More ups and downs of visual processing

M. W. Levine & J. J. McAnany

Department of Psychology
University of Illinois at Chicago

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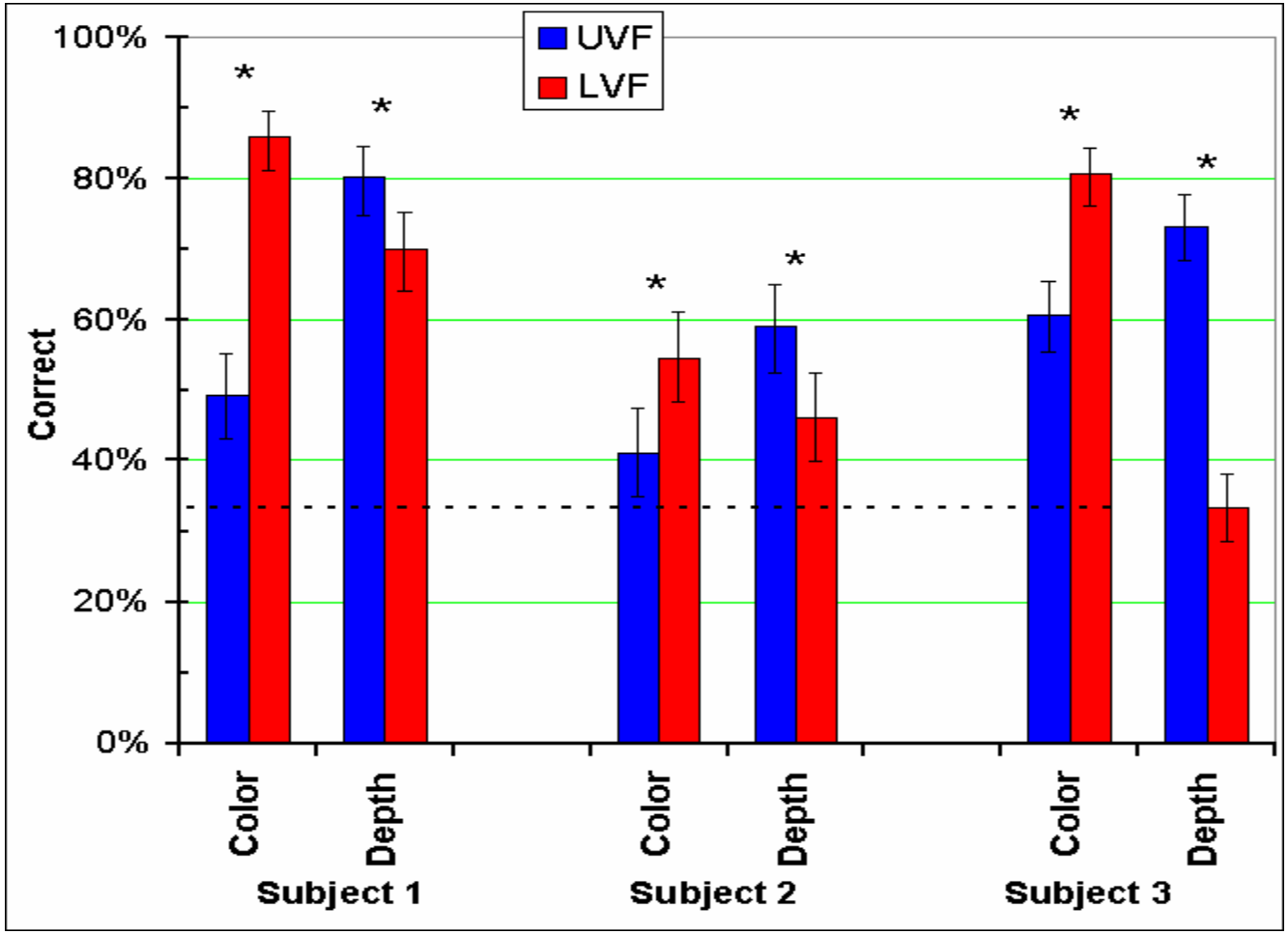
Upper and lower visual fields have different capabilities

- Hinted at in earlier publications and posters
- It was the topic of our poster at VSS 2004*
  - ✓ Test by presentation of a random array of disks, randomly placed in upper or lower field; those in one of three positions differ from all the rest
  - ✓ Performance in lower visual field (LVF) is better at color and contrast, and (perhaps) lateral motion
  - ✓ The upper visual field (UVF) is better at depth discrimination

**See Figure 1, in which color discriminations were interlaced with depth discriminations*

Figure 1: Upper and lower field differences



Performance in the upper and lower visual fields for stimuli that differ in color or in apparent depth. Results of three subjects with color and depth presentations randomly interlaced.

(* signifies UVF different from LVF with $p < 0.05$)

This poster asks whether the difference is due to dorsal *vs* ventral streams

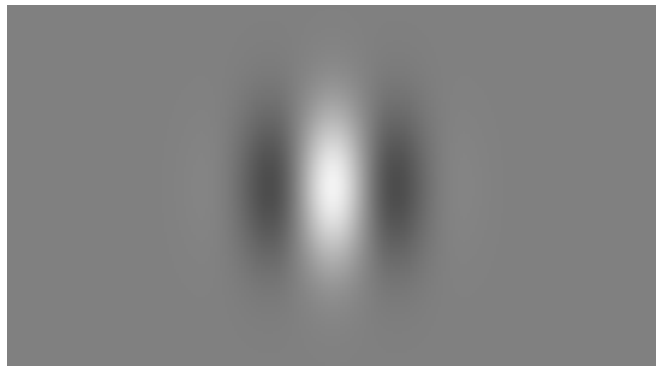
or

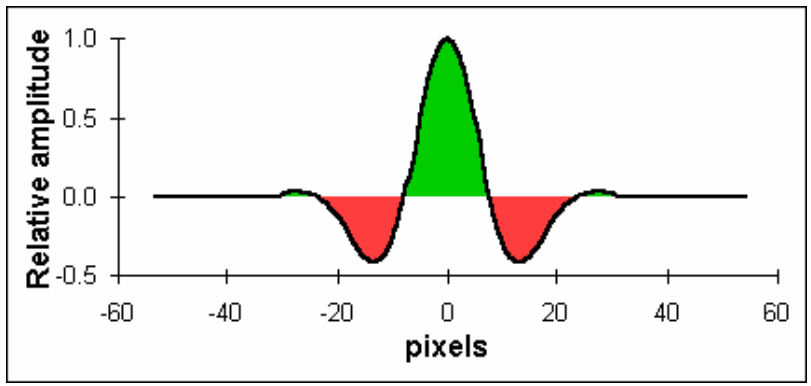
magnocellular *vs* parvocellular pathways

- Similar paradigm to before:
  - ✓ Three patterns appear 12° above or below fixation (at random); presentations are for less than 0.3 sec
  - ✓ Target pattern differs in orientation from the other two; Subject must choose which is different (3AFC)
  - ✓ Interlace two different patterns at random
  - ✓ 90 trials of each pattern (15 in each position)
- Two principal subjects (males), two additional subjects (one male, one female; overall age range 25 to 62)

Vary spatial frequency – use Gabor patches

- Gabor patches are sinusoids multiplied by a Gaussian function
- Typically, the Gaussian is centered on a peak (cosine phase)
- An example is to the right (Luminance *vs* position for a horizontal cut through the center shown underneath)

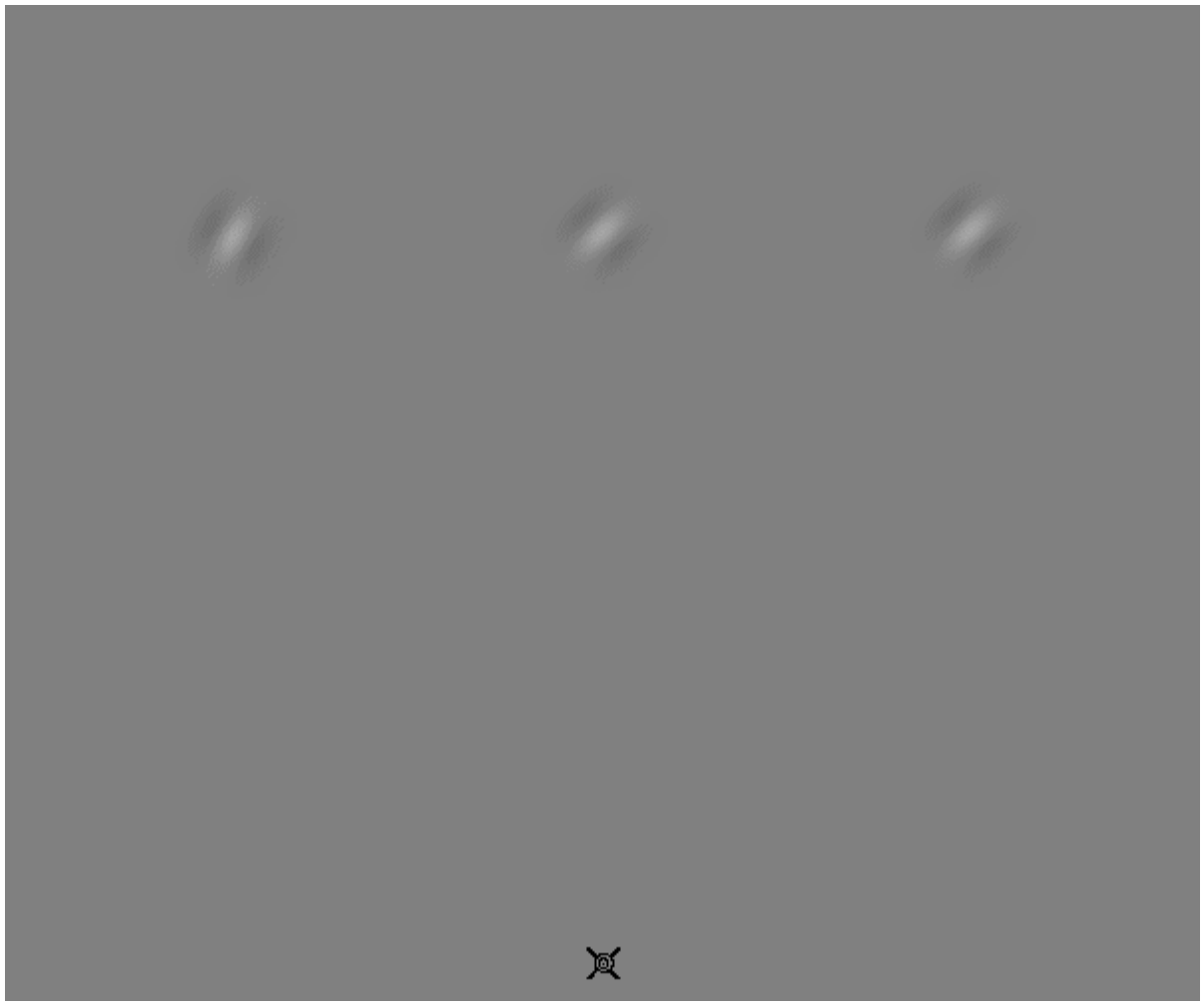




- All Gabor patches in this study were made with 30% contrast sinusoids (multiplied by 100% Gaussians) upon a 23.6 Cd/m^2 gray background

Example:

- The left patch is steeper; the other two are at 45°
- 45° used to avoid the natural ability to discern vertical or horizontal



(Note that the gray field actually extends equally far below the fixation point.)

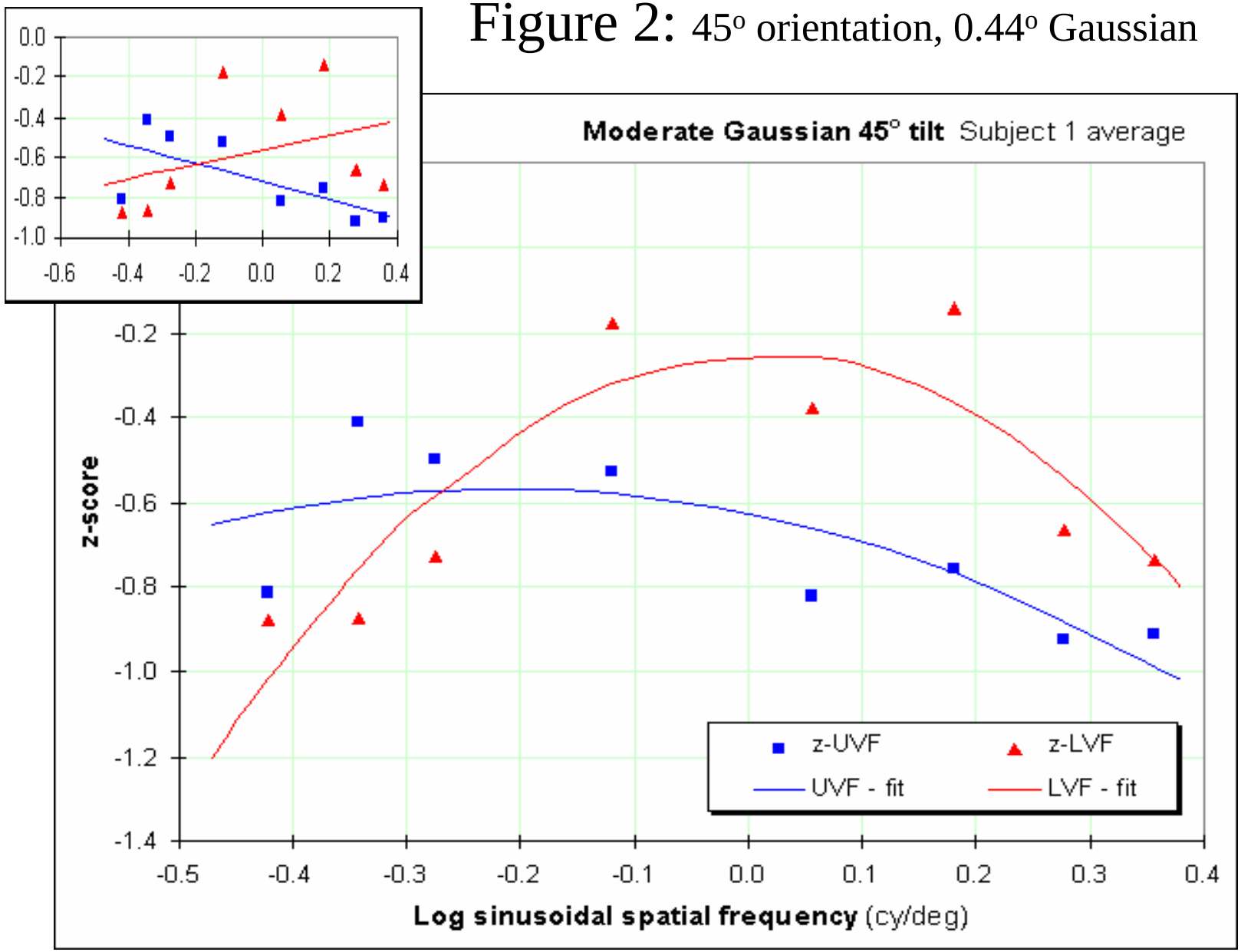
Results with 45° cosine Gabors

- Changing spatial frequency (but not the Gaussian window) changed the relative capabilities in the upper and lower visual fields
- As a rule, performance in the UVF was relatively better for low spatial frequencies; this was mainly because the LVF showed more improvement for moderately high frequencies
- Performance in both fields declined at the highest frequencies, even though the stimuli were visible
- Differential effect of spatial frequencies can be seen in parabolic fits to the data (Figure 2) or by linear regression (inset). Similar for Subject 2.

z-scores were used in place of raw percentages so that cumulative normal functions would plot as straight lines. *z*-scores were derived from fraction correct (3AFC) by

$$z = (fraction - 1/3)3/2$$

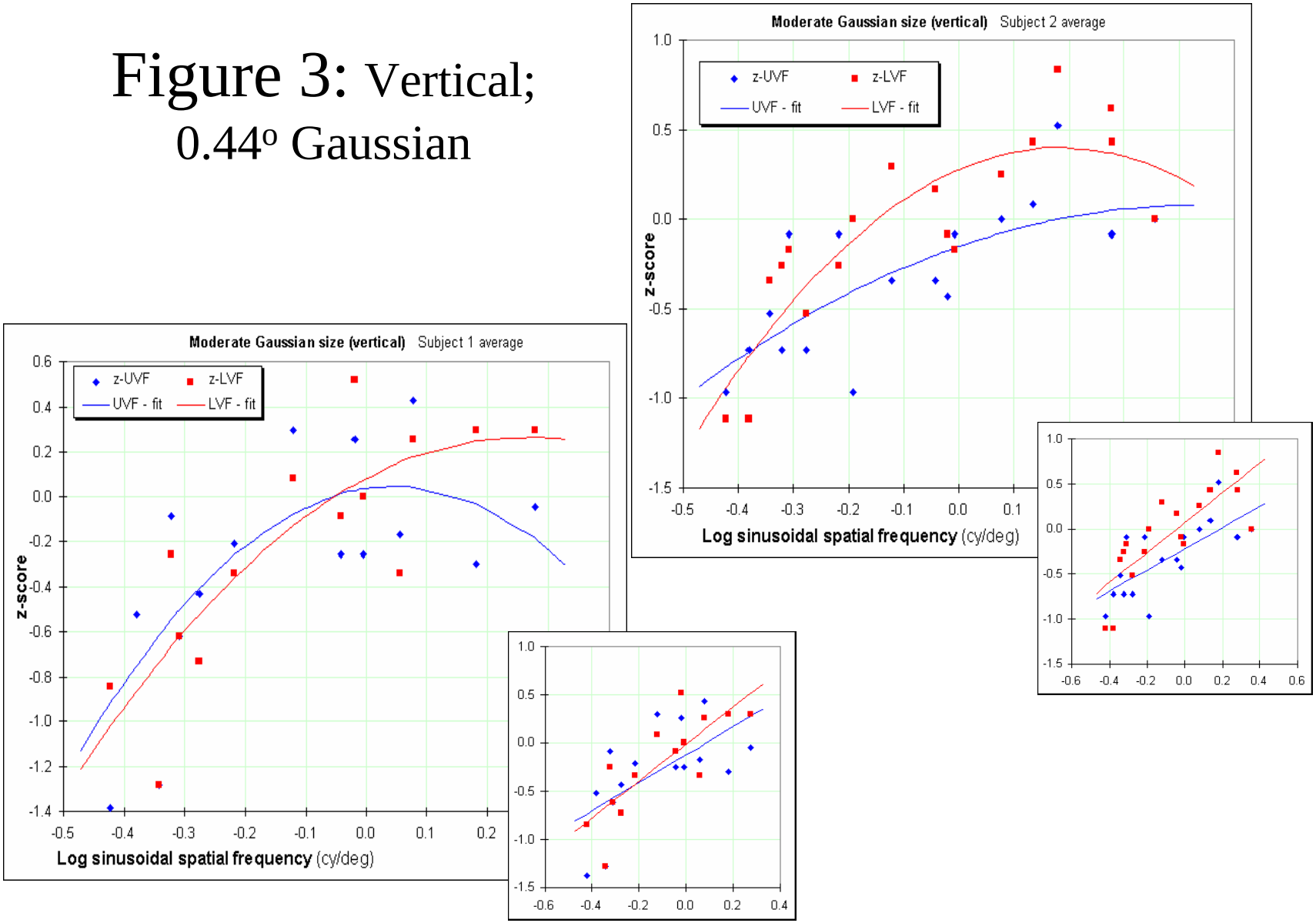
Figure 2: 45° orientation, 0.44° Gaussian



Results with vertical cosines

- Vertical orientations easier to compare because of our natural oblique effect
- Results very similar to diagonal orientations – perhaps a bit less variable, with a slight improvement in sensitivity
- Differential effect of spatial frequencies can be seen in the parabolic fits to the data (Figure 3) or by linear regression (insets)

Figure 3: Vertical; 0.44° Gaussian



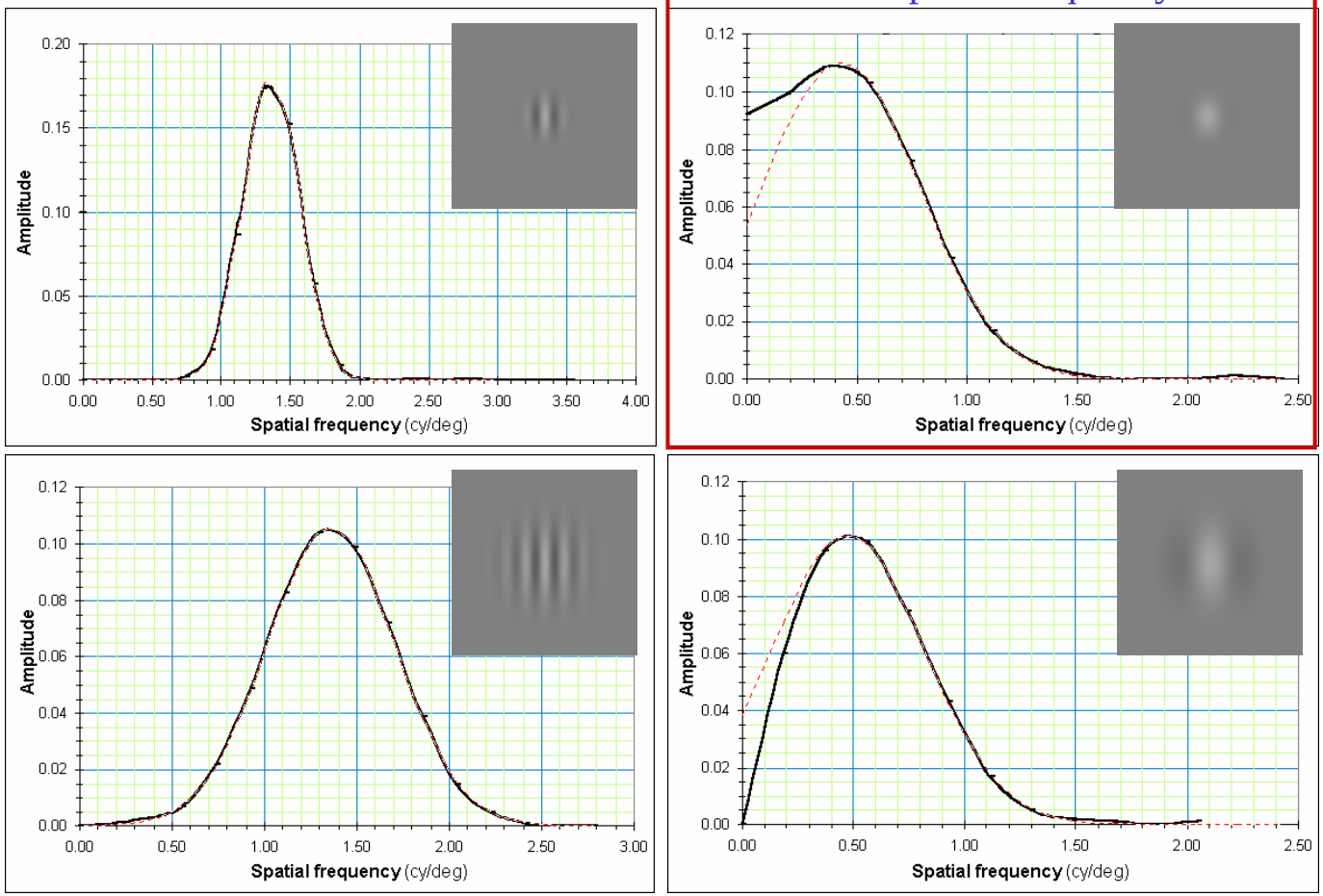
Problem: at low spatial frequency, the spectrum wraps "negative" frequencies

High spatial frequency

Low spatial frequency

Medium Gaussian window (Standard deviation ≅ 0.44 degrees)

Larger Gaussian window (Standard deviation ≅ 0.76 degrees)



*The dashed red curve is a Gaussian at the central frequency; the **solid black** curve is the actual spectrum*

Results with larger Gaussians

- Larger Gaussians have narrower bandwidth and less low frequency “clutter”
- Results very similar to what was found with smaller Gaussians
- Test all four subjects with 280 ms presentations of vertical cosine Gabors; Standard deviation = 0.81 degrees.
- Differential effect of spatial frequencies can be seen in the parabolic fits to the data (Figure 4 and Figure 5) or by linear regression (insets)

Figure 4: Vertical; 0.81° Gaussian

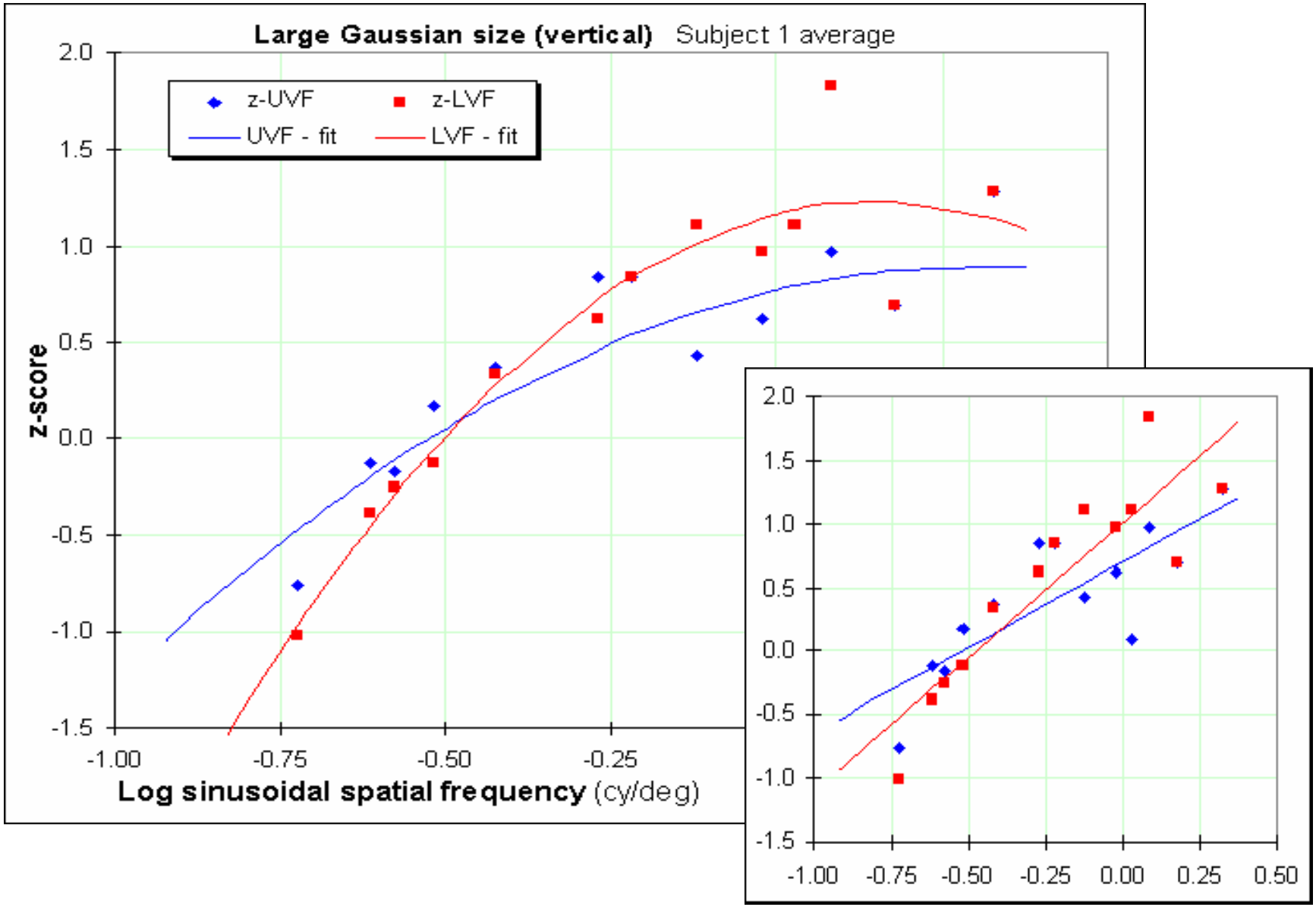


Figure 5: Vertical; 0.81° Gaussian

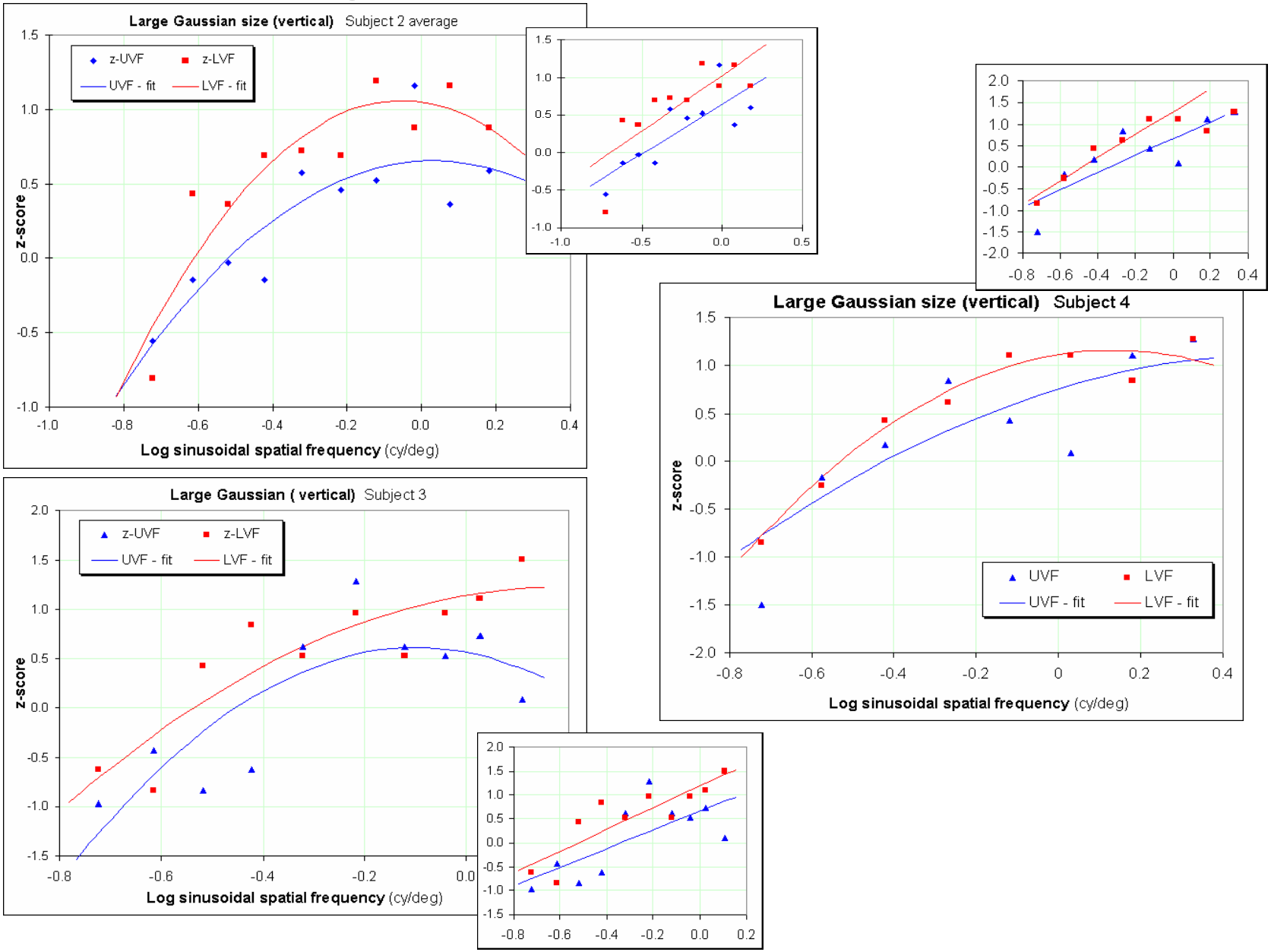
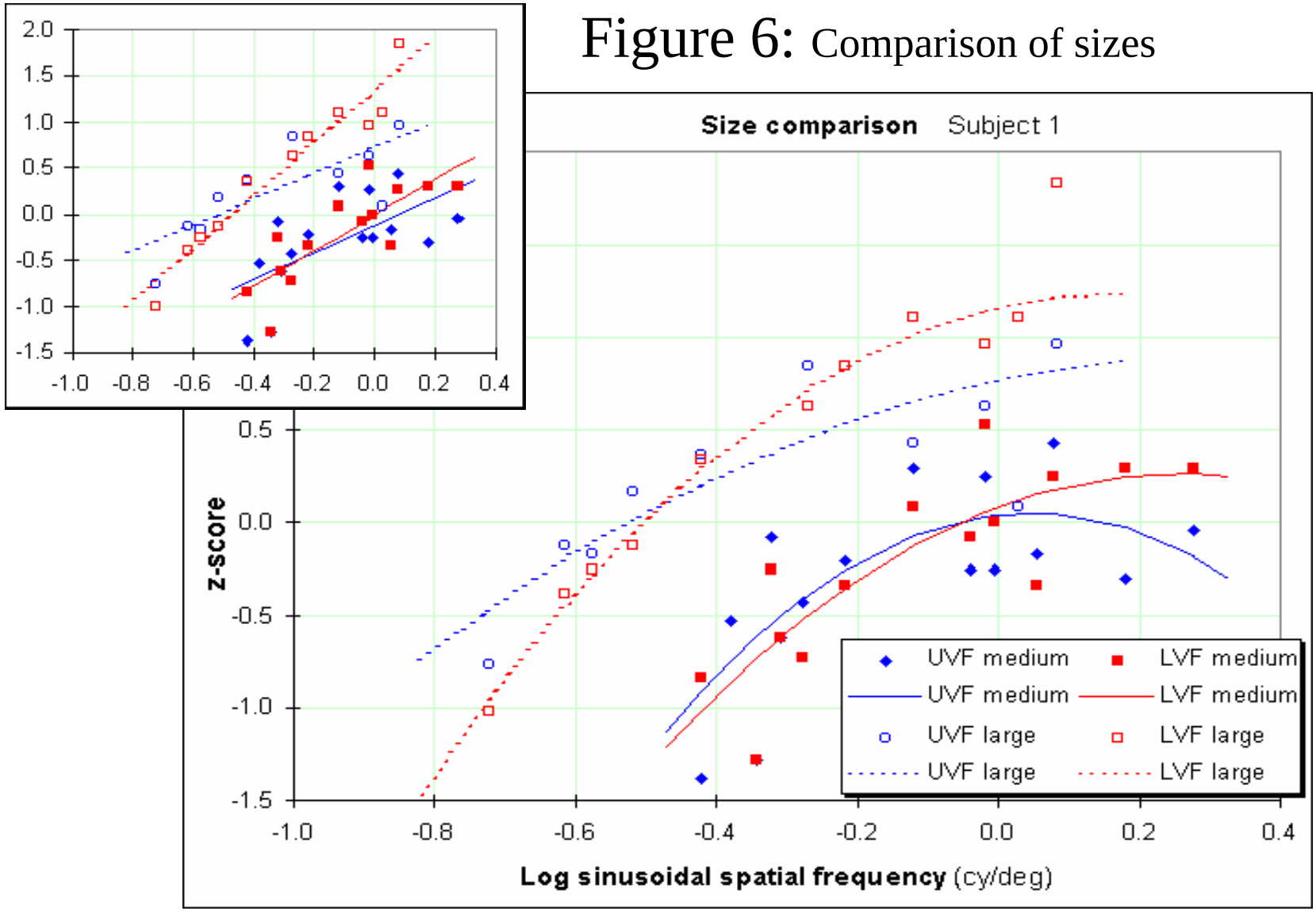


Figure 6: Comparison of sizes



Change in size seems to cause a shift in sensitivity for each field.

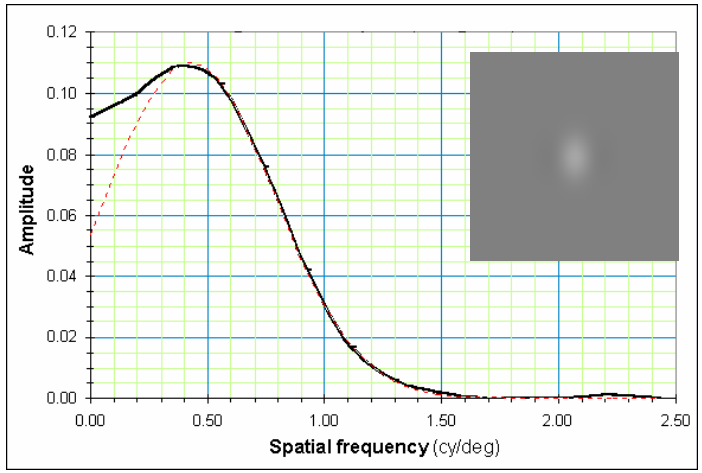
Comparison of 0.81° Gaussian to 0.40° Gaussian standard deviations

Another test for frequency: sine phase Gabors

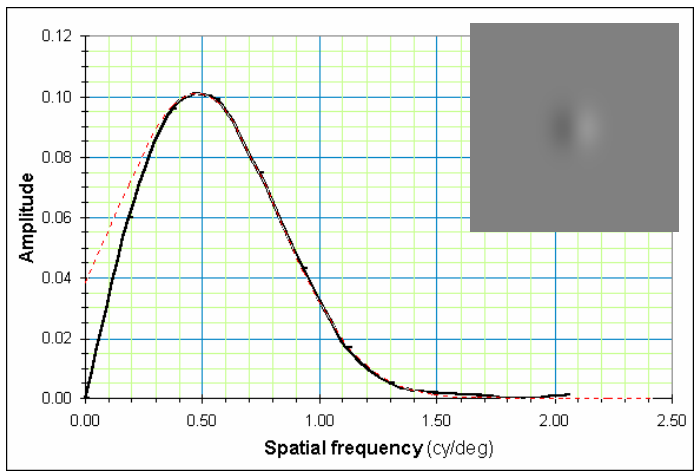
- In sine phase, the lowest frequencies are ***reduced***, rather than enhanced

(Comparisons shown for 0.44° Gaussian standard deviations)

Cosine phase



Sine phase



Results with sine phase Gabors

- Performance in both fields declined at the highest and the lowest frequencies
- As with cosine phase, performance in the UVF was better (relative to LVF) for low spatial frequencies
- Examples are shown for two subjects in Figures 7 & 8 (Gaussian standard deviation = 0.81 degrees)

Figure 7: Sine *vs* cosine (0.81° Gaussian)

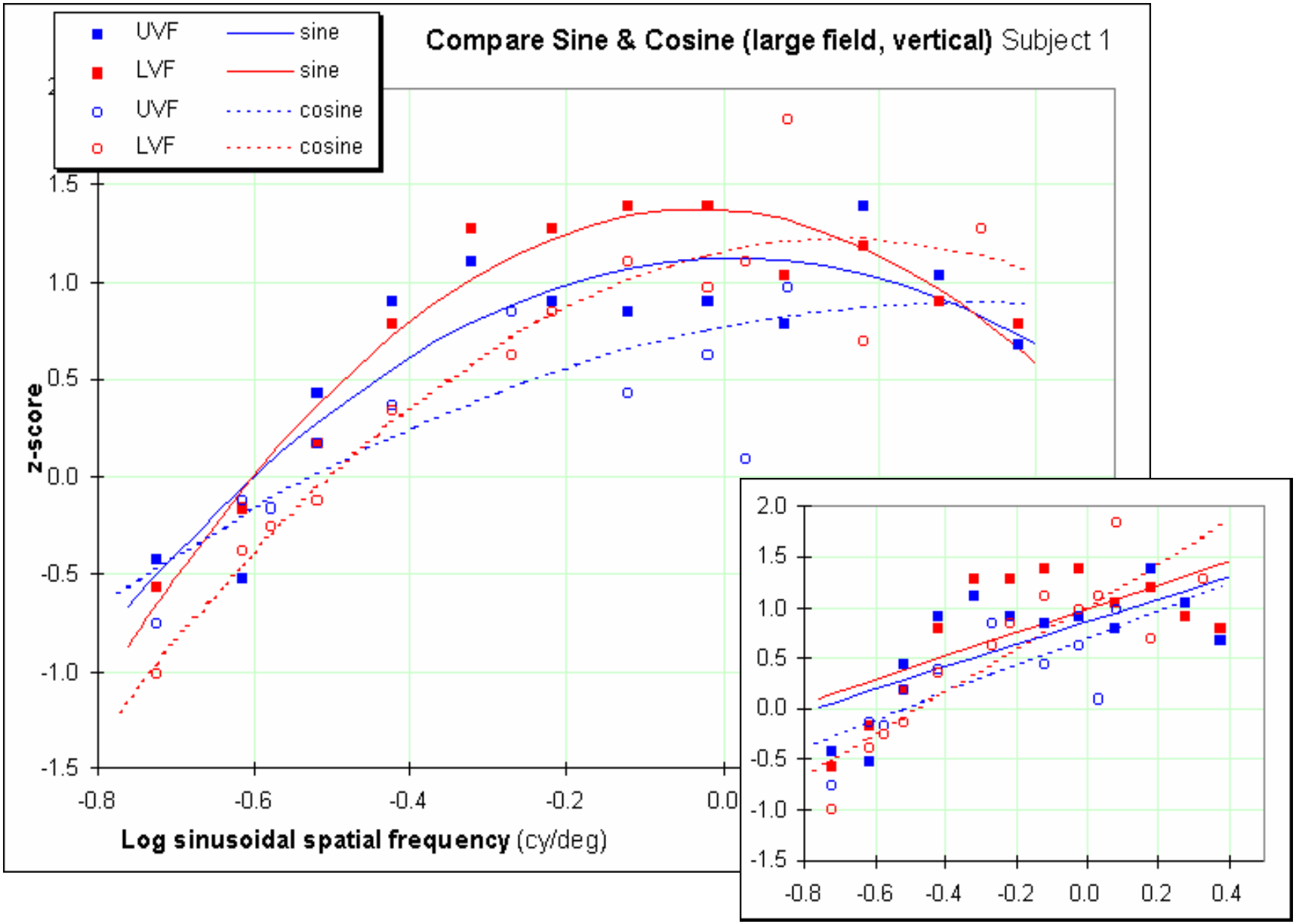
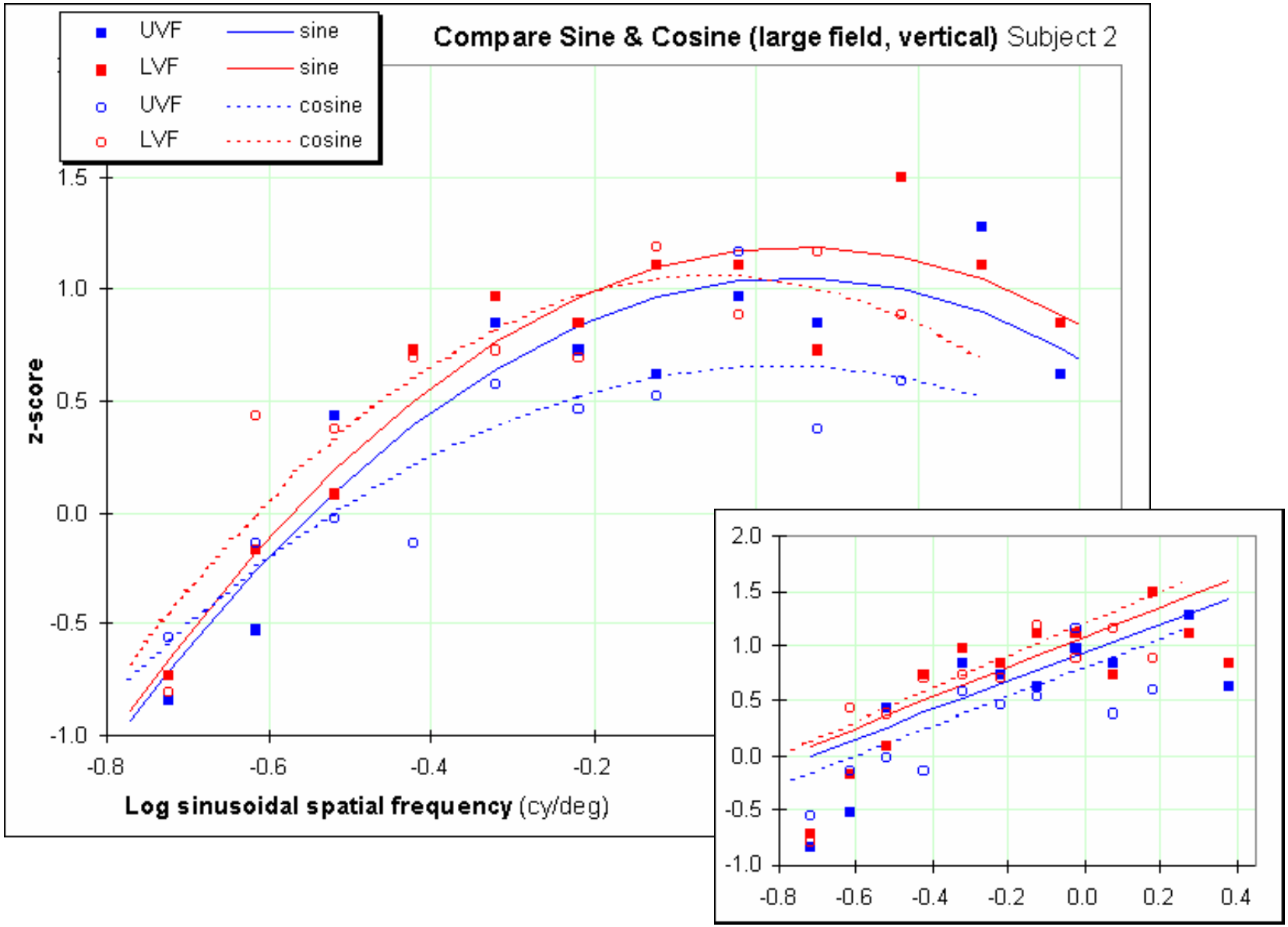


Figure 8: Sine *vs* cosine (0.81° Gaussian)



Comparison of sine and cosine phase Gabors

- Figures 7 to 9 show the results of sine phase Gabors (solid functions) compared to cosine phase with the same Gaussian size (standard deviation = 0.81 degrees in Figures 7 & 8; 0.40 in Figure 9)
- The added low frequencies in the cosine phase boost the UVF function for cosine phase (dotted blue)
- Spectra of sine and cosine phase Gabors with a standard deviation of 0.81 degrees are shown for representative spatial frequencies in Figure 10

Figure 9: Sine *vs* cosine with interlaced trials (0.40° Gaussian)

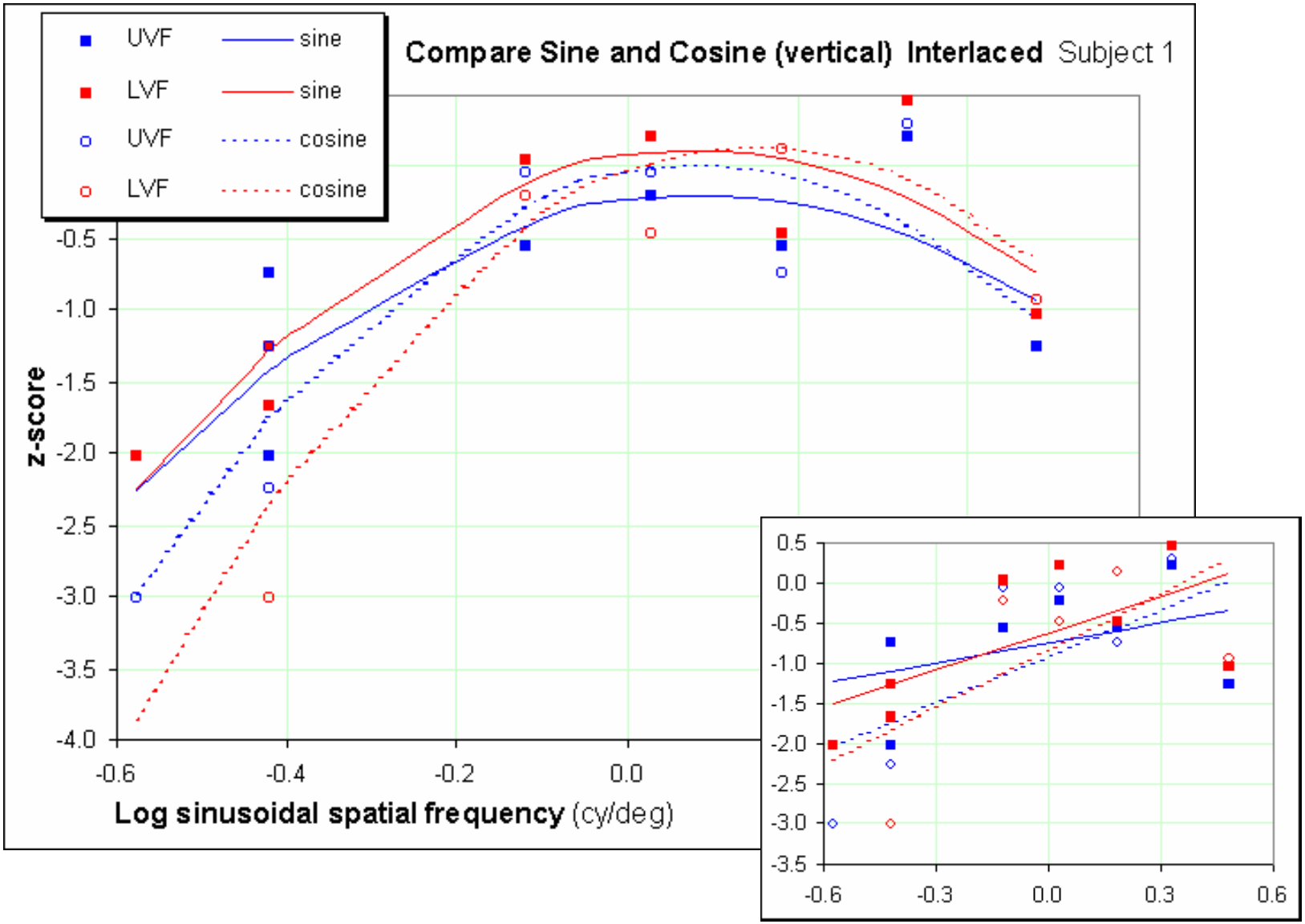
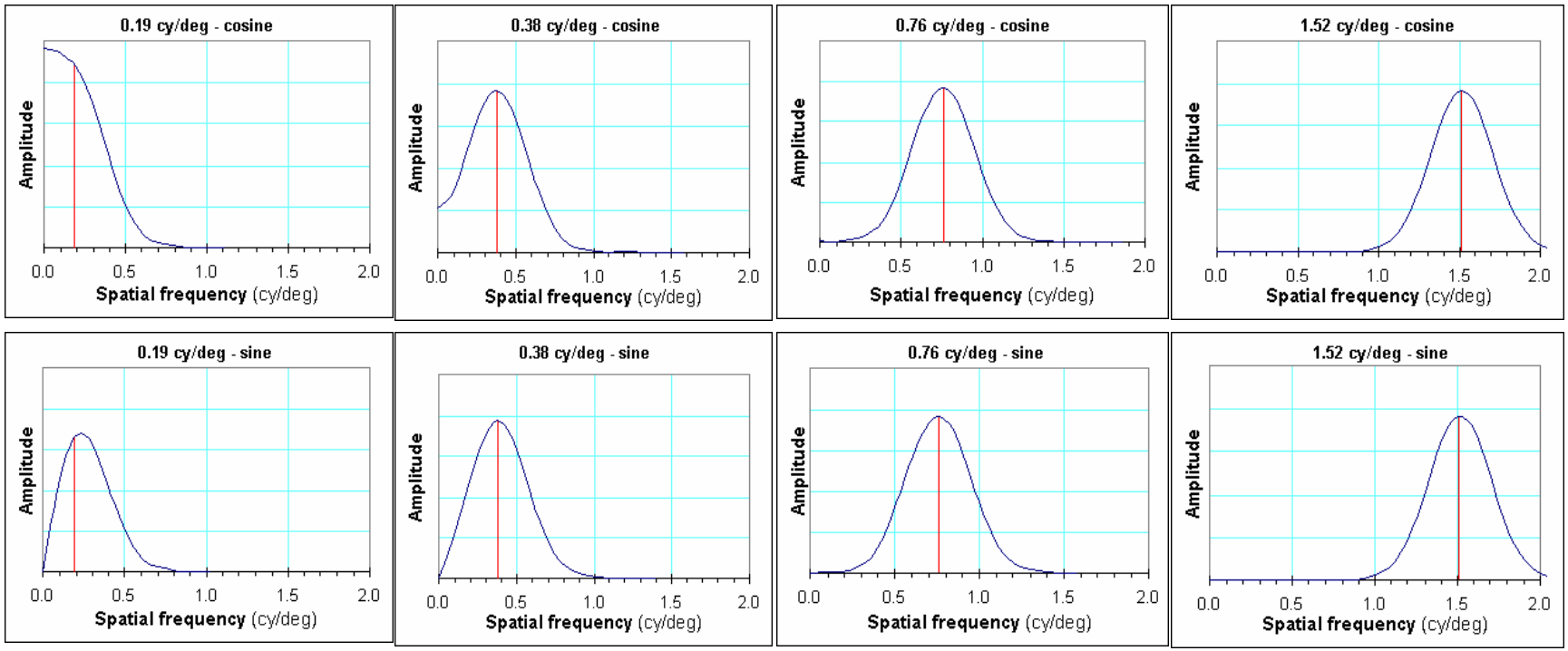
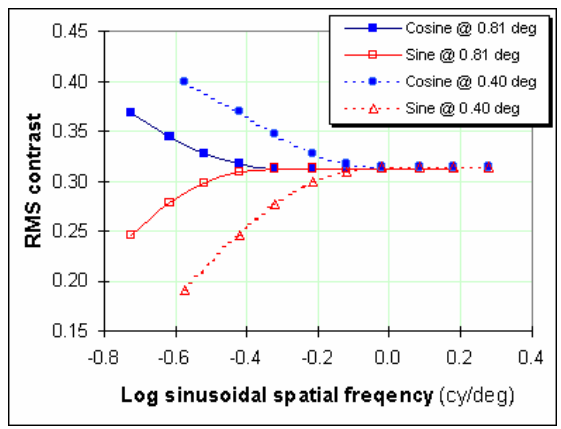


Figure 10: Spectra of sine and cosine functions in Figures 7 & 8

-.72 Log cy/deg **-.42 Log cy/deg** **-.12 Log cy/deg** **0.18 Log cy/deg**



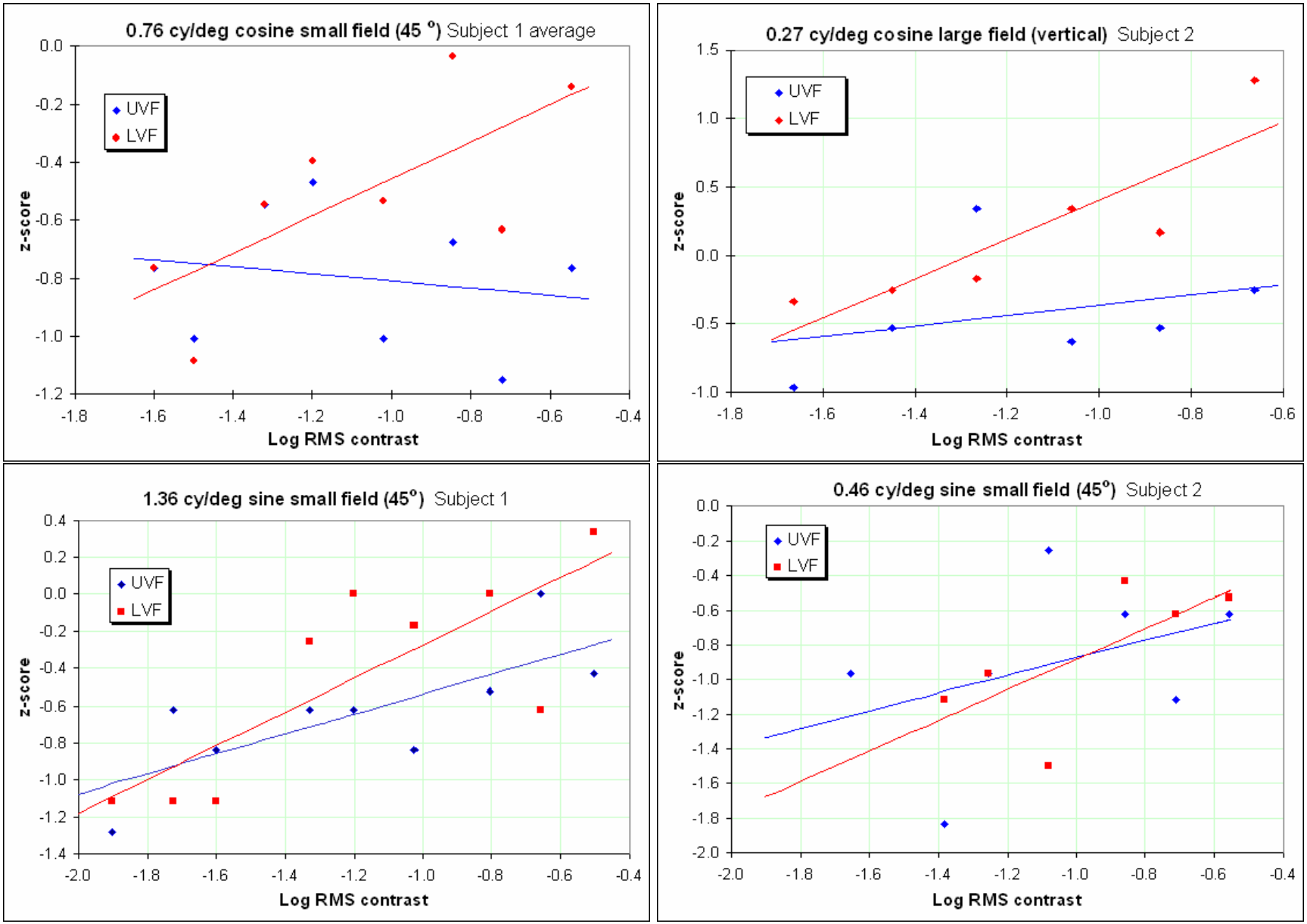
- Red lines indicate the sinusoidal spatial frequency (listed at the top in log units)
- Cosine phase is in the top row, sine phase in the 2nd
- All spectra are on the same scale; all refer to the larger Gaussian standard deviation (0.81 degree)
- RMS contrasts for both sizes are shown to the right



Could this simply be due to ganglion cell densities?

- Density of ganglion cells is greater in the superior retina (LVF). If coverage is the same, the spatial frequency response function would be shifted to higher spatial frequencies in the LVF, accounting for the shift in preferences
- To test for this, we performed the same tasks at various contrast levels; the gain with contrast should be the same for UVF and LVF if there were a simple shift of peak sensitivity
- The LVF shows a steeper rise with contrast than the UVF, so this is not a simple shift of preferred spatial frequency (see examples in Figure 11)

Figure 11: Effects of contrast



Conclusions

- The UVF and the LVF differ **slightly** in their spatial frequency preferences for detecting differences in orientation; the LVF gains greater advantage at moderately higher spatial frequencies
- At high spatial frequencies, ability to discriminate orientation deteriorates in both fields
- This is consistent with a slightly stronger magno-cellular contribution to the UVF, and a slightly stronger parvocellular contribution to the LVF
- It is unlikely that these effects are because the LVF contrast sensitivity function is shifted to higher spatial frequencies; the effect of contrast is not the same for both fields