Interactions of Local Motion Signals

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Motivation and Background

Motion signals are a rich source of information used in many everyday tasks, such as segregation of objects from background, and navigation. Motion analysis is generally considered to consist of two stages: extraction of local motion signals, followed by spatial integration. Studies using synthetic stimuli show that there are many kinds and subtypes of local motion signals. When presented in isolation, these stimuli elicit behavioral and neurophysiological responses in a wide range of species, from insects to mammals. However, these mathematically-distinct varieties of local motion signals typically co-exist in natural scenes (Nitzany & Victor 2014).

This study focused on interactions between two kinds of local motion signals: Fourier (F) and Glider (G). F signals (Reichardt, 1961) are typically associated with translation, while G signals (Hu&Victor, 2010) occur when object looms or recedes.

Here, using a novel class of synthetic stimuli, we expand our previous study (SFN 2014) and ask:

- How do distinct kinds of local motion signals interact?
- Does context influence sensitivity to local motion signals?

Methods

Visual stimuli

- Movies: 1-sec clips containing one or two kinds of local motion signals
- Each movie:
  - 10 frames, 100 ms each
  - Frames: 20 x 30 array of black and white checks
  - Check size: 0.45 x 0.45 degrees
  - Fixation aid: movies preceded and followed by central red X on gray background for some subjects; chin-mount was used for some subjects
  - Motion direction: randomly right or left

Task: Determine the direction of motion (two-alternative forced choice).

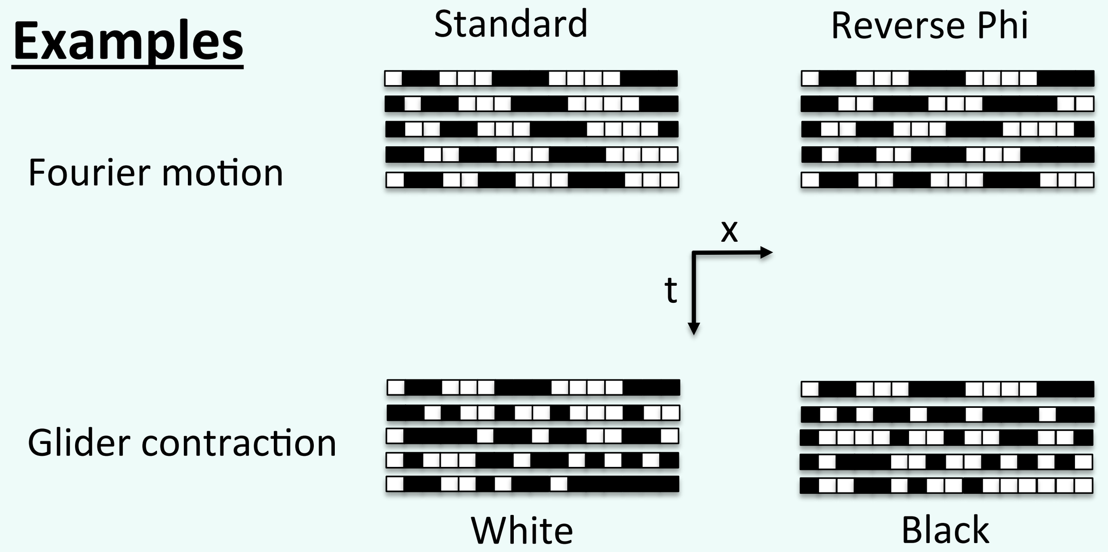
Stimulus construction

We synthesized stimuli that combined two kinds of motion signals: Fourier (F) and Glider (G). Each motion signal corresponds to a correlation rule inside a space-time template of checks (see table). For F motion, the template is a pair of checks on a diagonal line in space-time. For G motion, the template consists of three checks in a spatiotemporal triangle. Short XT-slices of standard Fourier motion and Glider contraction, at maximum strength, are shown below. Stimuli with intermediate strengths are shown at the bottom of the column to the bottom right.

Motion signal types

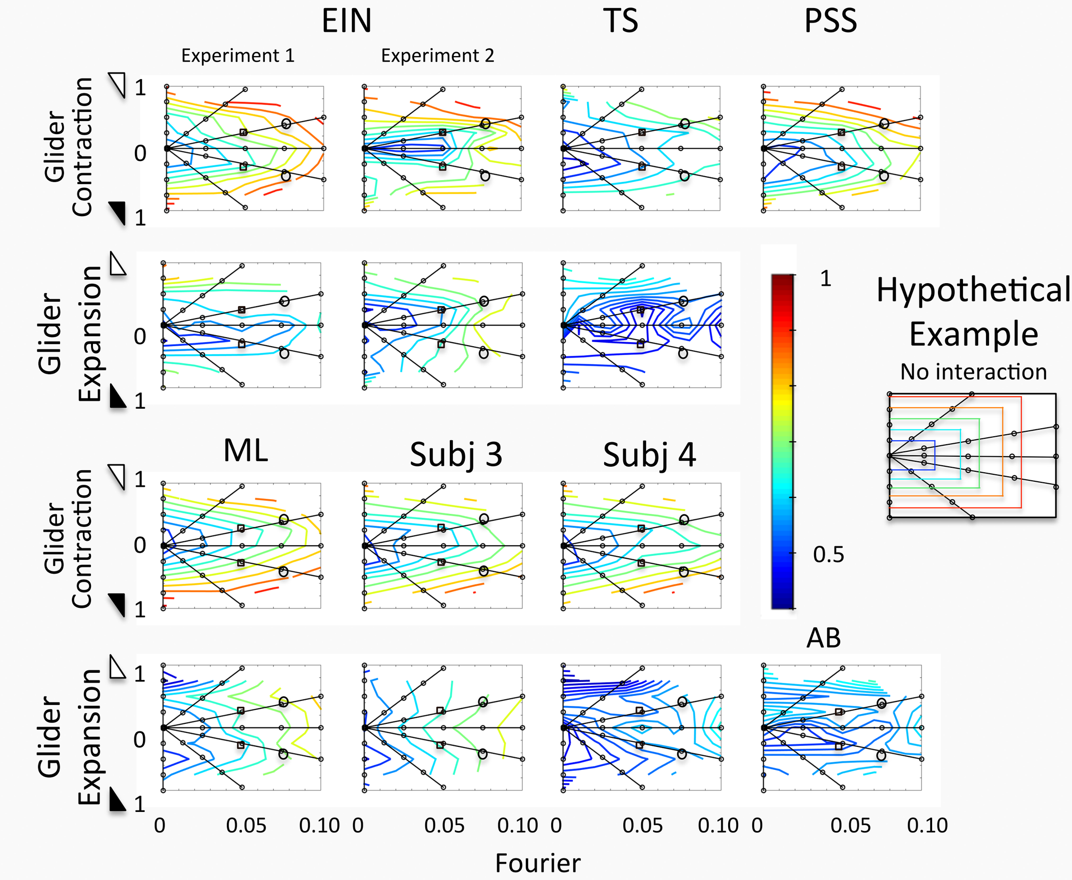
Kind	Subtype	Template	Subtype	# black	# white
2-point (Fourier)			Standard Reverse phi	0 or 2 1	0 or 2 1
3-point (Glider)	Expansion		Black exp. White exp.	1 or 3 0 or 2	0 or 2 1 or 3
	Contraction		Black cont. White cont.	1 or 3 0 or 2	0 or 2 1 or 3

Examples



Experimental Results

Psychophysical performance



- Accurate performance at maximal strength for mixtures of F and G contraction, but not for mixtures of F and G expansion
- Consistent with previous studies .
- Reduced sensitivity to F motion signals in expansion context

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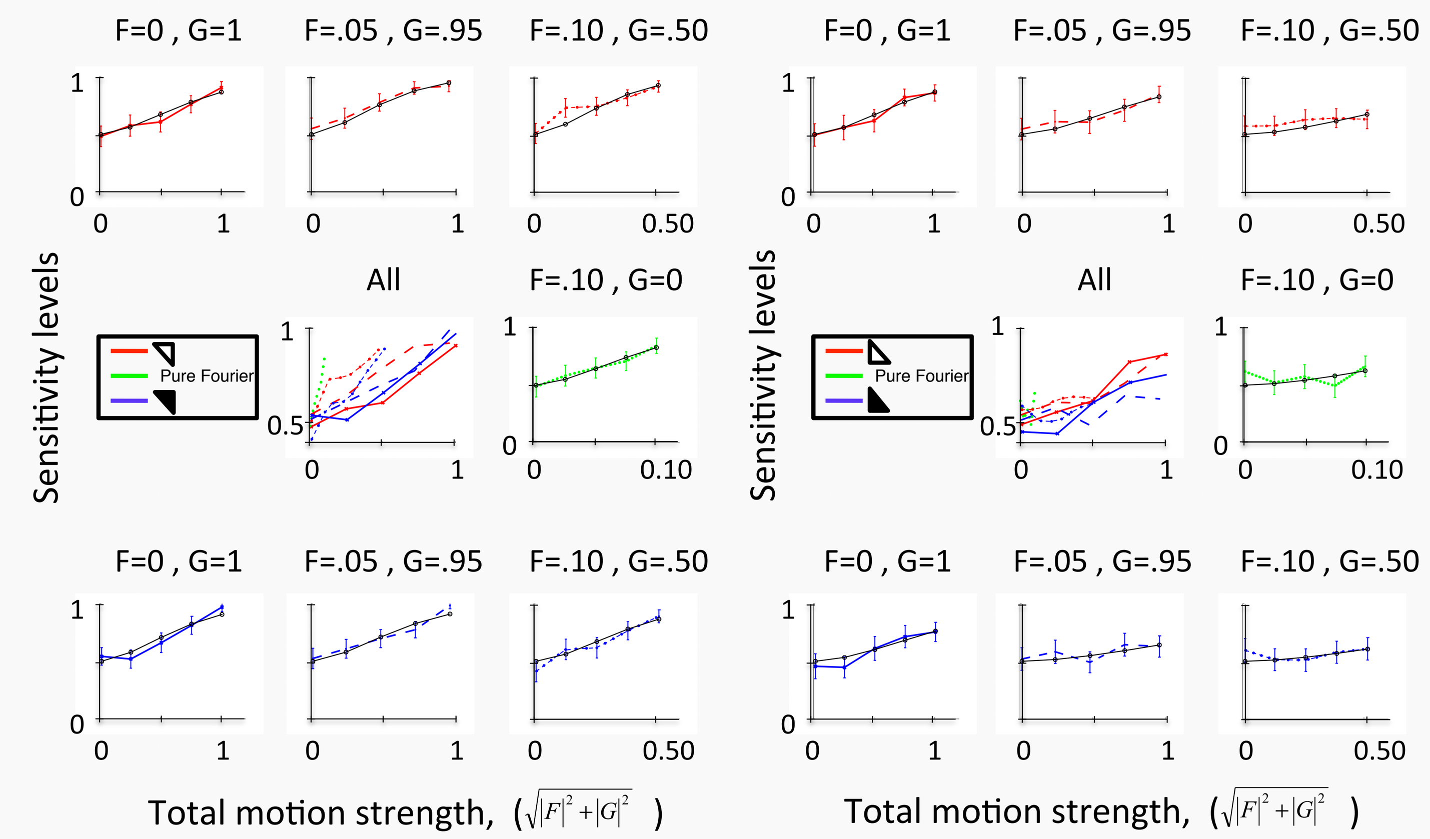
Determination of Thresholds



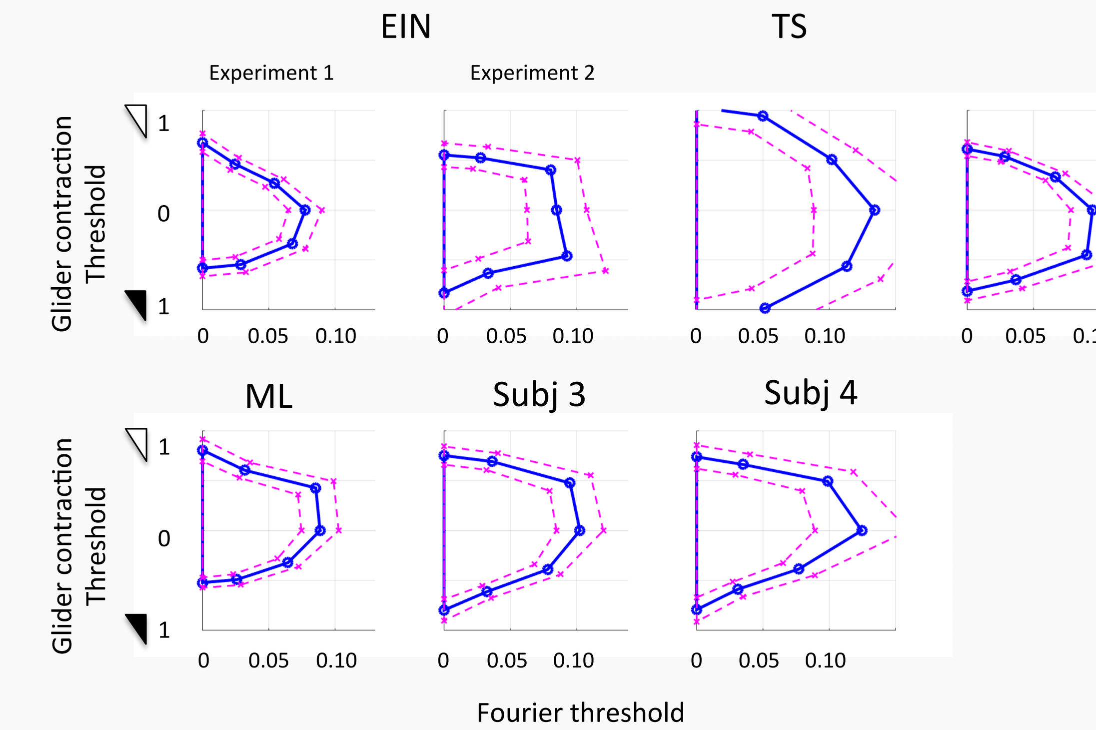
- A Weibull function with exponent 2 yields a good fit
- Fourier sensitivities are approximately 10-fold greater than Glider

Psychometric function

$$Fraction\ correct = \frac{1}{2} + \frac{1 - 2^{-(x/\alpha)^2}}{2}$$

Isodiscrimination contours (G Contraction)

(fraction correct = 0.75)



- For mixtures of F and G contraction, fraction correct increases when motion signals are combined

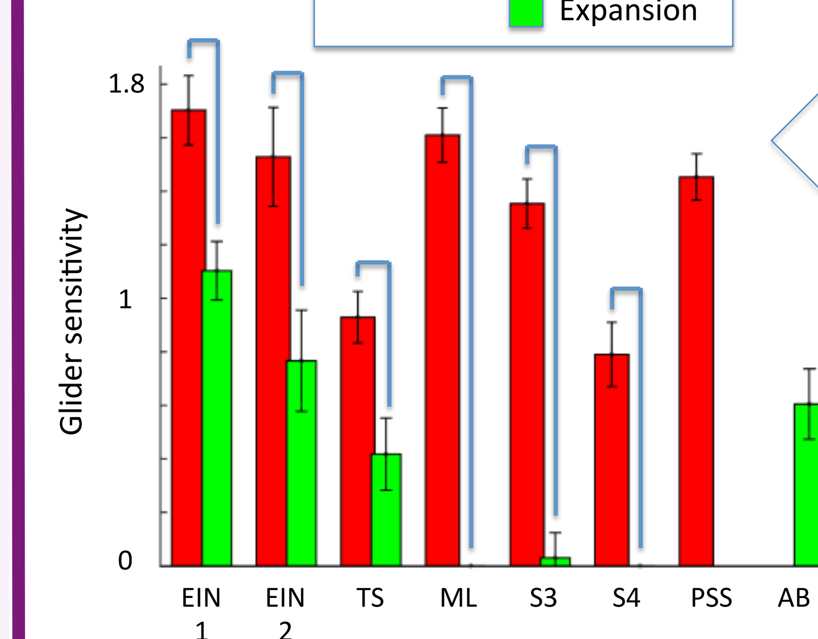
Setup

- 7 ratios of motion signal strengths :
  - Pure Fourier
  - Pure Glider black
  - Pure Glider white
  - 4 mixtures of Fourier and Glider
- 5 strength points along each of the above rays

Rays (Maximum percentage levels)

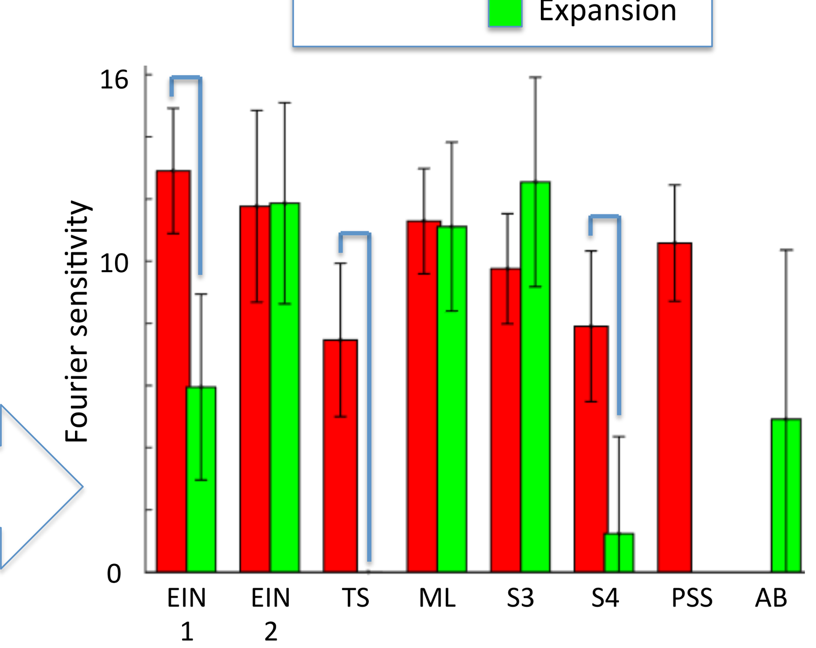
	% Fourier	% Glider (cont./exp.)
Glider Black	0	100
	5	95
	10	50
Pure Fourier	10	0
	10	50
Glider White	5	95
	0	100

Comparing sensitivities



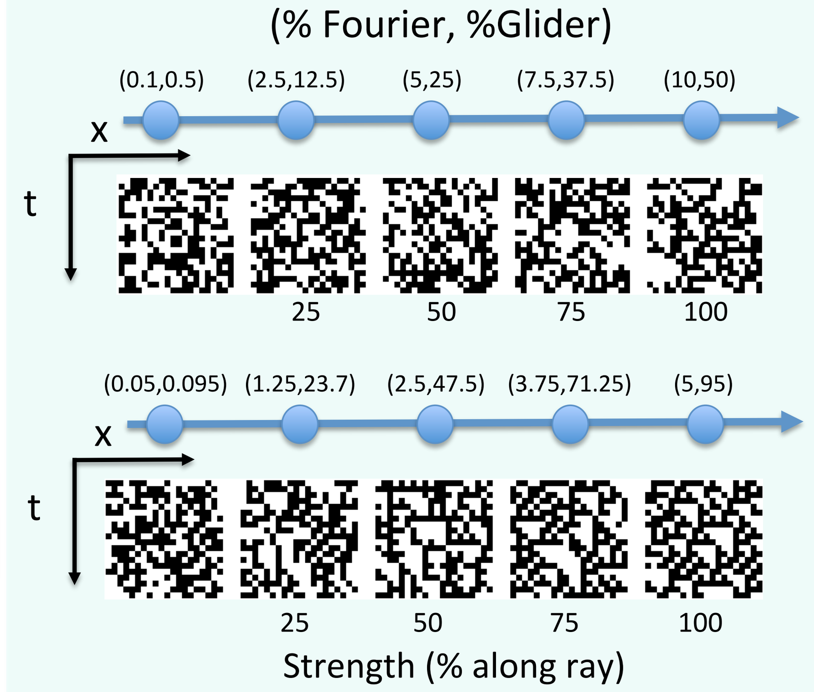
Two kinds of G motion:
Sensitivity to G contraction is higher than to G expansion

F motion in two contexts:
Sensitivity to F motion is generally higher in the context of G contraction, than in the context of G expansion



Combining Two Local Motion Signals

(% Fourier, %Glider)



To combine two kinds of local motion signals, we used a maximum-entropy approach: we created clips that had the required Fourier and Glider local motion signals, but were otherwise as random as possible. This was done by adapting the texture generation algorithms of Victor and Conte (2012) to spatiotemporal stimuli.

Summary

- Considered separately, Fourier motion signals, as expected, are stronger than Glider motion signals
- Fourier and Glider motion signals interact substantially
  - Fourier and Glider contraction signals, when combined, are perceived at a lower threshold than either signal presented in isolation
  - In a context in which Glider expansion signals are present, sensitivity to Fourier signals is reduced

Future

This approach extends to study:

- Integration of other motion signals
- Integration of motion signals in opposing directions

References

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