Abstract

The visual input system of the brain possesses a centre-surround receptive field organisation incorporating lateral inhibition. Consequently, cells in the retino-thalamo-striate pathway strongly respond to stimuli varying sinusoidally in the frontal plane. Due to the left-right *anatomical* hemispheric symmetry of these pathways, researchers have assumed that *functional* hemispheric asymmetries for the processing of simple sinusoidal stimuli would not be found. Indeed, only minor hemispheric asymmetries in Simple Reaction Time (SRT) studies have been reported, but in all cases, only a limited number and range of stimuli were used. There is cause, therefore, to examine hemispheric asymmetries over a much wider range of stimulus variables in a SRT paradigm, to confirm the absence of functional asymmetry, and further to examine the inter-relationship of stimulus variables with respect to neuroanatomical and neurophysiological properties of visual input pathways.

The present study varies the contrast (10 levels), spatial frequency (3 levels), luminance (3 levels), and eccentricity (4 levels) of sinusoidal grating stimuli presented in both visual fields of two subjects, and derives a linear coefficient relating contrast level and SRT. This linear factor correlates well with anatomical and physiological properties of visual input pathways in man and other animals, and offers distinct advantages over using raw SRT data. When this factor is plot against eccentricity for different spatial frequencies and luminances, a ‘Space-Ship’ plot emerges which reflects further pathway properties. Perceptual-motor hemispheric asymmetries, inter-stimulus, and inter-subject variability were found for raw SRT data, but not for the derived linear factor, supporting the assertion that this second-order measure better reflects early visual processing.

‘The Space-Man Cometh’

or

‘Simple Visual Reaction Time to Lateralised Sinusoidal Gratings’

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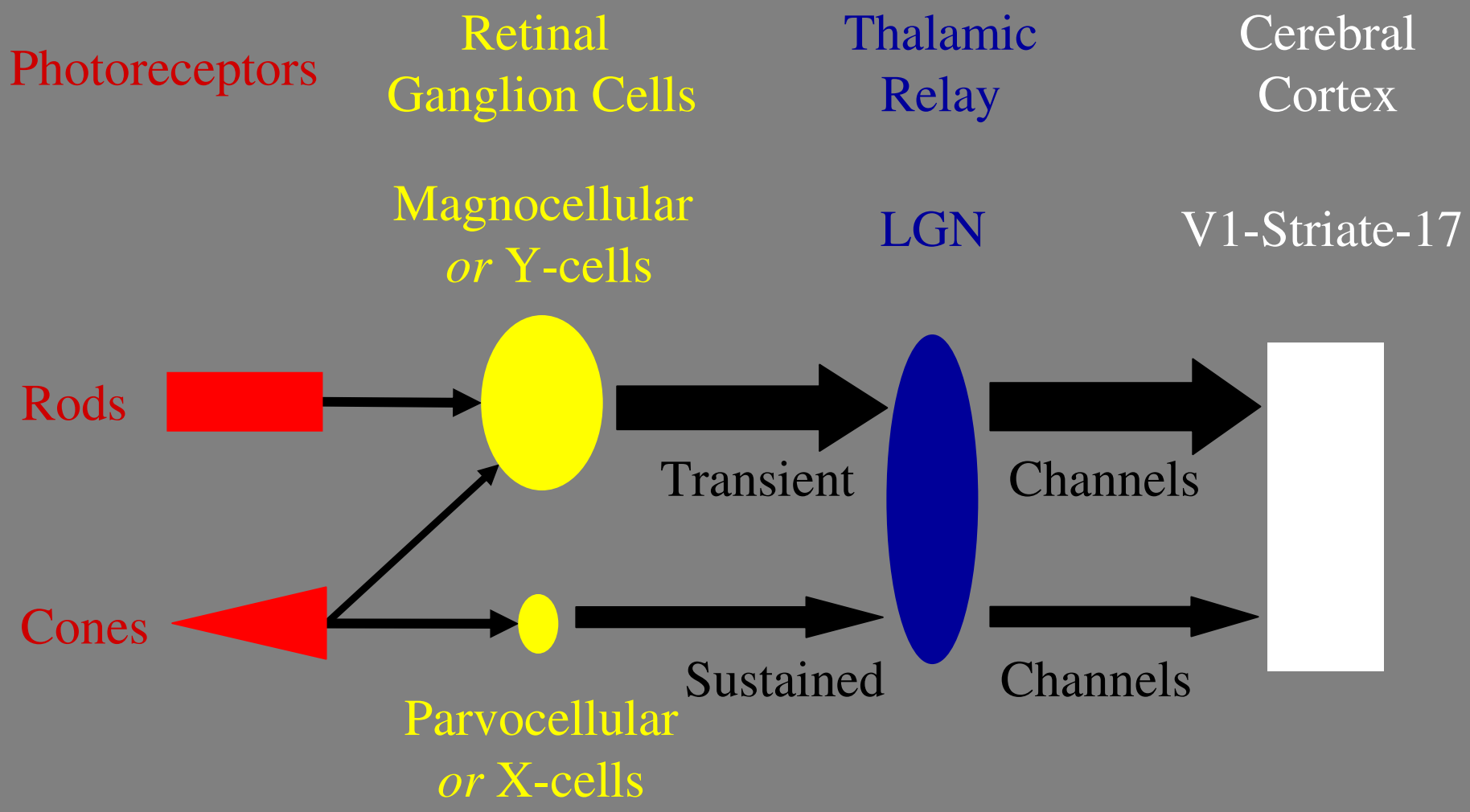
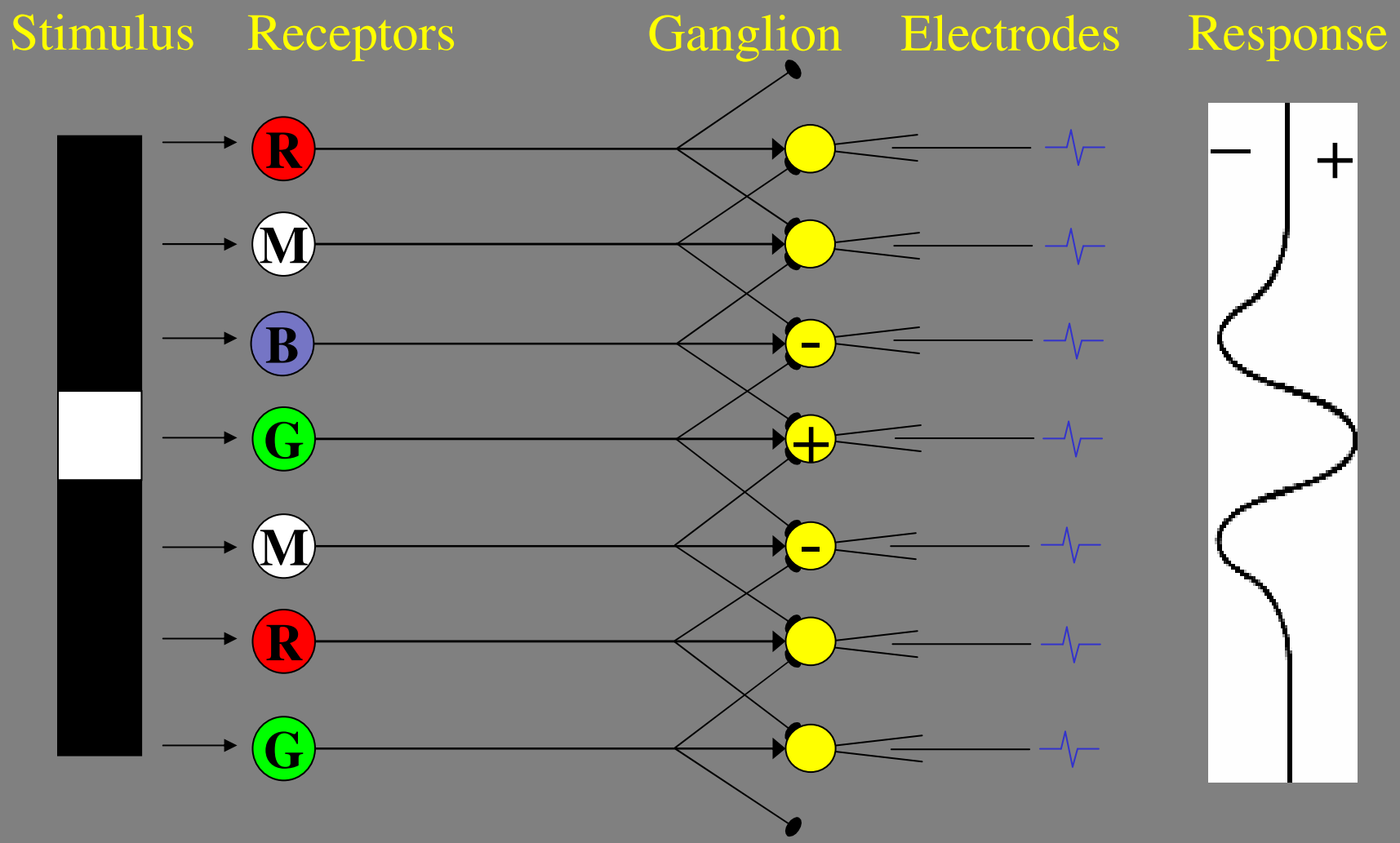
Early Visual Pathways

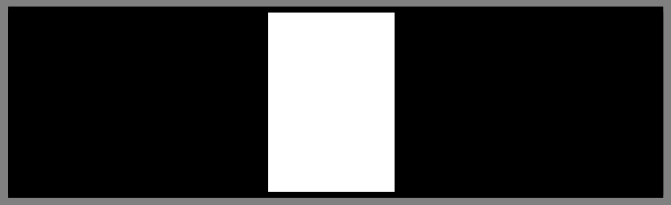


Lateral Inhibition

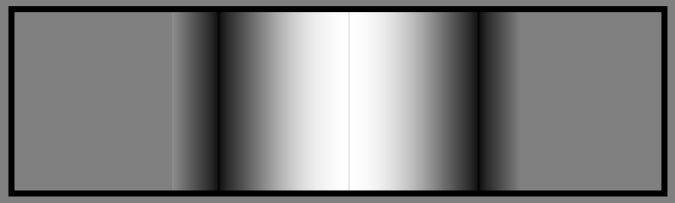


The Ideal Stimulus?

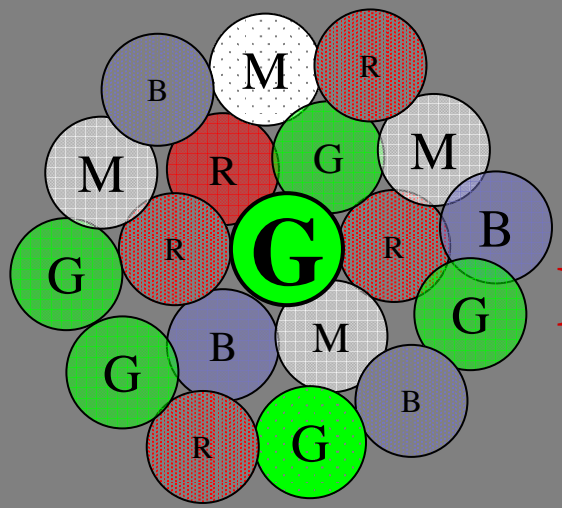
Square-wave



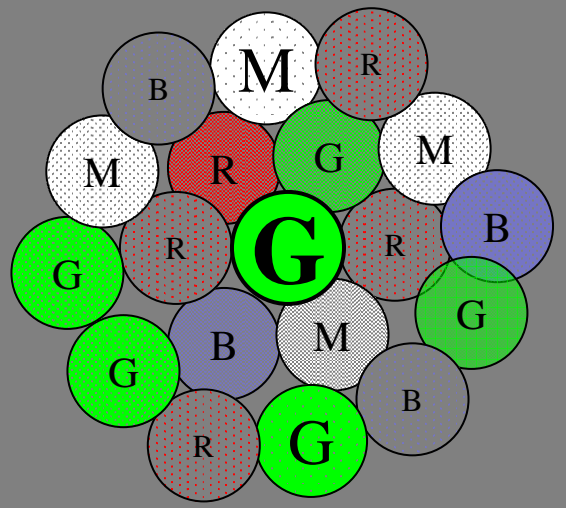
Sinusoidal



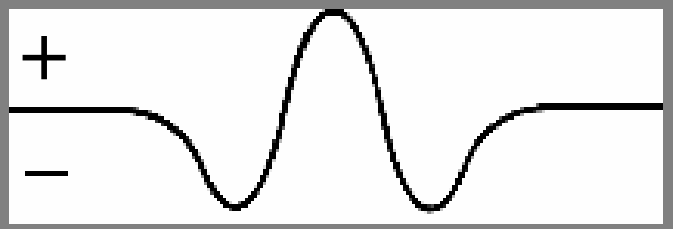
Stimulus



Photoreceptors



RG Response



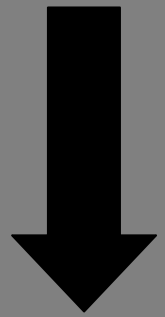
Simple Reaction Time (SRT)

Subjects make a response as quickly as possible following the onset of a visual stimulus

For sinusoidal gratings, SRT increases with...

Spatial Frequency
Eccentricity

Contrast
Luminance
Size
Duration



Stimulus Variables

To study neurophysiological/anatomical properties of the input pathways w.r.t. hemispheric asymmetry

Contrast (C_{10}), Spatial Frequency ($SF_{3\text{-}2}$), Luminance ($L_{2\text{-}3}$), Eccentricity (E_3), & Visual Field (VF_2) are varied*...

...while stimulus Size & Duration are held constant

* Different combinations of stimulus conditions = 10 x 3 x 2 x 7 = 420

Interacting Stimulus Variables

C, SF, E, L have interacting effects on RT...

Variable-reducing solutions for RT-C plots…

1. x-axis: Stimuli fixed at $C = C_0 + k.\text{Log units}$

2. y-axis: Comparisons made with $RT_a = RT_b$

3. dy/dx: Relation between C and RT derived

Hemispheric Asymmetry?

Attentional Processing

Left Hemisphere - High Spatial Frequencies
Right Hemisphere - Low Spatial Frequencies

- Spatial Frequency Hypothesis (Sergent, 1983)

Pre-Attentional Processing

No Hemispheric Asymmetry

- Anatomical Symmetry (Braun *et al.*, 1996)
- 'Modular' Processing (e.g. Fodor, 1983)

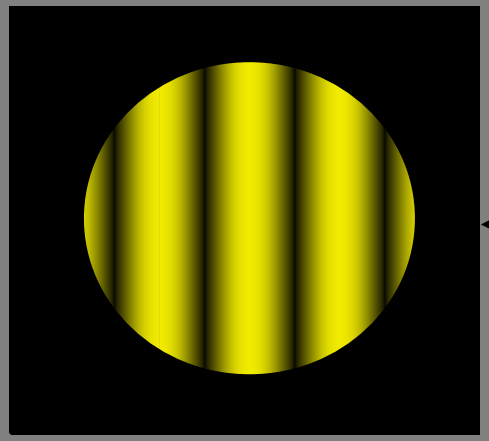
Aims

1. Explore further the RT-Contrast relationship over varying stimulus characteristics

2. Compare right and left visual hemi-fields

3. Define a methodology for SRT studies, using RT-Contrast coefficients

Apparatus



Red-Green Monitor
(Barco CCID 7651)

Generator Card
(Millipede Prisma VR1000)

GC

Controller Card

CC

Software Interface

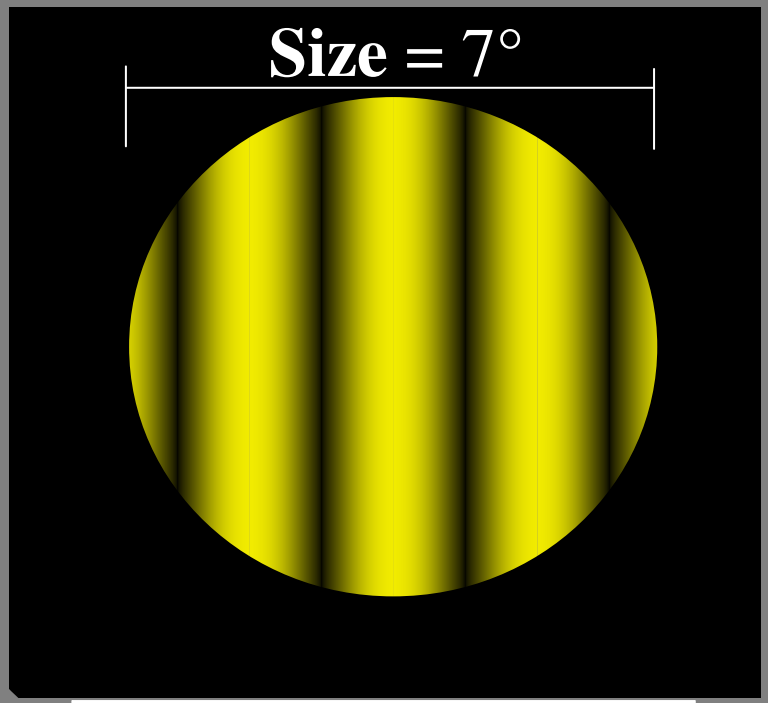
Timer Interface

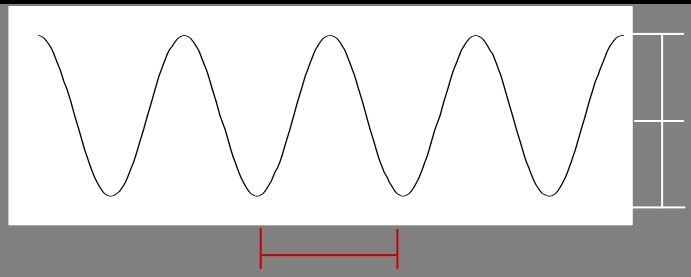
CED 1401

IBM 386 SX Computer

Response Button

Stimuli





Spatial Frequency
= 0.5, 1.73, 5.61 cpd

Luminance
= 0.02, 0.2, 2 cd/m^2

Hue ≈ 'yellow' (585 nm)

Eccentricity
= 0°, 5°, 10°, 15°

Contrast
$(L_{max} - L_{min}/2L_{mean})$
= **0.006 to 0.5** (10 levels)

Stimulus Timing

TONE sounds

Foreperiod = 1 - 3 sec

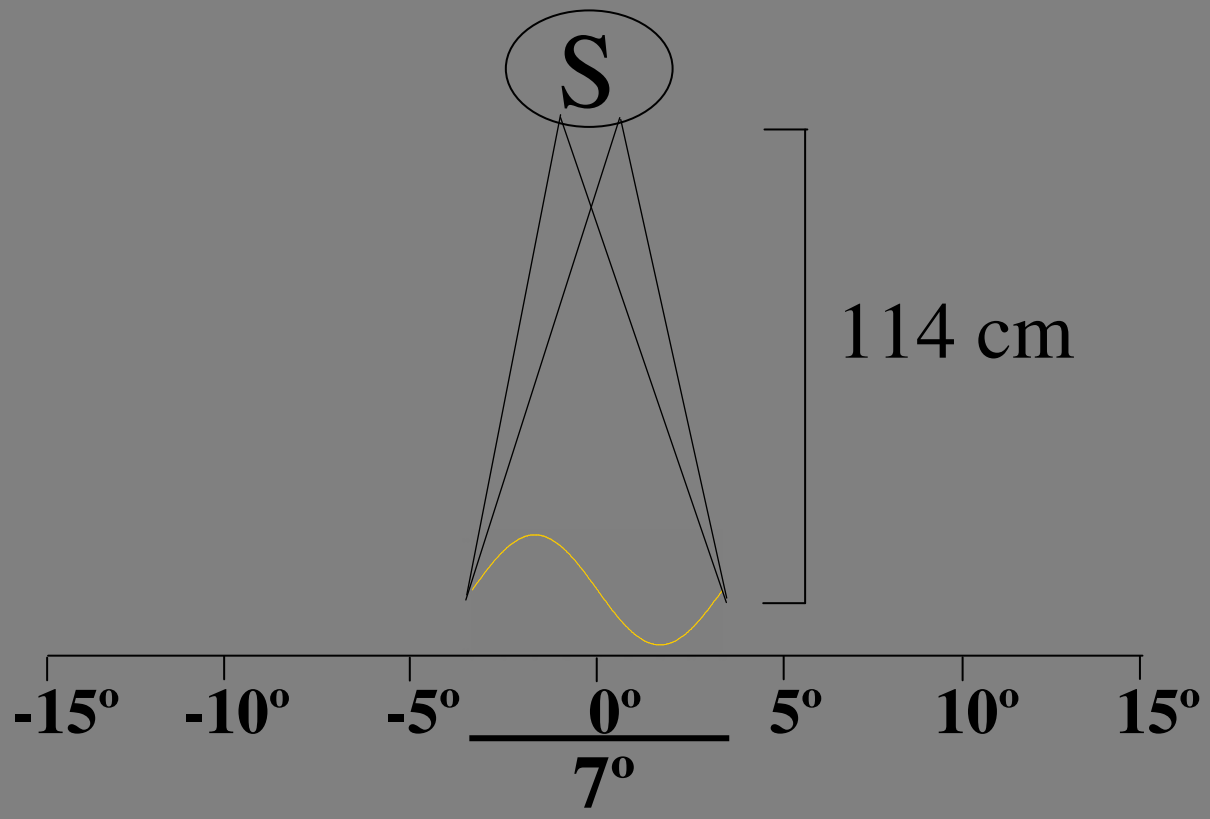
Duration = 340 ms

Interval = 2 sec

Subjects

2 Males (23 & 29 yrs); Right-handed, Corrected Vision

SP highly practised, NH unpractised



Data

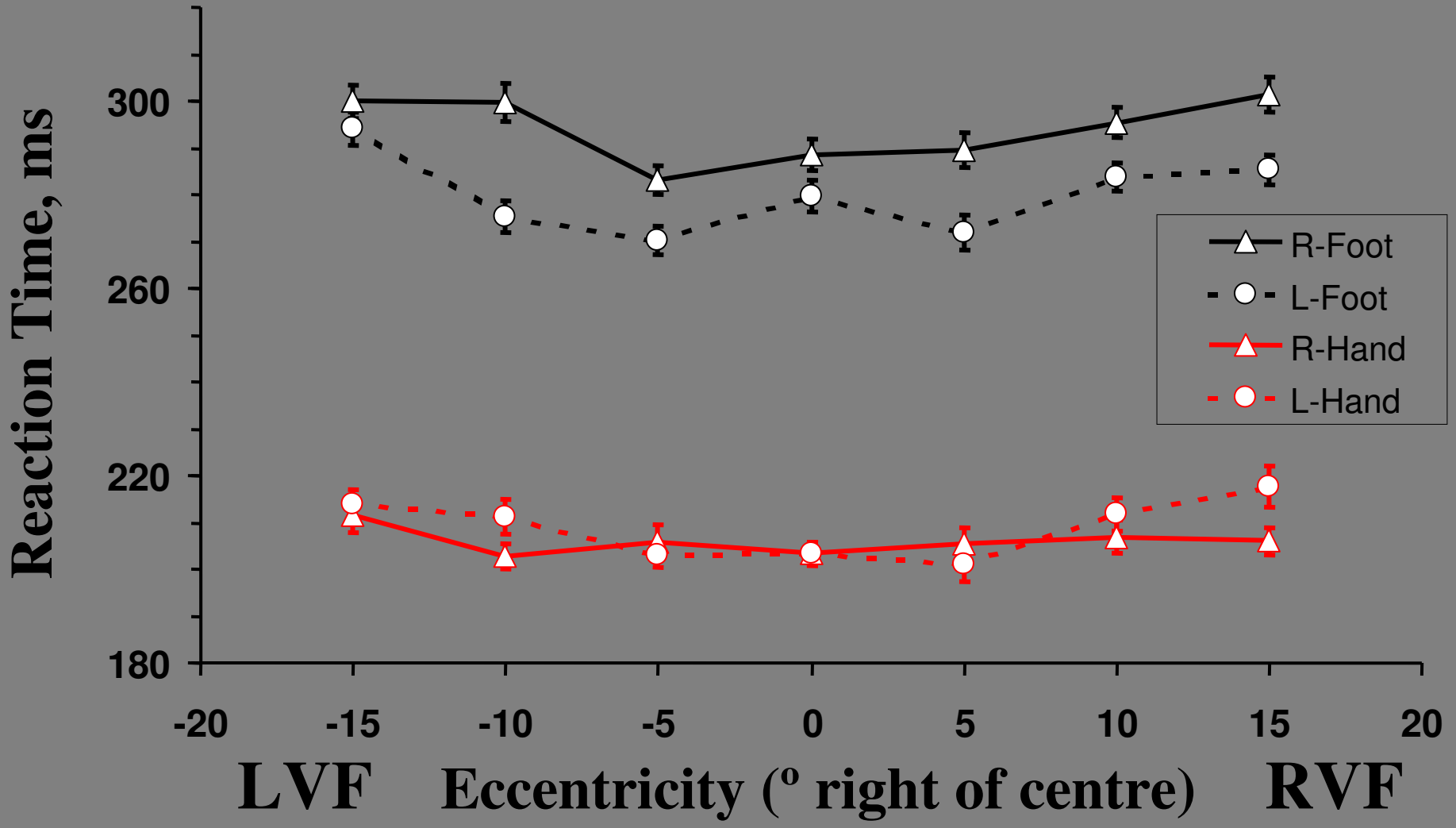
Reaction Times

- Recorded to 1 ms
- Valid Data:
  - 150 ms ≤ RT ≥ 800 ms
  - mean ± 2 s.d.
  - n > 19

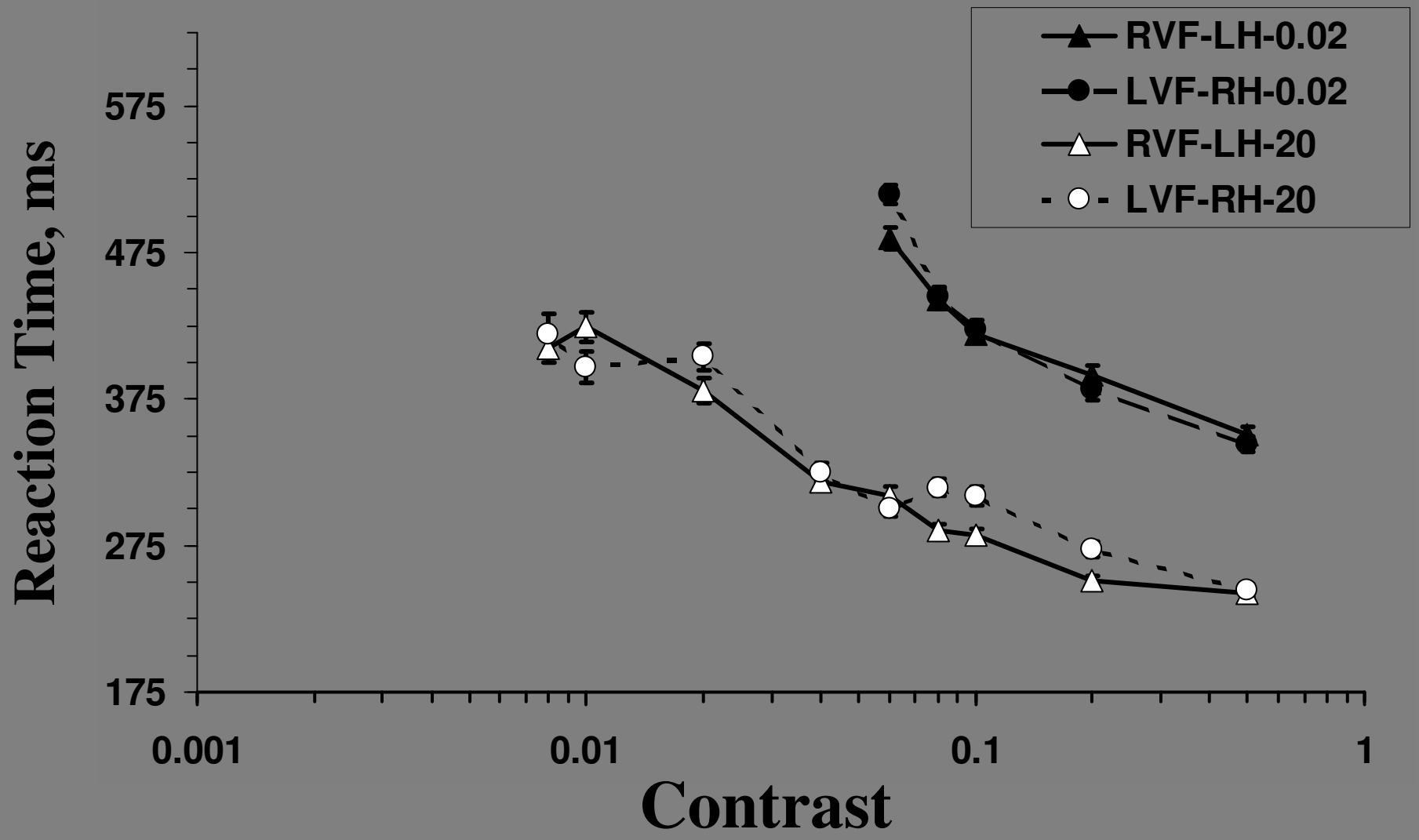
Plots

1. RT vs. C
2. RT vs. C^{-1}
   - Regression
   - $\Rightarrow$ slope factor (m)
3. RT-C^{-1} factor (m) vs. E
   - The "Space-Ship" Plot

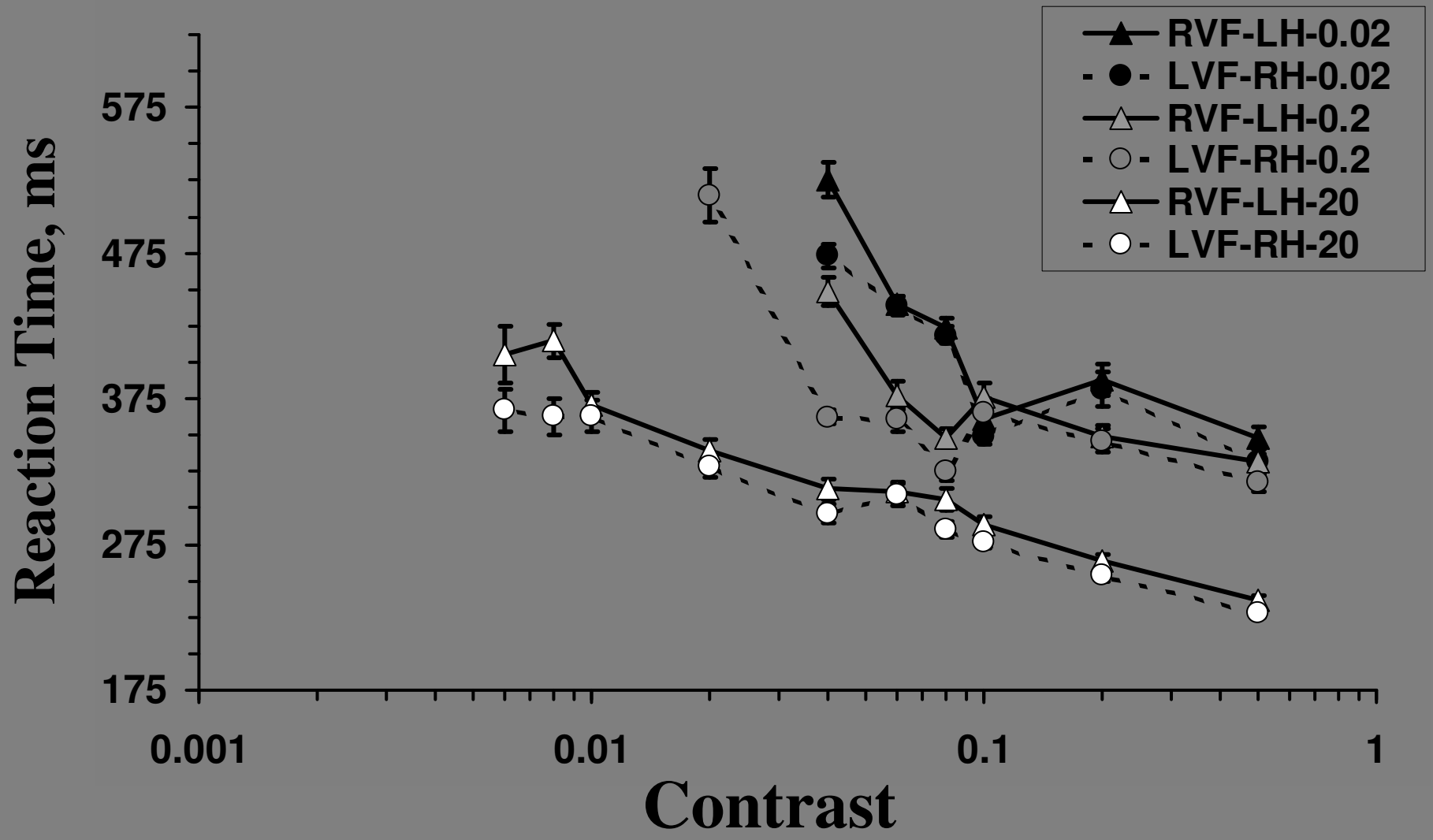
Results: Control



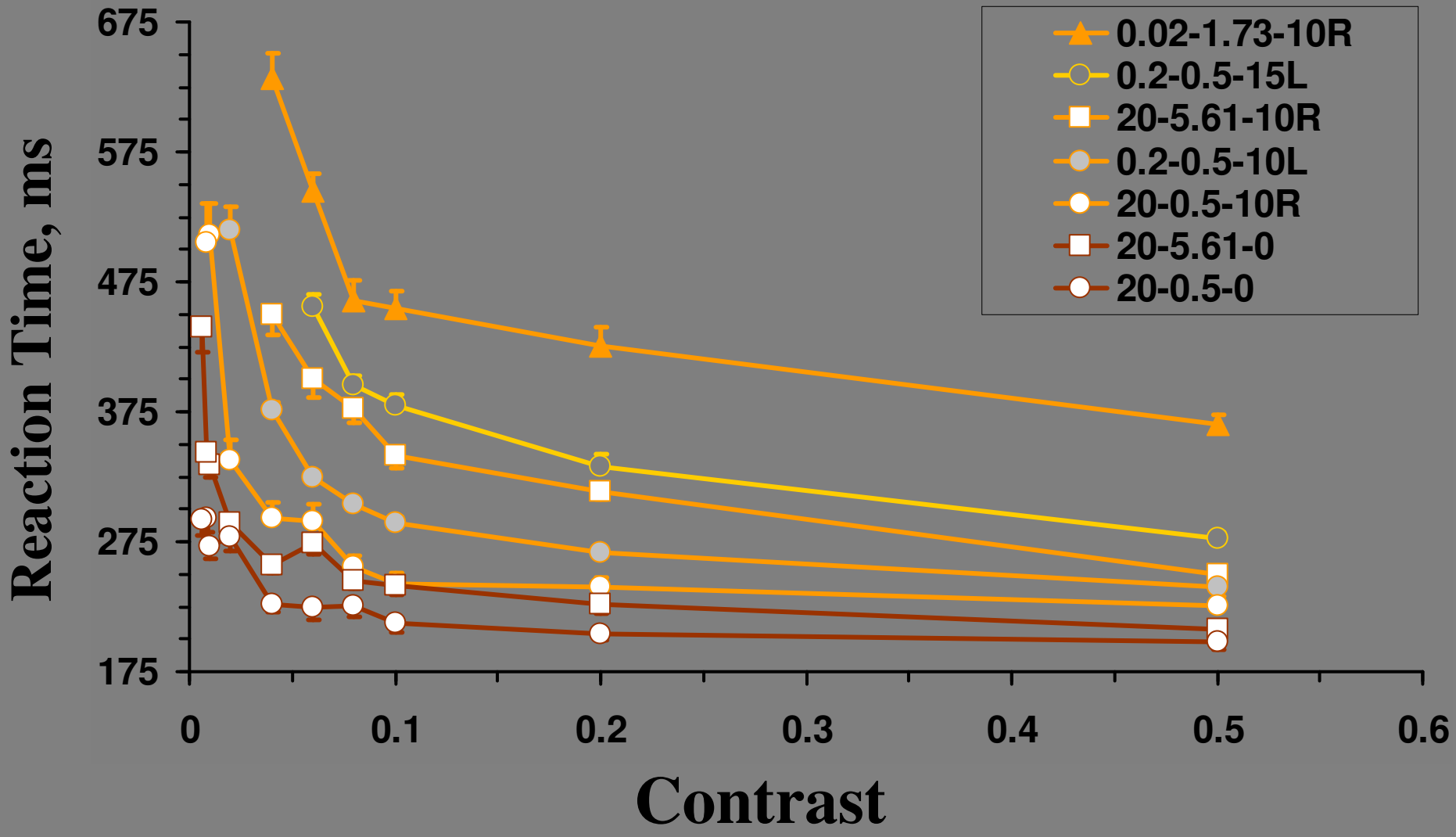
Results 1a: LVF vs RVF - NH



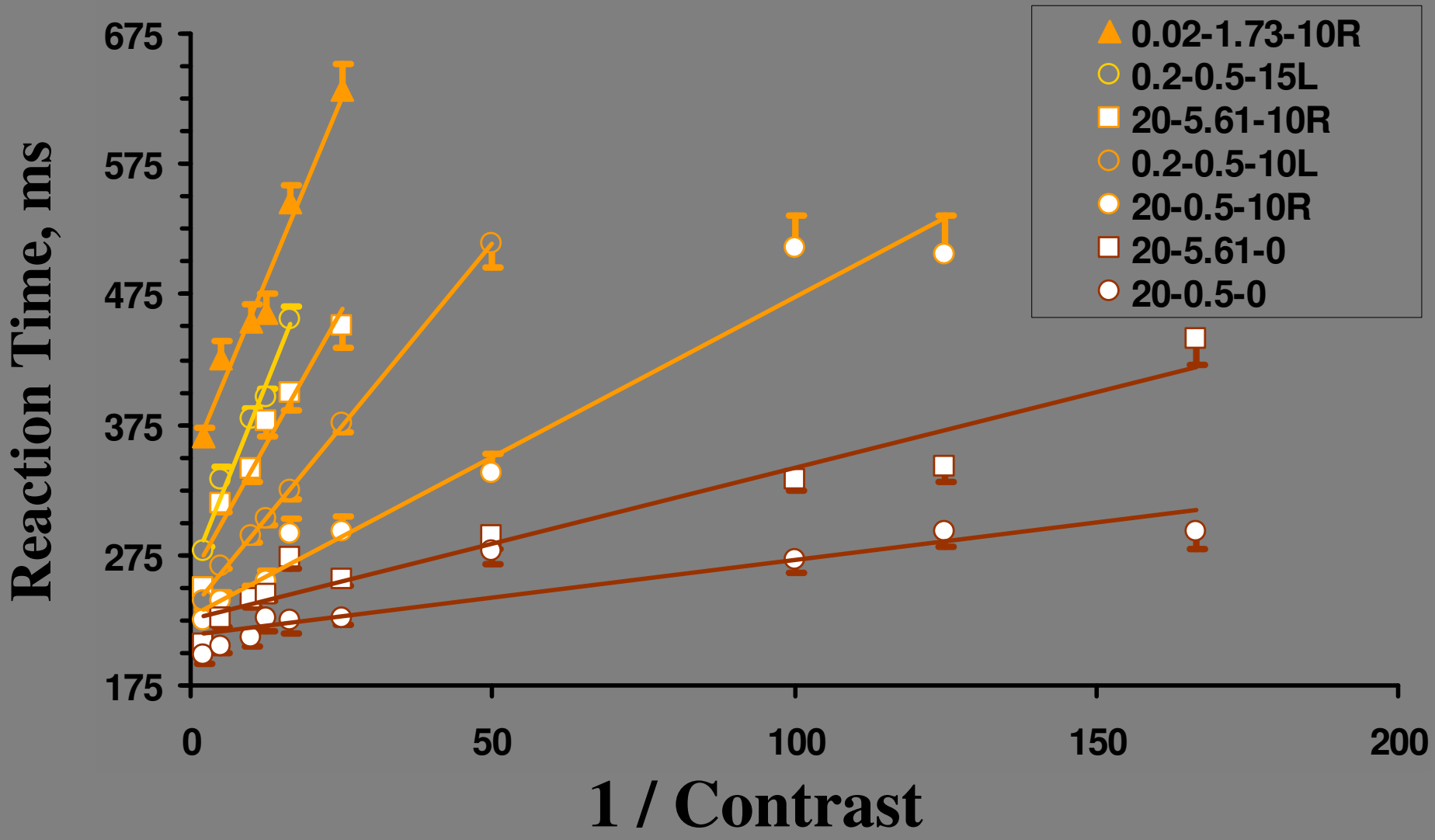
Results 1b: LVF vs RVF - SP



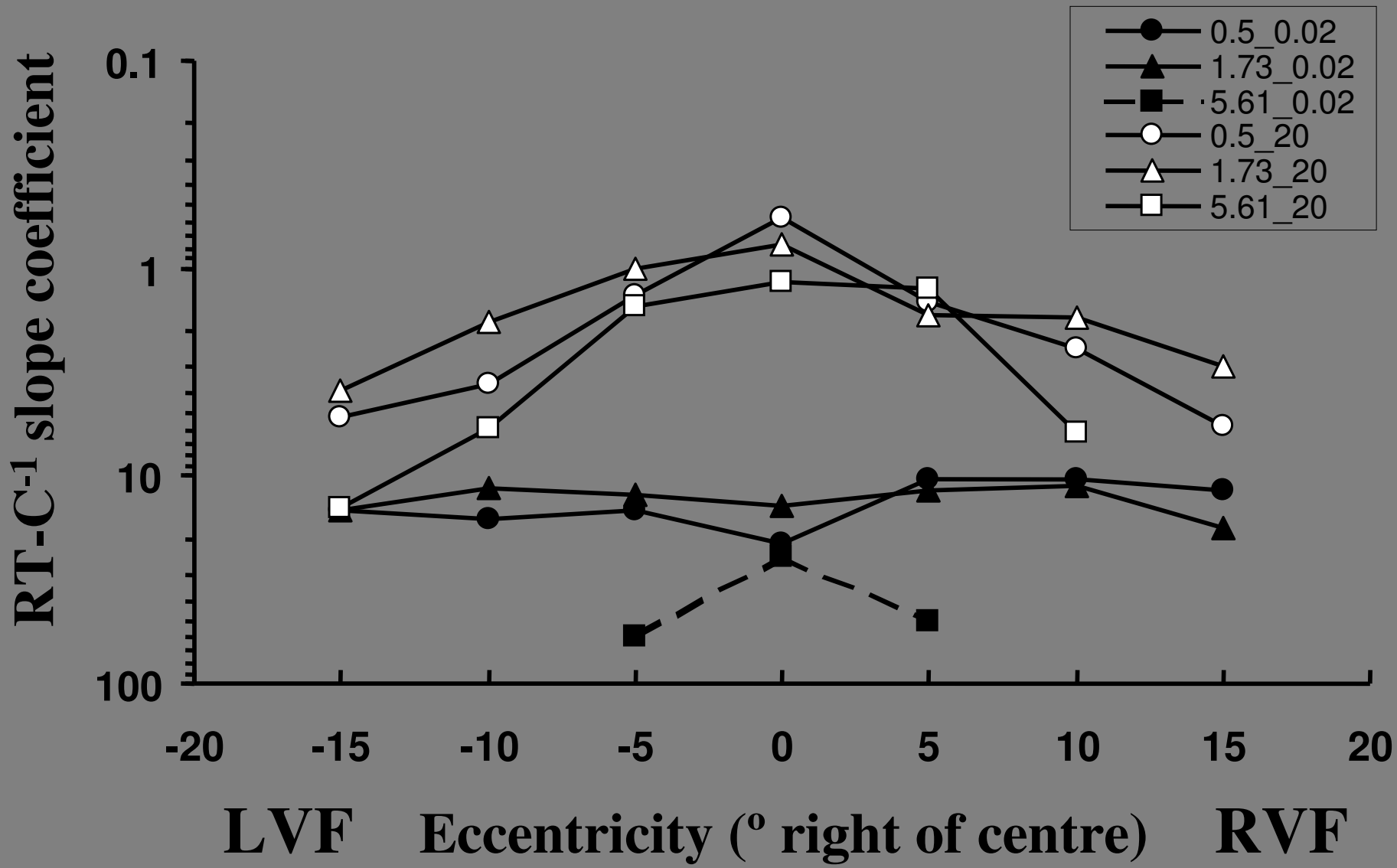
Results 2: RT - Contrast



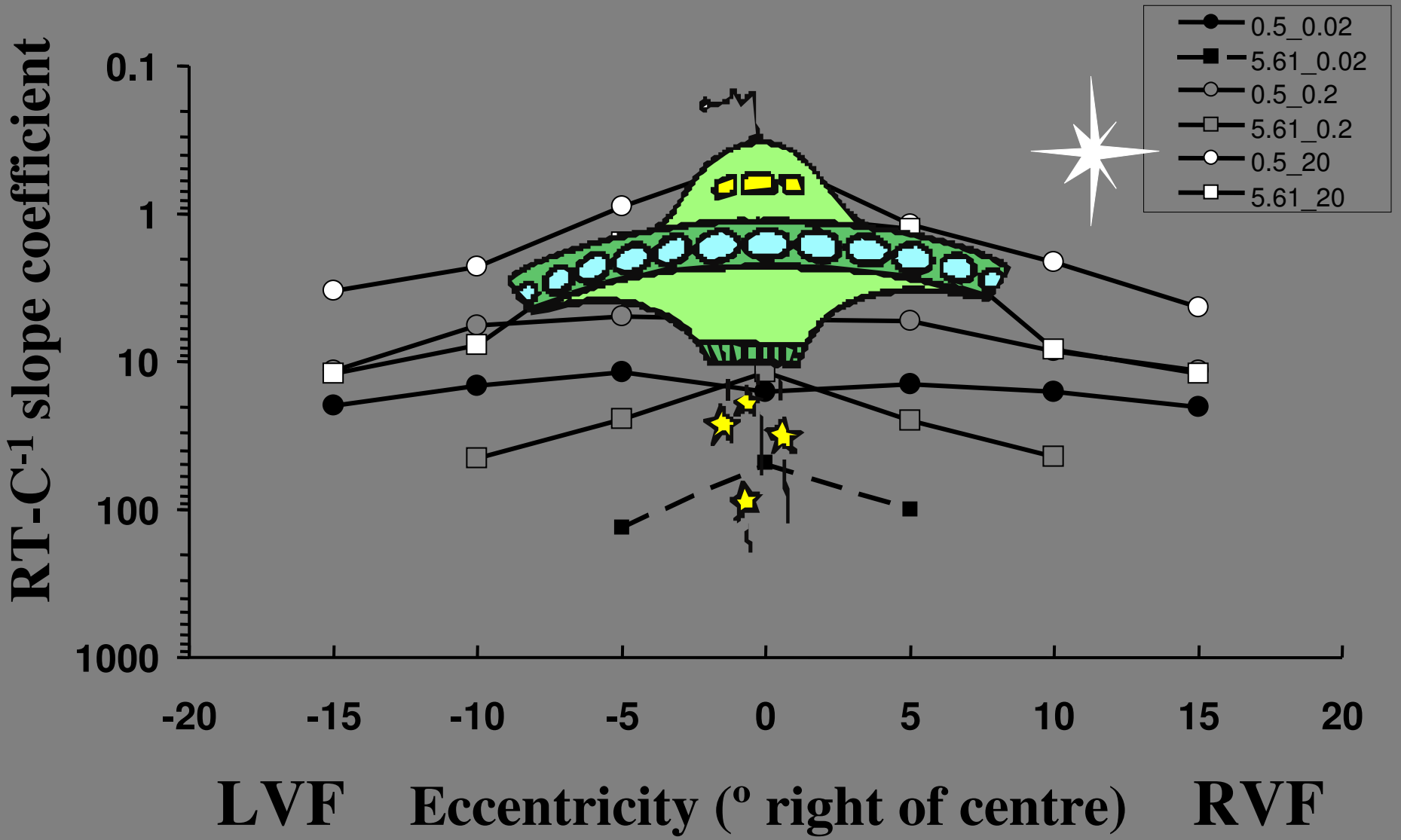
Results 3: RT-1/Contrast



Results 4a: The Space-Ship - NH



Results 4b: The Space-Ship - SP



Discussion 1

Hemispheric Asymmetries in RT?

Subject NH

- no consistent asymmetries across conditions
- significant *left foot* advantage (13.5 ± 2.5 ms)

Subject SP

- consistent and significant RH-LVF advantage of 19.1 ± 4.4 ms

Discussion 2

RT-Stimulus Relationships

1. Reaction Times Increase with...

Eccentricity
Spatial Frequency

Luminance
Contrast

2. RT is linearly proportional to C^{-1} for all conditions

That is, $RT = mC^{-1} + k$

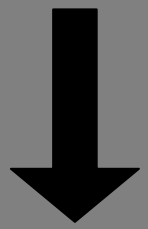
where, m = slope coefficient
k = constant

Discussion 3:

RT-1/C Slope Coefficients Increase with...

Eccentricity

- Photopic only
- More for high SFs



Luminance

Asymmetries?

- Little LVF-RVF asymmetry
- Some anomalies
- However, n = 2, ∴ requires replication

Anatomy & Physiology

RT-C^{-1} Slope Coefficients....

1. Reflect Contrast Sensitivity

- Lowest at 1.73 cpd (inverse of CSF)
- Modulated by Eccentricity and Luminance

2. Correlate with Retinal Cell Type / Density

- High Lum - cone, Low Lum - rod activity
- Cone density high in fovea, decreases with E
- Rod density more even, but absent in fovea
- Photoreceptor density affects high SFs more

Anatomy & Physiology Cont...

RT-C^{-1} Slope Coefficients....

1. Reflect Transient / Sustained Dichotomy

- Low Lum - Trasient, Y-Cell / Magno system
- High Lum - depends on SF and E:
  - Low SF / High E - Transient
  - High SF / Low E - Sustained

2. Reflect Single Unit Primate Results

- Coefficient predicts contrast gain & sensitivity in Macaque RG cells (Plainis et al., 2000)

Conclusions

SRT asymmetries for sinusoidal gratings may best be assessed by deriving a linear factor from RT - Contrast plots

This factor correlates well with anatomical and physiological properties of cat, primate, & human retino-striate projections

RT data showed asymmetries & large intra- & inter-subject variability. This was not seen for RT-C^{-1} coefficients

Acknowledgements

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Dr Nuala Brady†

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