DYNAMICS OF CONTOUR INTEGRATION

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(For more info: http://www.psych.mcgill.ca/labs/mvr/William/PROJECTS/Dynamics.html)

PURPOSE

We previously investigated the dynamics of contour integration by measuring reaction times for path integration as function of contrast, curvature & chromaticity [3]. In the present work we determined the dynamics of contour integration by varying the temporal properties of the individual elements in a stimulus composed of arrays of randomly oriented Gabors, as well as those of the contour they form. We measured the dependency of its temporal resolution on contrast and curvature.

METHODS

The task requires the linking of orientation across space to detect a 'path' [1]: stimuli were arrays of oriented band-pass elements (Gabor patches of 1.5 cpd, = 0.17 deg) randomly positioned within a 14 x 14 degree square grid, in which 10 adjacent elements were aligned along a path. Path curvature is defined as the angle difference between adjacent path elements. Paths with low curvatures are relatively straight, and paths with high curvatures are more snaky. Stimuli were generated in real-time on a Cambridge Research Systems VSG 2/4 with 15 bits of resolution.

Path detection was measured using a temporal 2AFC method of constant stimuli with path and no-path intervals, and with a 500 ms inter-stimulus interval. Path curvature and elements contrast were varied in all experiments. Feedback was given after each trial, and a black fixation mark appeared in the centre of the stimuli. Subjects were 3 experienced observers with normal, or refracted to normal vision. All experiments were done under binocular conditions.

EXPERIMENTS

In experiment 1, we looked at path detection as a function of stimulus duration. The path stimulus was masked before and after with a no-path stimulus identical to the test stimulus but with random orientation of its individual elements.

In experiment 2, we measured the effect of this temporal modulation of orientation of the individual elements as a function of temporal frequency. The path and no-path stimuli were presented cyclically for 1 s modulated by a temporal Gaussian window.

In experiment 3, we looked at the effect of temporally modulating the contrast of all the individual elements under spatial in-phase and out-phase conditions.

RESULTS

These experiments reveal the dynamics of contour integration:

1) while these dynamics are quite poor when the contour linking per se is modulated in time (below 12 Hz), they are better (10-30 Hz) when the contrast of the individual elements is modulated in time;

2) the temporal resolution of contour integration is best for straight paths (6-12 Hz), and declines for more curved paths falling to 1-2 Hz, and

3) is not dependent on the absolute contrast of the linking elements so long they are visible.

CONCLUSIONS

Contour integration is:

1) significantly slower than contrast integration,

2) slower for curved than for straight paths, compatible with our previous results on reaction times [3].

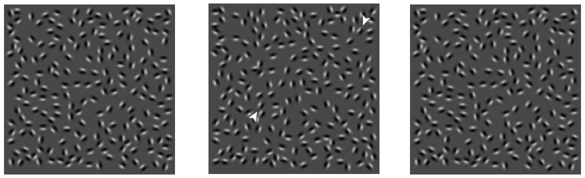
This is consistent with a two-stage model: a fast contrast integration stage followed by a slow orientation linking stage. Moreover, since it is unlikely that contours of different curvatures are each detected by dedicated detectors [2,3], we suggest that path detection could arise from a dynamic process intrinsically tuned to straight paths and temporally evolving to match the spatial properties of the path [3,4]. Such a process is likely to depend on intra- and extra-cortical feedback known to be important in contextual modulation.

References

1. Field DJ, Hayes A, Hess RF (1993) *Contour integration by the human visual system: Evidence for a local "Association Field"*. Vis. Res. 33(2), 173-193.
2. Mullen KT, Beaudot WHA, McIlhagga WH (2000) *Contour integration in color vision: A common process for the blue-yellow, red-green and luminance mechanisms.* Vis. Res. 40(6), 639-655.
3. Beaudot WHA, Mullen KT (submitted) *Processing time of contour integration: The role of color, contrast and curvature*. (cf. Beaudot & Mullen, ARVO'99, S809)
4. Hess RF, Beaudot WHA, Mullen KT (submitted) *Dynamics of contour integration.*

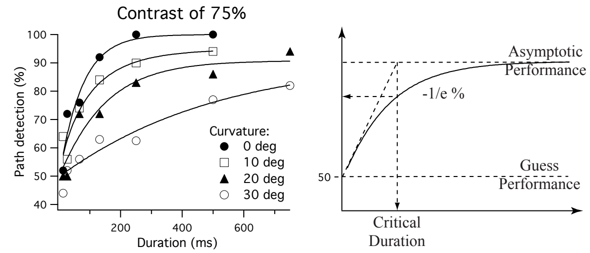
EXPERIMENT 1: Effect of Duration

STIMULI SEQUENCE

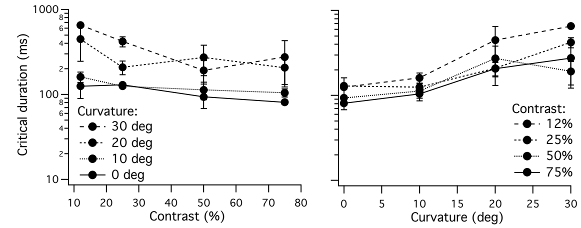


Forward Mask (500 ms) | Test (variable duration) | Backward Mask (500 ms)

PATH DETECTION AS A FUNCTION OF CONTRAST & CURVATURE



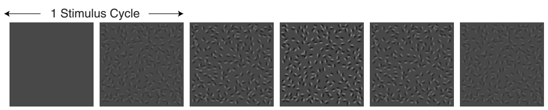
CRITICAL DURATIONS FOR CONTOUR INTEGRATION



Contour integration requires at least 80 ms of stimulus processing. This critical duration for contour linking:
i) is strongly affected by orientation masking,
ii) increases significantly with curvature,
iii) shows little dependence on contrast.

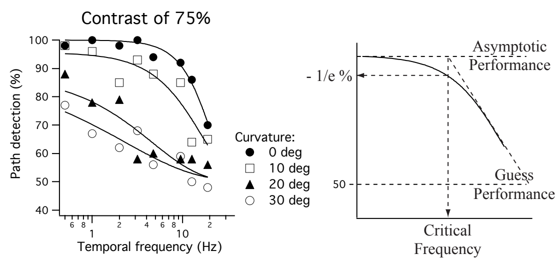
EXPERIMENT 2: Effect of Orientation Modulation

STIMULI SEQUENCE

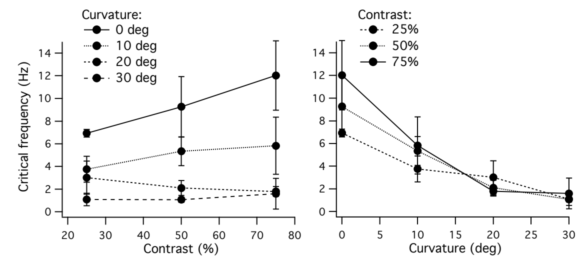


Critical frequency for contour linking:
i) decreases significantly with curvature,
ii) does not benefit from a multi-shot presentation,
iii) shows little dependence on contrast.

EFFECT OF TEMPORAL FREQUENCY

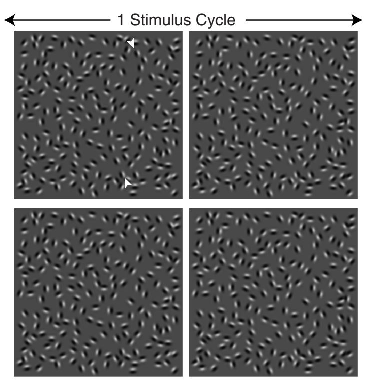


CRITICAL FREQUENCY



EXPERIMENT 3: Effect of Contrast Modulation

STIMULI SEQUENCE

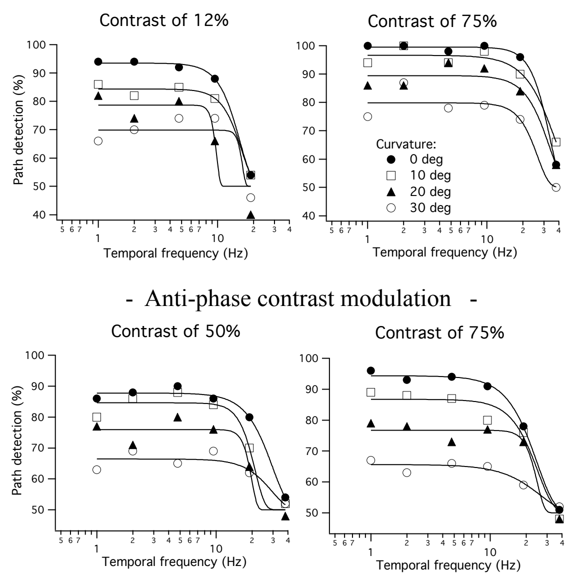


Spatial In-phase Condition

Spatial Anti-phase Condition (path elements alternate in their contrast polarity)

Critical frequency for contrast integration of contour elements:
i) increases significantly with contrast,
ii) is not affected by curvature & spatial phase,
iii) is much higher than critical frequency for contour linking.

EFFECT OF TEMPORAL FREQUENCY



CRITICAL FREQUENCY