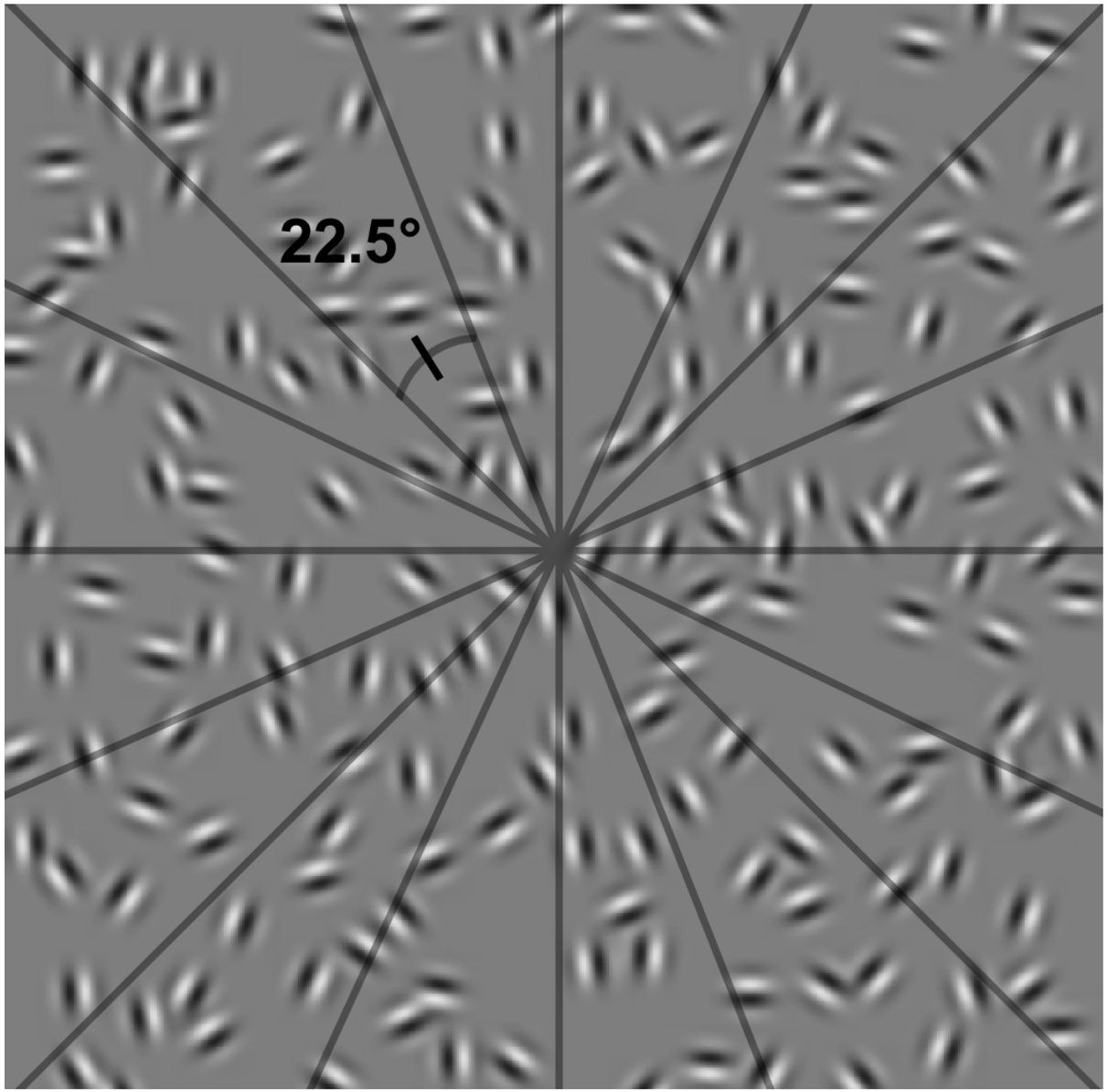
Methods:

- Presented an image containing path
- Image presented for 10 seconds
- 30cm viewing distance



Subject DS (Left Eye) Fovea →
Green area represents functional retina

EXP. 3B – RESULTS



- 8 distinct finger tracing directions – 22.5° increments
- 1/8 = 12% (Chance)
- Answer counted as correct only if reported/traced out correct path
- Subject DS correctly reported/traced out 48% SP and 44% AP

EXP. 3 – RESULTS SUMMARY

- All 3 CFL subjects were able to detect AP paths using their eccentric retinal fixation (PRL)

- PRL's were located beyond 10° eccentricity from fovea

- Subjects DG and RG did not perform significantly better than NV subjects at same eccentricities (DG slightly worse, RG slightly better)

CONCLUSIONS

- **Could not confirm Hess and Dakin's (1997, 1999) findings**
- **NV and CFL subjects were able to detect AP paths beyond 10° eccentricity (NV could up to 24°)**
- **No evidence of cortical reorganization or neural adaptation in CFL subjects using this paradigm**
- **Contour path detection, as with most visual functions, declines steadily with eccentricity, with the more difficult task (AP) declining faster.**

REFERENCES

Hess, RF and Dakin, SC (1997). Absence of contour linking in peripheral vision. *Nature* 390(6660): 602-4.

Hess, RF and Dakin, SC (1999). Contour integration in the peripheral field. *Vision Research* 39(5): 947-59.

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COMMENTS