Improved glare (halos and scattered light) measurement for post-LASIK surgery

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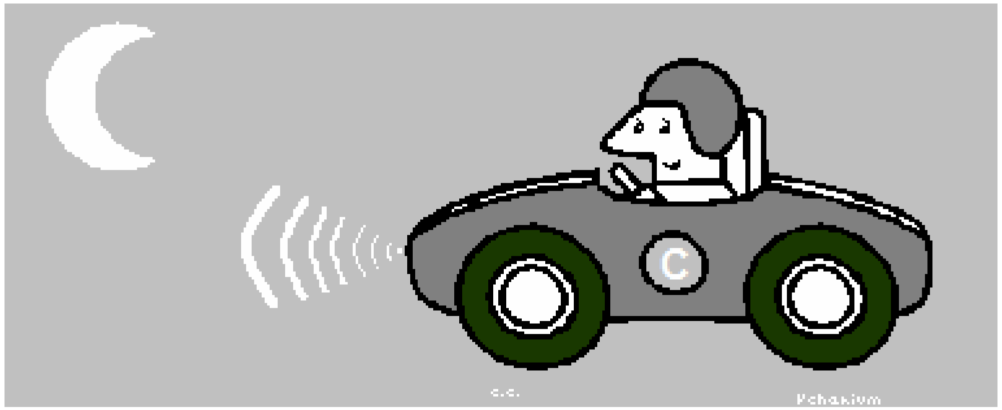


The need for a new vision test

There are complaints about night vision for which there are no adequate objective psychophysical tests (following refractive surgery, orthokeratology and other anomalies).

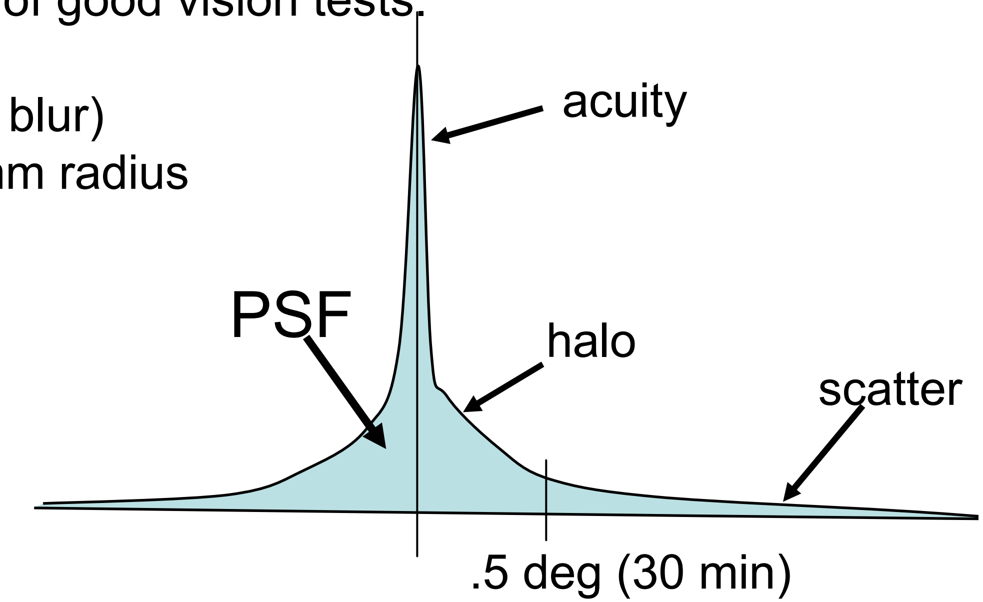
There are three regimes of interest.

1) The acuity regime (set by Strehl). Lots of good vision tests.

2) The halo regime (set by transition zone blur)
suppose D=3 diopters of blur at p=3 mm radius

θ = D p = 3 diopters * 3 mm = 9 mrad
= 3.4 D p (min) = 30 min

3) The scattered light regime.
θ > 30 min



There aren't any good objective vision tests for the halo and scattered light regimes.

The three regimes of visual function

	Acuity regime.	The halo regime.	Scattered light regime.
range (radius)	< 3 min	3 – 30 min	>30 min
psychophysics	acuity, CSF>10 c/deg	listen to complaints no good objective test	listen to complaints no good objective test
retinal plane metrics	Strehl (with a little Neural TF blur)	tails of PSF (3-30 min) (not much research)	PSF (double pass since wavefront fails here).
pupil plane metrics	wavefront rms % pupil area (Corbin et al SPIE)	wavefront slope** (converted to min)	Not available in wavefront information

**The validation of the importance of wavefront slope may need to wait for the development of objective tests of vision that are sensitive to the tails of the PSF. That is part of the motivation for developing an improved night vision (glare) tester.

Criteria for a good glare test

Glare Index (GI) independent of instrument

Present instruments measure lines lost (but problems)

Glare index: % of light scattered > ½ degree

Assess glare with large pupil

Night driving is a problem (refractive surgery, et al.)

Flash glare source and target simultaneously (dark room)

Cheap & small & quick & easy to use

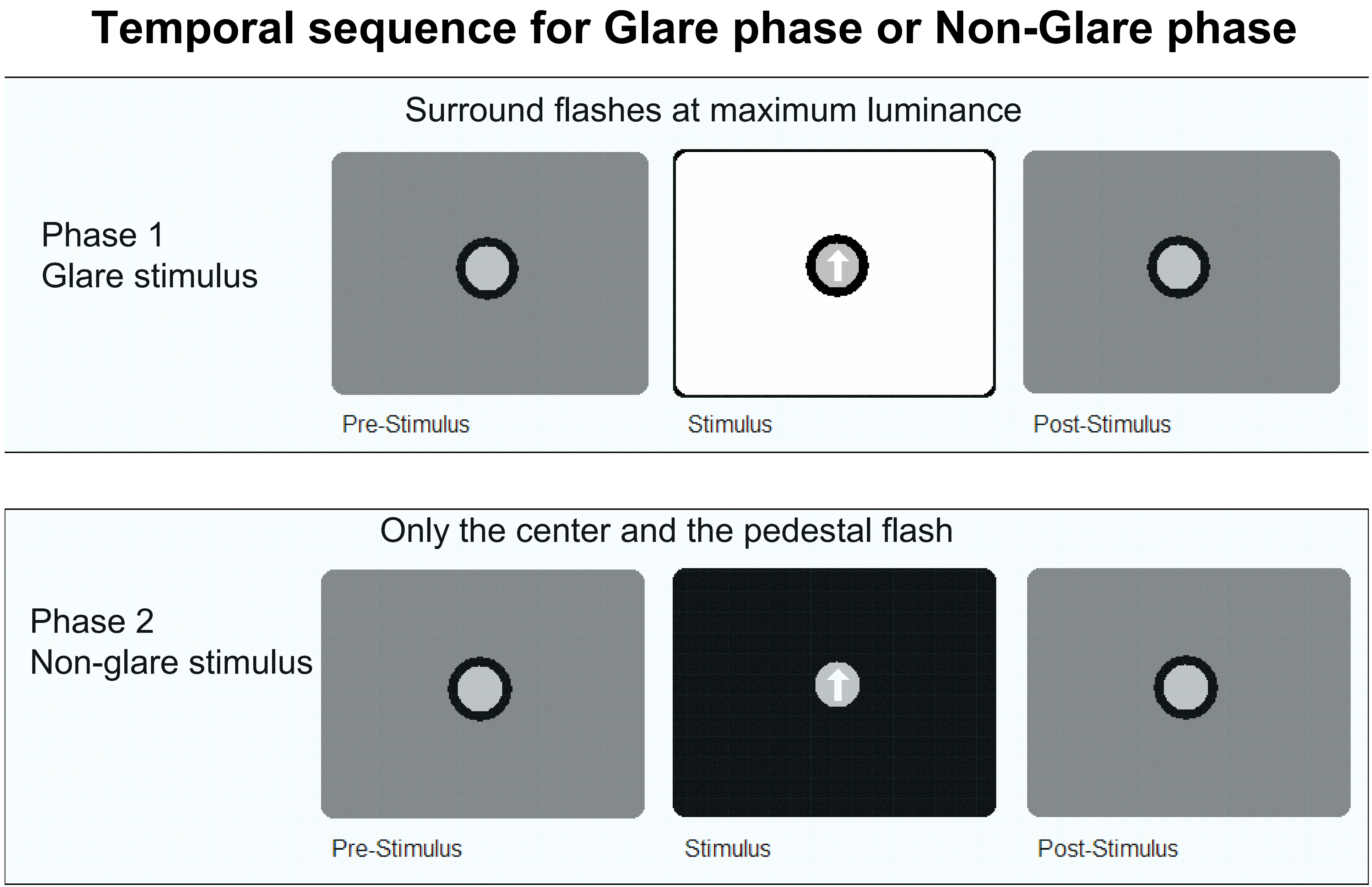
This is to be a clinical instrument

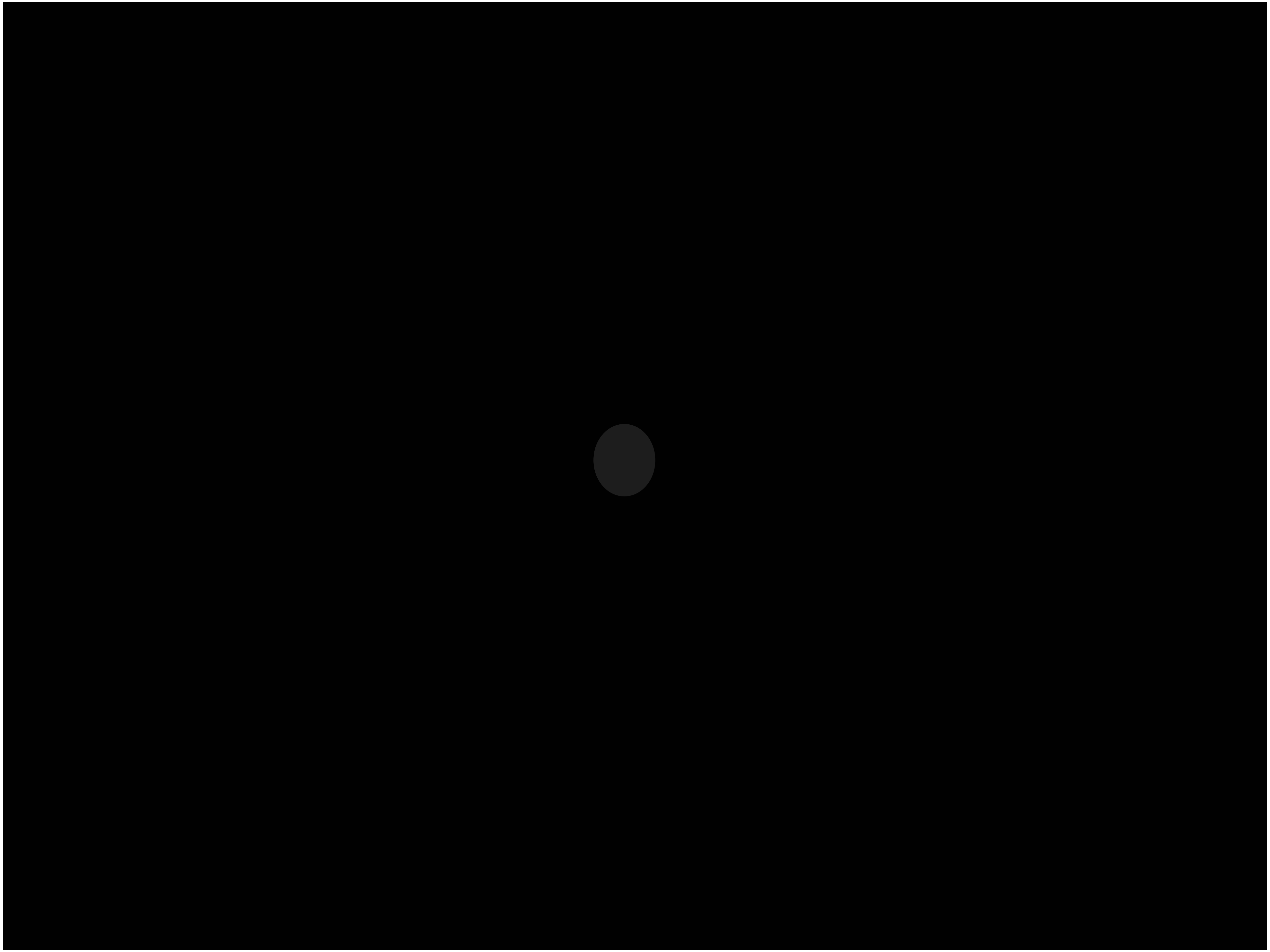
Use standard computer and monitor (for now)

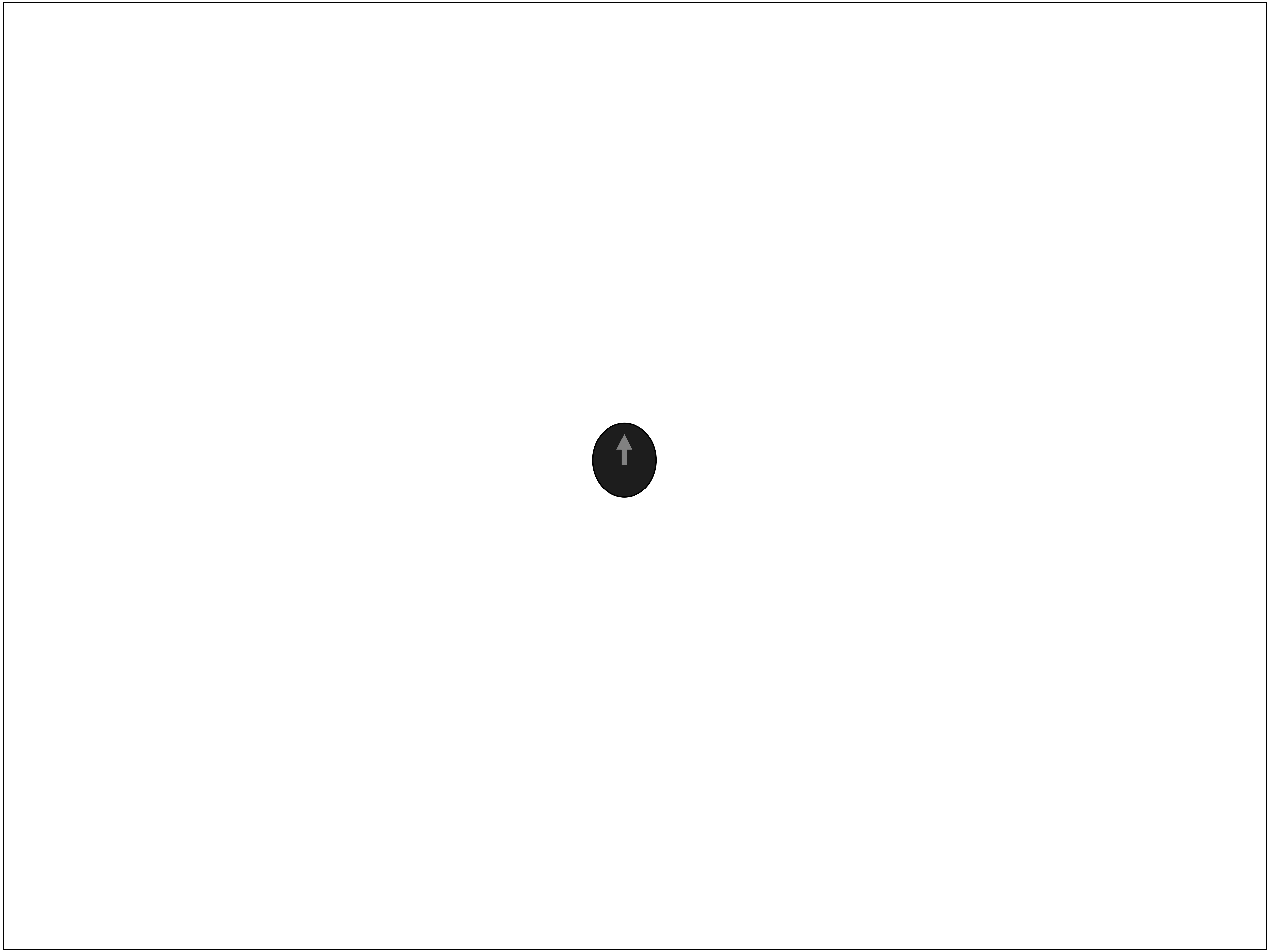
Accurate & precise

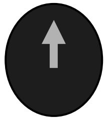
What psychophysics is needed?

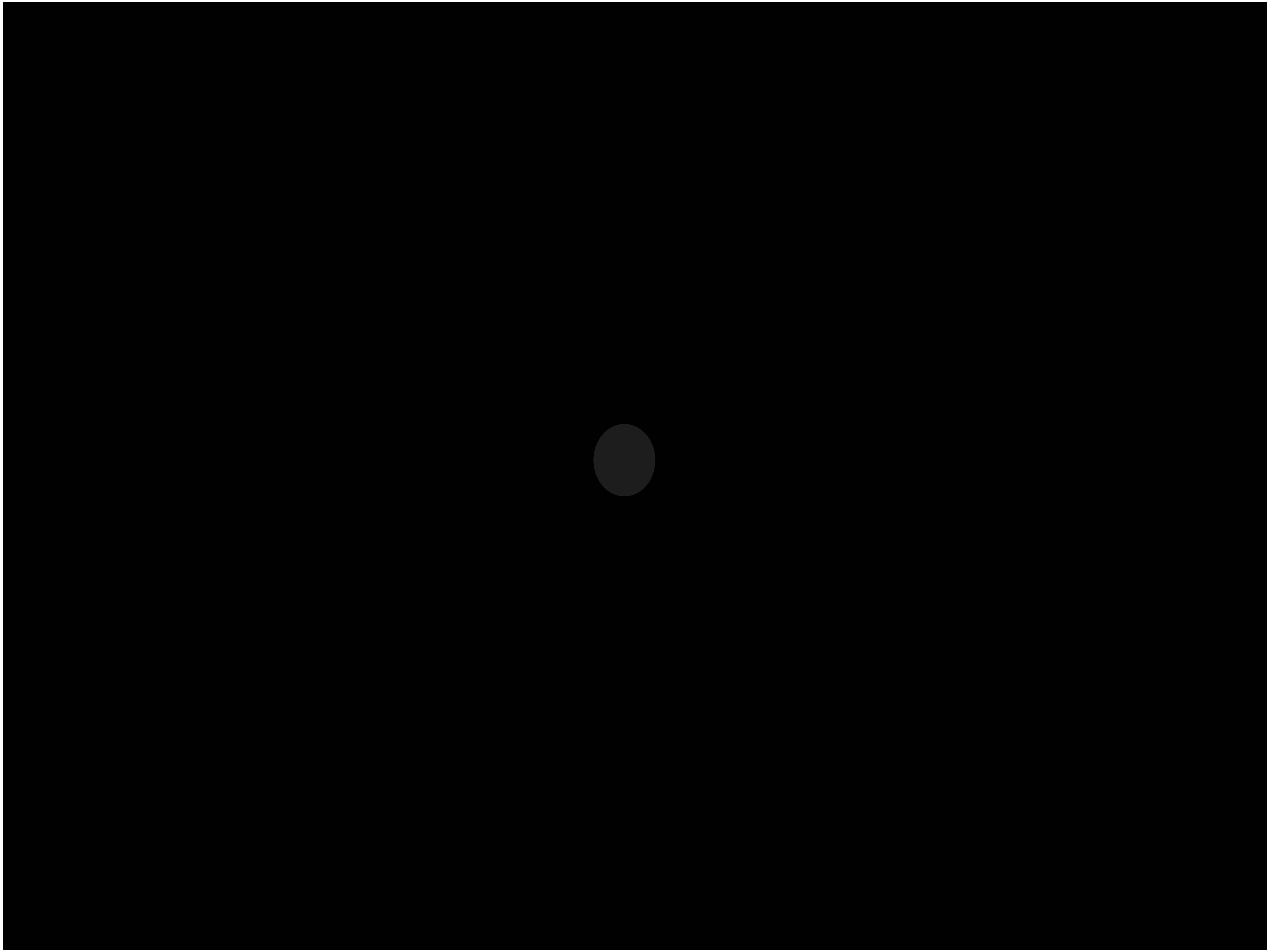
A topic of this talk and a topic for discussion

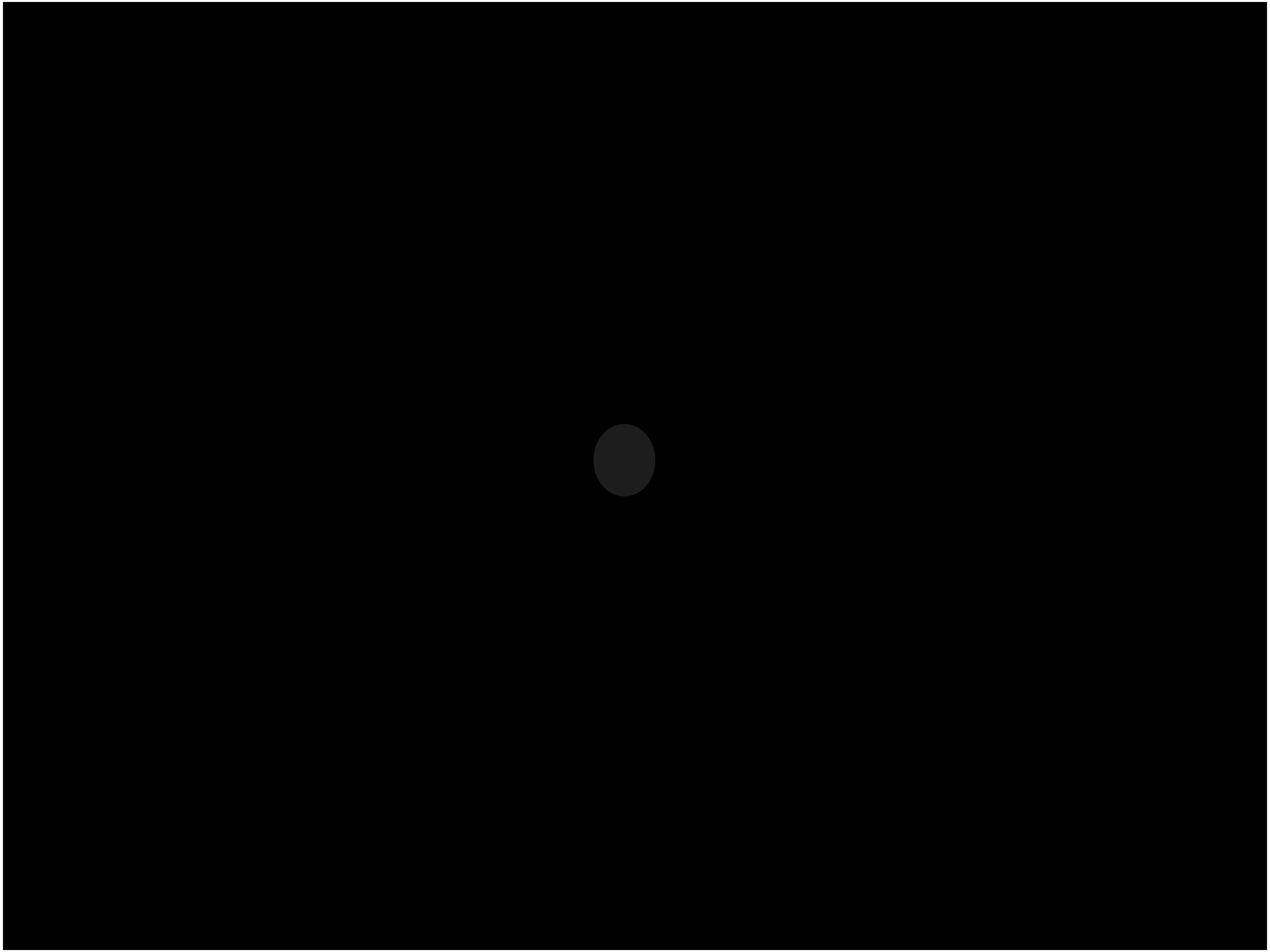

Temporal sequence for Glare phase or Non-Glare phase
Surround flashes at maximum luminance
Phase 1
Glare stimulus
Pre-Stimulus
Stimulus
Post-Stimulus
Only the center and the pedestal flash
Phase 2
Non-glare stimulus
Pre-Stimulus
Stimulus
Post-Stimulus



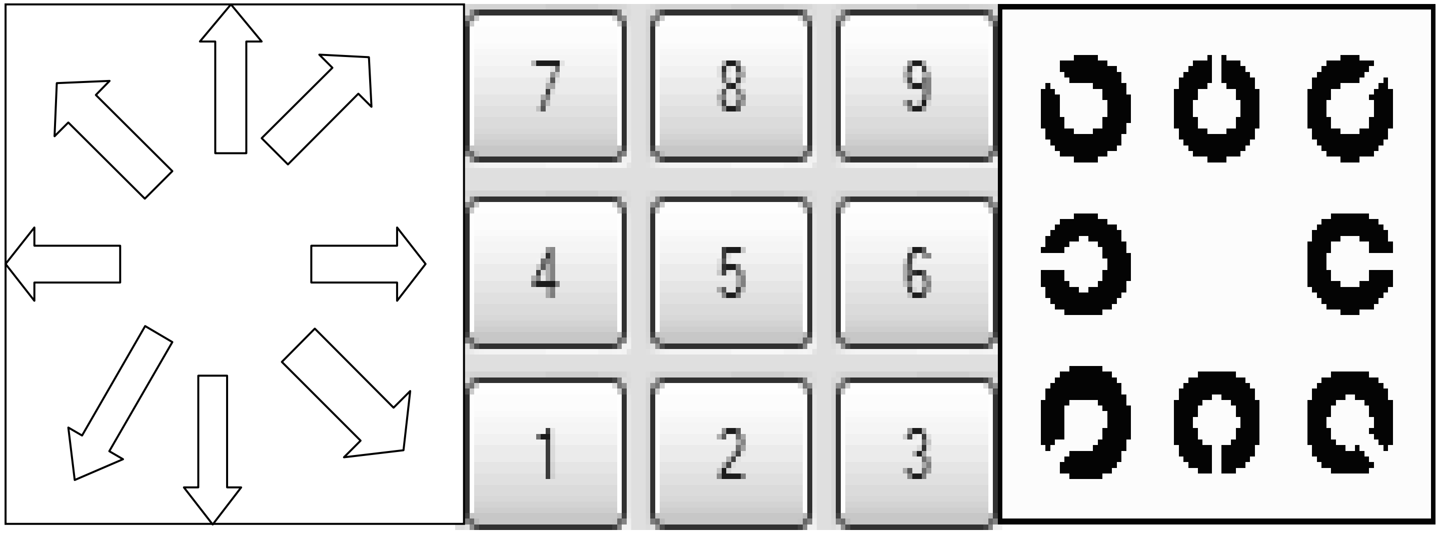








Number pad response for two types of stimuli: arrows and Landolt C's.



Eight alternative forced choice with 12.5% false alarm rate and with homogeneous stimuli results in a steep psychometric function with precise thresholds.

The Glare Index

GI is % of photons scattered greater than ½ deg

The % scattered from a point to > ½ deg
= % of scatter from > ½ deg by reversibility

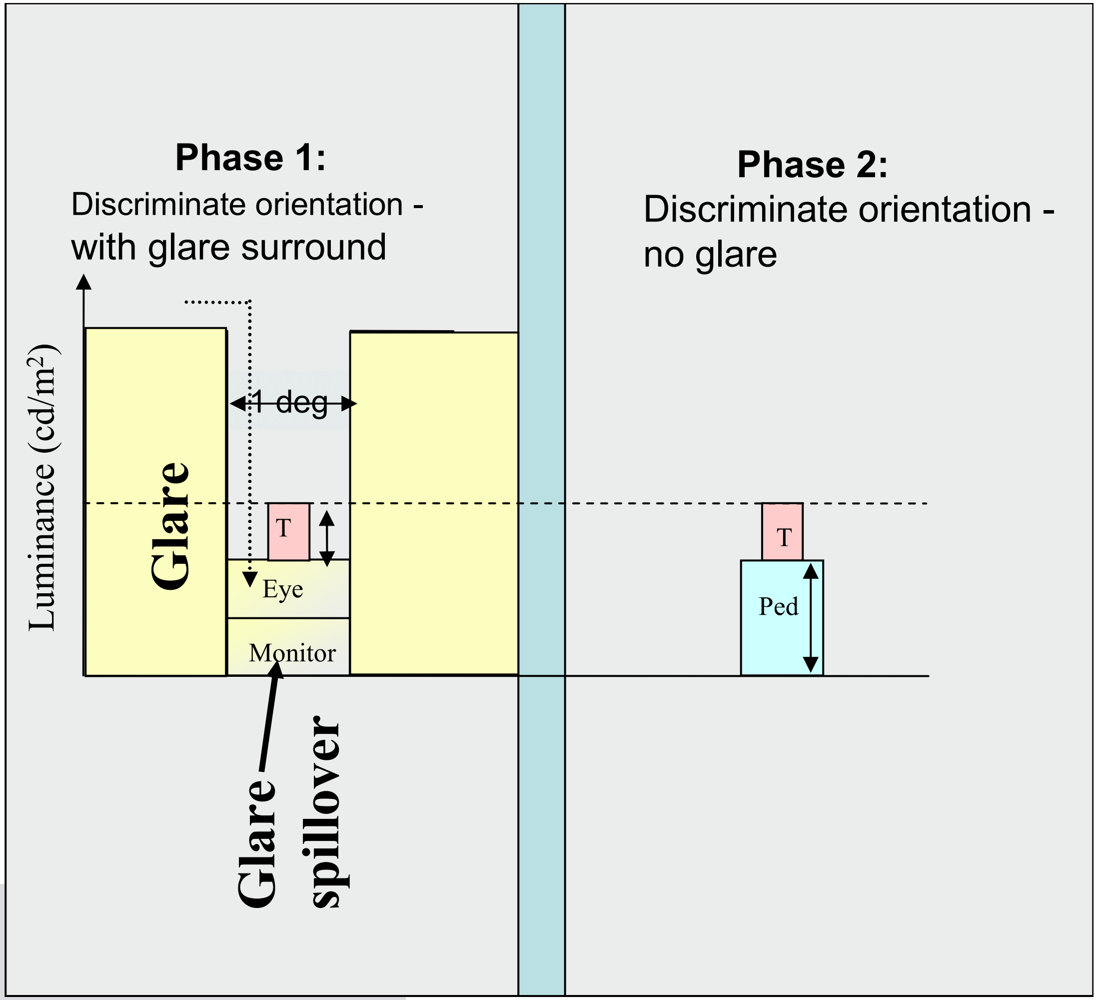
Thus we can use a glare stimulus of 1 deg in diameter and ask what is the threshold elevation of a target in center.

We can simultaneously measure halo and scattered light since the tip of arrow is only 15 min from glare source while the arrow stem is 30 min from glare source. 180 deg errors indicate halo since arrow tip is invisible.

Assumption and Derivation

We assume test thresholds are raised by glare due to scattered light spilling into the test region and acting as a background pedestal.

This spillover pedestal acts as a real pedestal and raises test threshold by Weber's law.

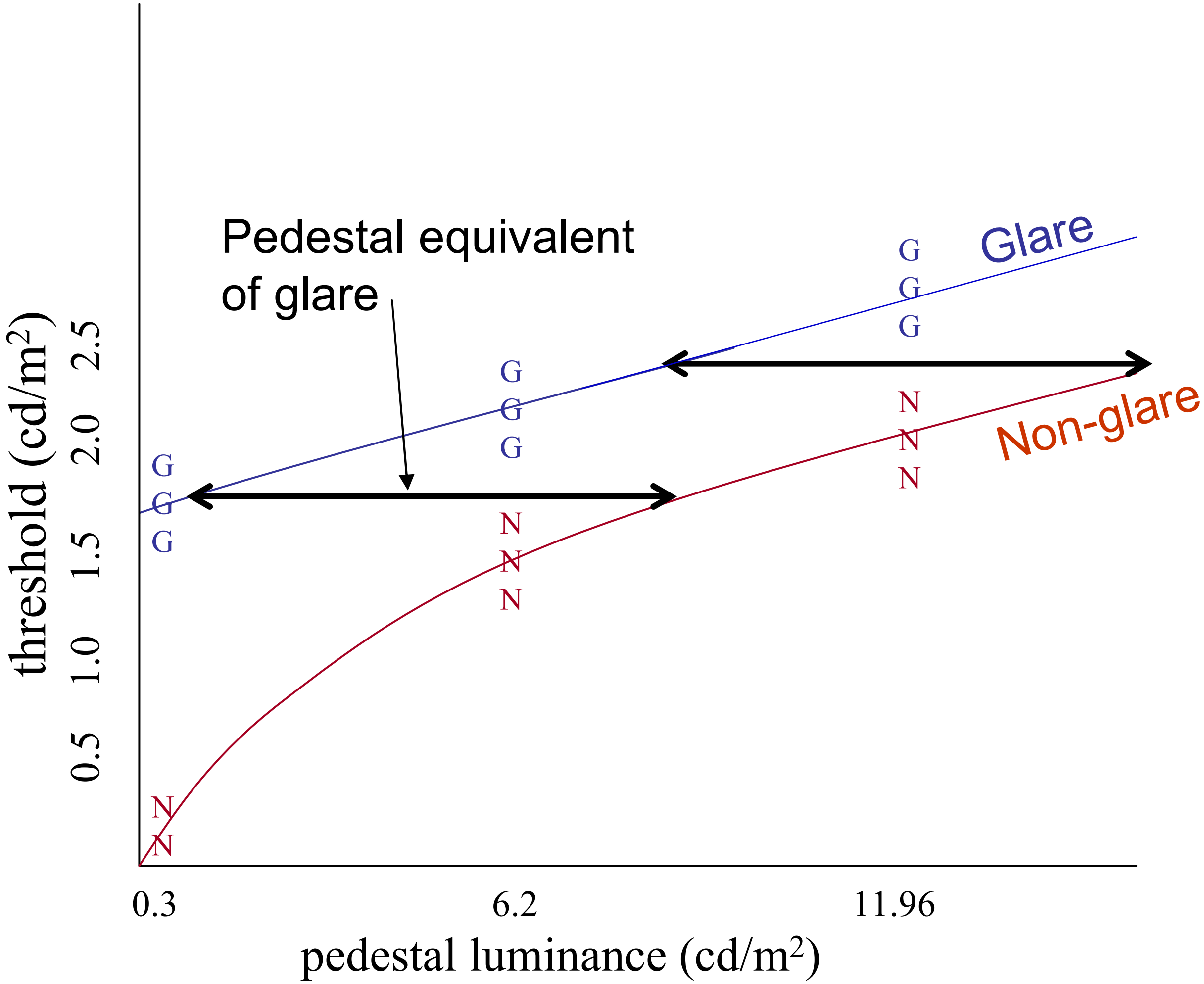


th = W(ped + GI* glare)
Phase 1: th_1 = W(GI*glare)
Phase 2: th_2 = W(ped)

$th_1 = th_2$ implies GI*glare = ped or

GI = ped (cd/m²) / glare (cd/m²)

TvP (Test vs Pedestal) plots for detecting the target with and without glare



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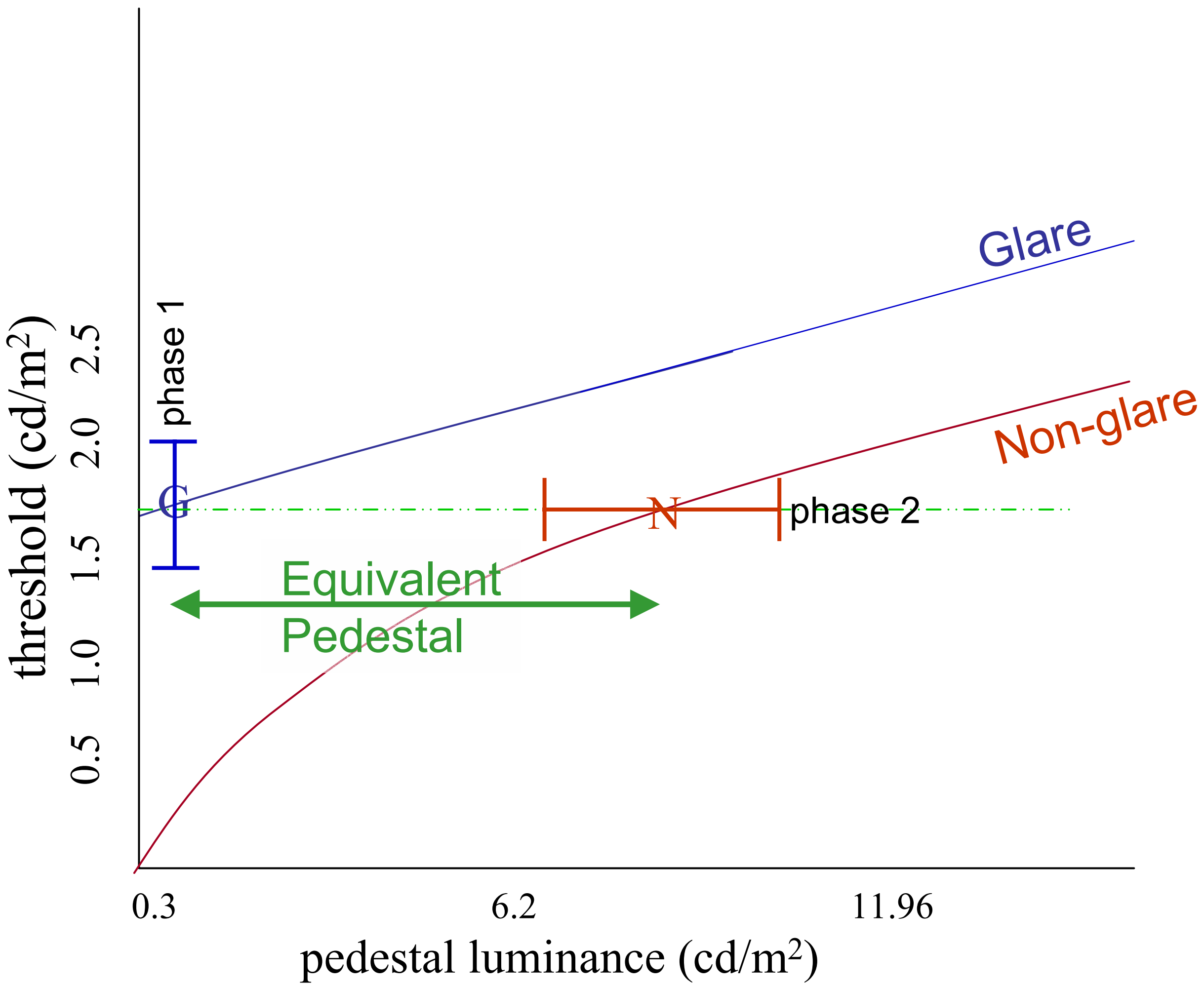

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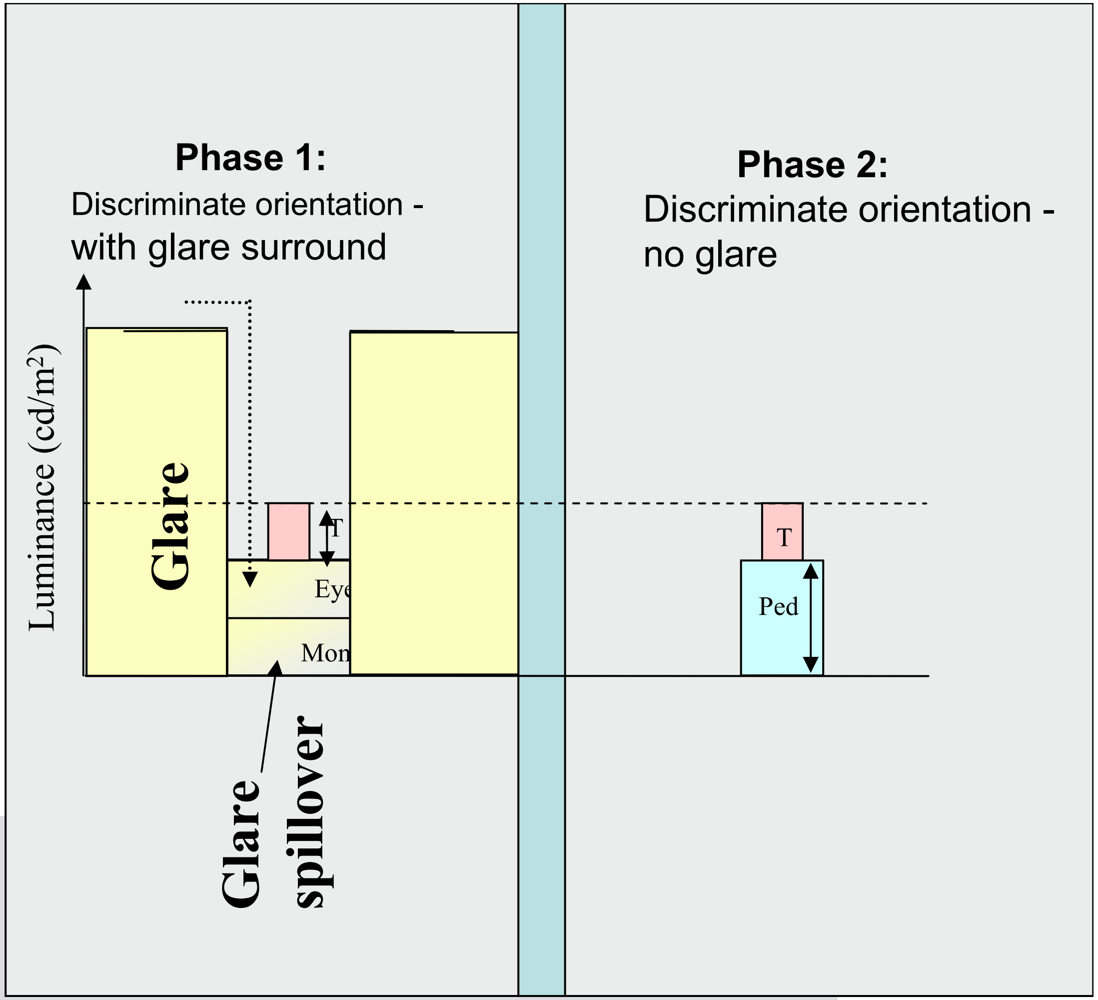
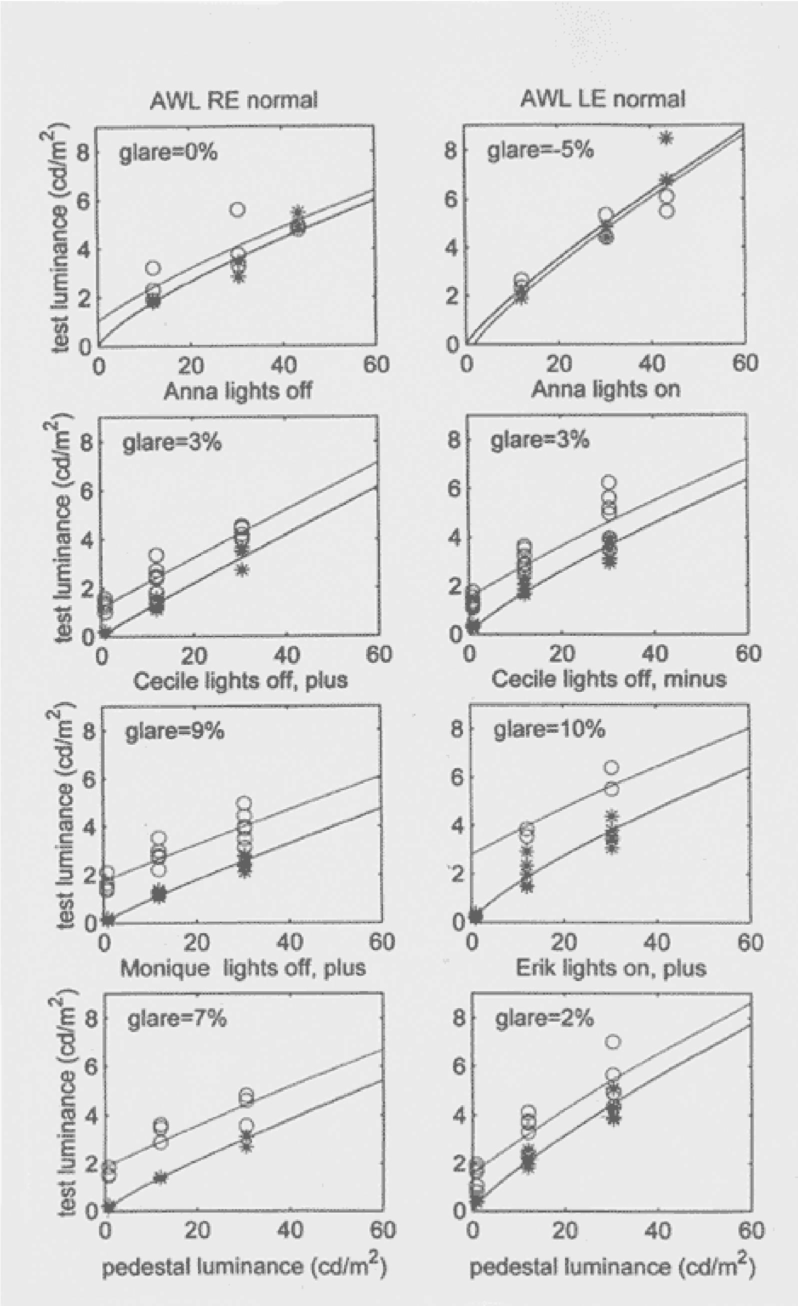


th = W(ped + GI* glare)
Phase 1: th_1 = W(GI*glare)
Phase 2: th_2 = W(ped)

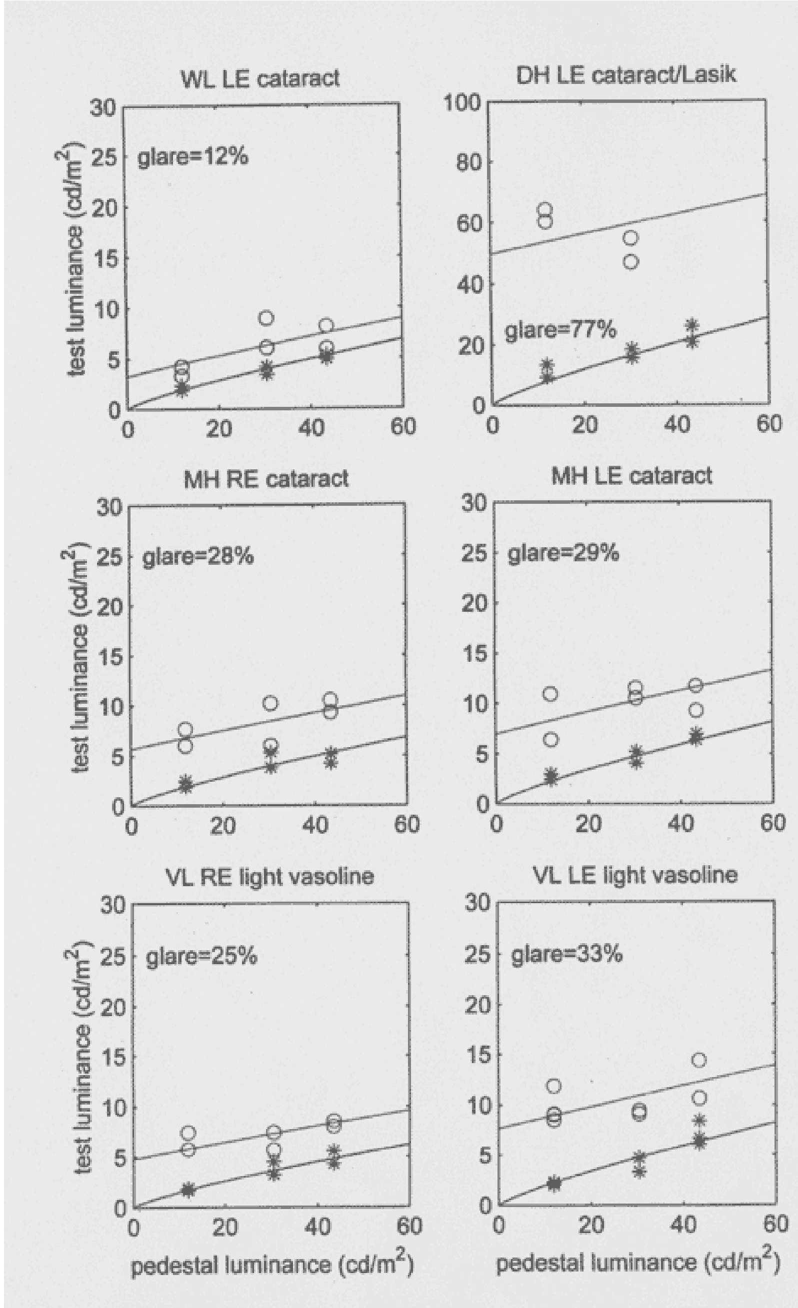
th_1=th_2 implies GI*glare = ped   or **GI = ped (cd/m²)/glare (cd/m²)**

Suppose with glare = 100 cd/m² and ped=0, the test threshold is 2.57 cd/m². And suppose with glare = 0 and test = 2.57 cd/m² the pedestal is 7 cd/m². The glare index of GI = 7/100 = 7% consists of scattered light in both the eye and the picture tube. We measured the picture tube glare to be 3%, thus the True Glare Index is 7% - 3% = 4%.

Normal Subjects



Abnormal Subjects



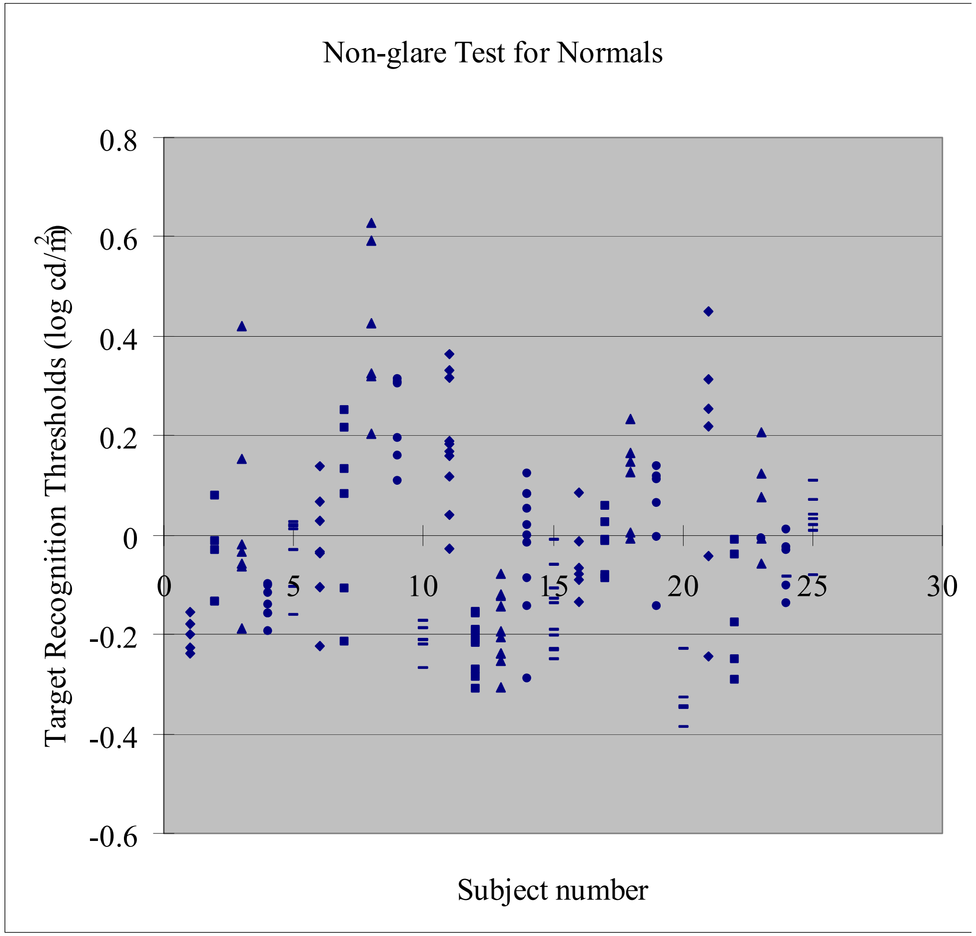
Population norms for non-glare condition

$$Th_{glare} = w^*Th_{individual\ non\text{-}glare} + (1-w)^*Th_{Population\ non\text{-}glare}$$

It is expected that subjects will be more similar on non-glare than glare condition. Bayes tells us to include some prior knowledge by averaging the non-glare measurement with the population mean.

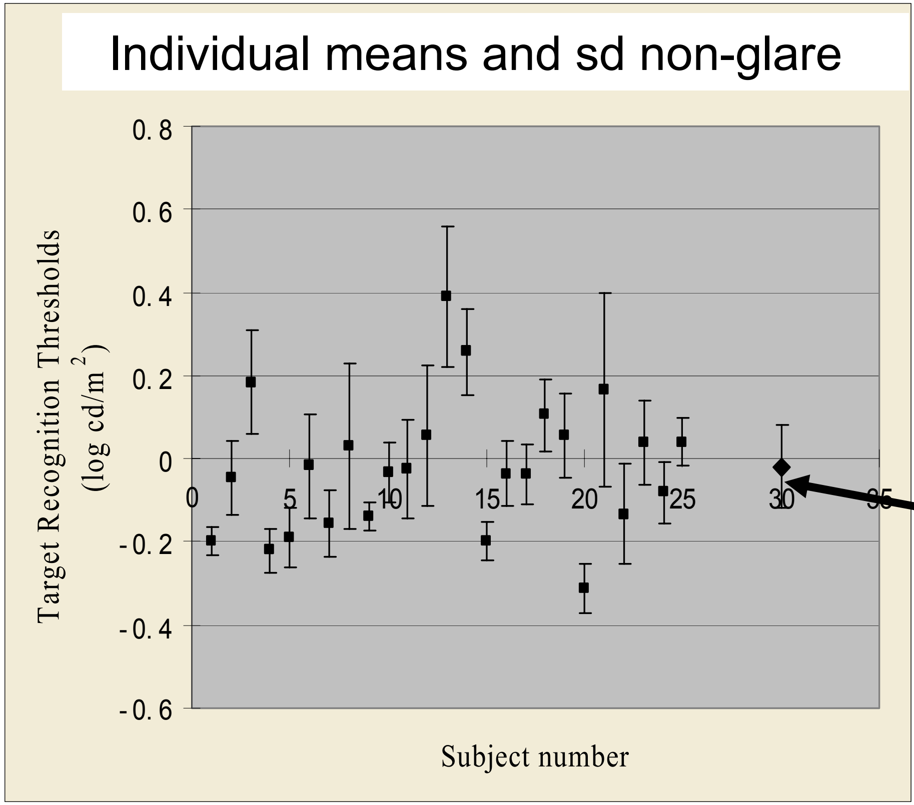
The weightings of the individual and of the population non-glare thresholds are the inverse of the variance of each.

The data is for getting population means.



Individual and population means and standard deviations.

The data shows that the variance of the population is about equal to the variance of each individual's threshold. Thus the weighting of the two should be about w = ½.



Population mean and standard deviation

Averaging the individual and population non-glare thresholds is conservative. That is, persons with high glare will tend to also have poor non-glare thresholds. By averaging their non-glare threshold with the population mean will exaggerate the GI. More runs would be useful to pin down the glare index..

Psychophysics details and questions

Is 8 alternative arrows (with stem and tip) optimal?

Can we simultaneously get a halo index and a scattered light index (remember the 180 deg errors).

What size target? Acuity vs. CSF

High and low confidence responses?

Are good clinical staircases available?
How to choose starting level and step size?

To what accuracy should acuity be assessed?

Is GI (%scatter>0.5 deg) a good index?

Questioning the Assumption

We assumed the effect of glare is due to the tails of the PSF acting as a background pedestal and raising test threshold by Weber's law.

However, there may be other factors besides a spillover can alter thresholds:

*distraction by surrounds

*inhibition (or facilitation) by nearby glare edge

Also, spillover isn't uniform across 1 deg center

Questioning measuring glare

Is it really useful to measure glare?

Is it really true that post-LASIK glare is much more severe at large pupil sizes?

Is the glare index (GI) an important step forward?

Summary

Refractive surgery patients still complain about night vision problems but they do fine on all acuity and CSF tests.

A new rapid test was proposed for measuring halos and scattered light with large pupils using a standard computer.

The glare index (GI = % of light scattered by more than 0.5 deg) is machine-independent.

The psychophysical method is pretty good and getting better.

The arrow target allows separate assessment of halo and scatter

Normal observers have GI <10% after the 3% scattered light in the monitor was removed.

For quick test one can spend less time on non-glare condition and do weighted average with population mean

More information at: cornea.berkeley.edu

How I plan to teach cylinder

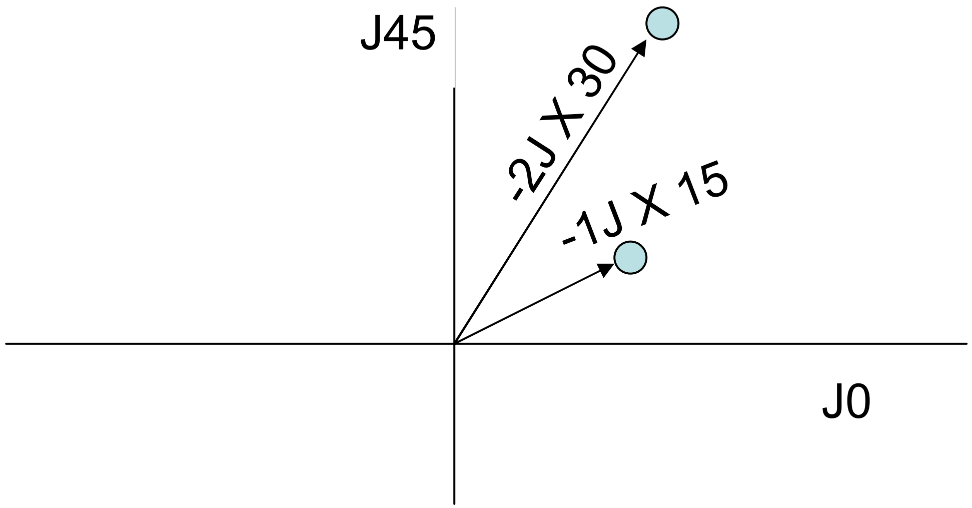
Standard minus cyl:	-5S -2C X 30
Jackson minus cyl:	-4M -1J X 30 ← no sign switch!!
Jackson plus cyl:	-4M +1J X 120
Standard plus cyl:	-3S +2C X120

Standard↔Jackson: M = S - C/2, J = C/2
or S = M + J, C = 2J

Change cylinder sign: S=S-C, C=-C, ang=ang+/-90
M=M, J=-J, ang=ang+/-90

I'll spend more time using Jackson notation than in the past

Summation of cylinders

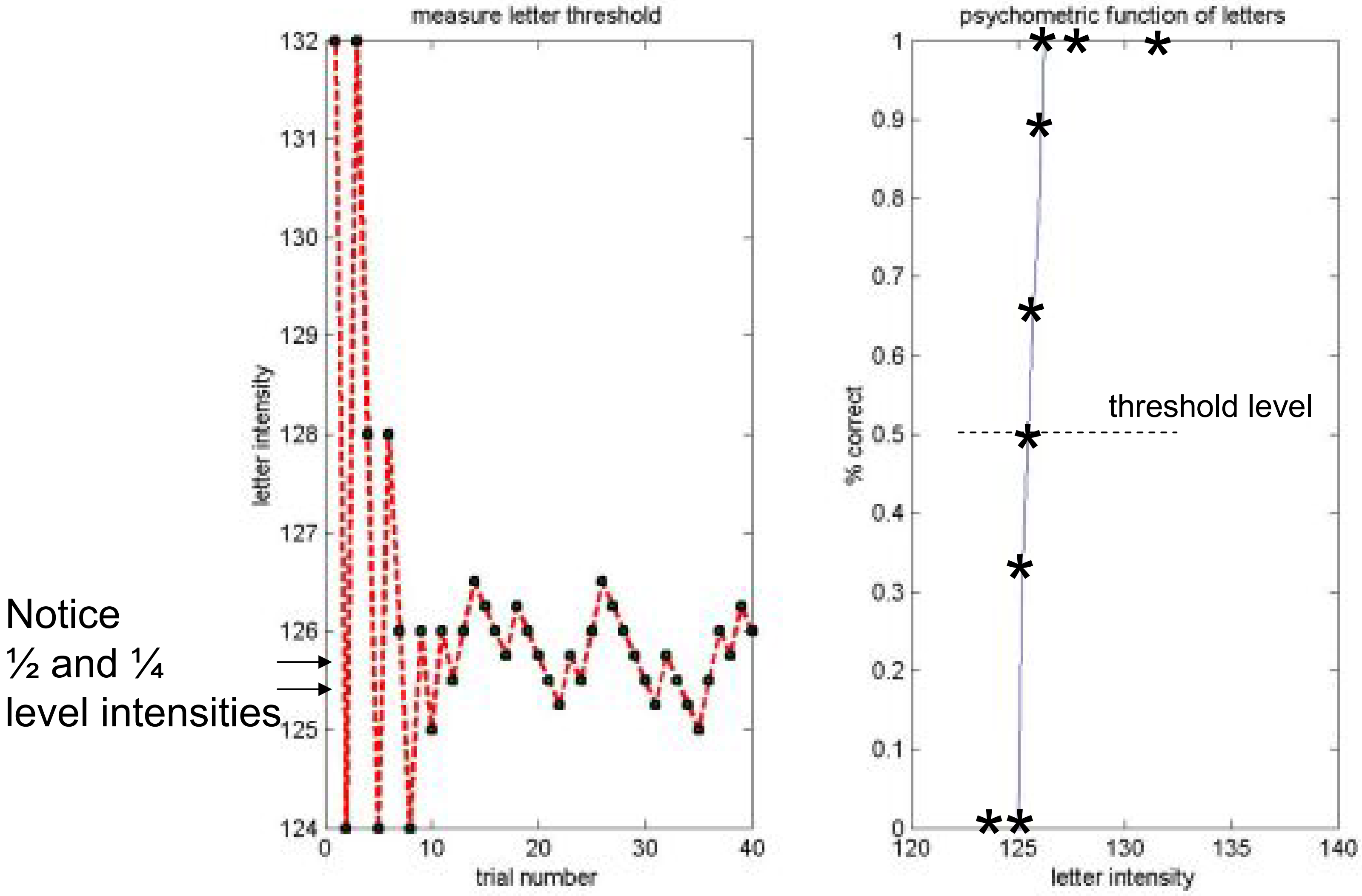


To add two cylinders double the angle and add the vectors.
There is no need to change the sign of the Jackson Cross Cylinder

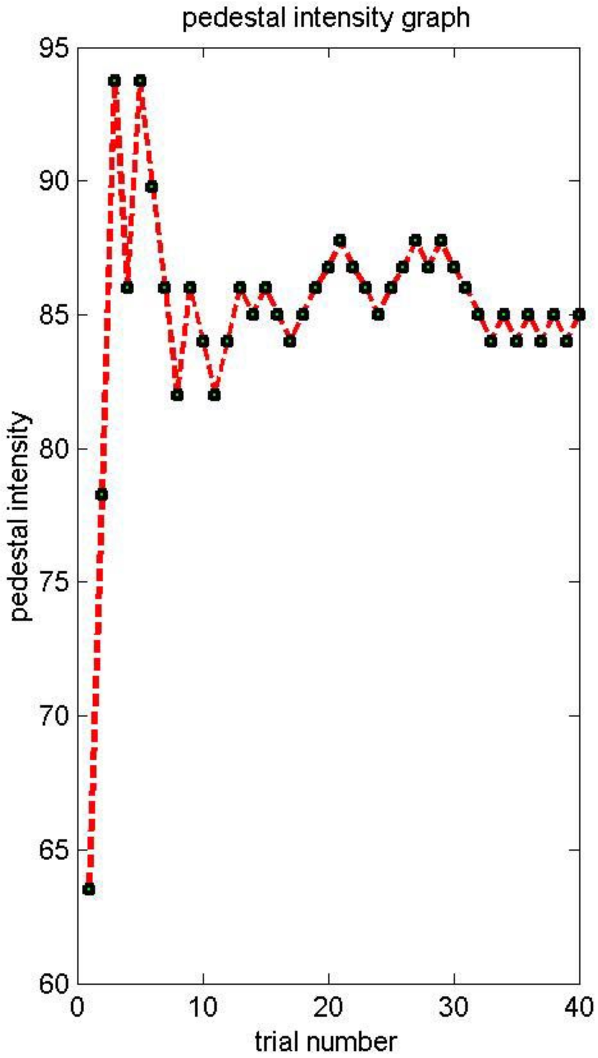
The simplest way to do the summation is to calculate the components along J0 and J45.
Students already need to do this type of calculation with prism.

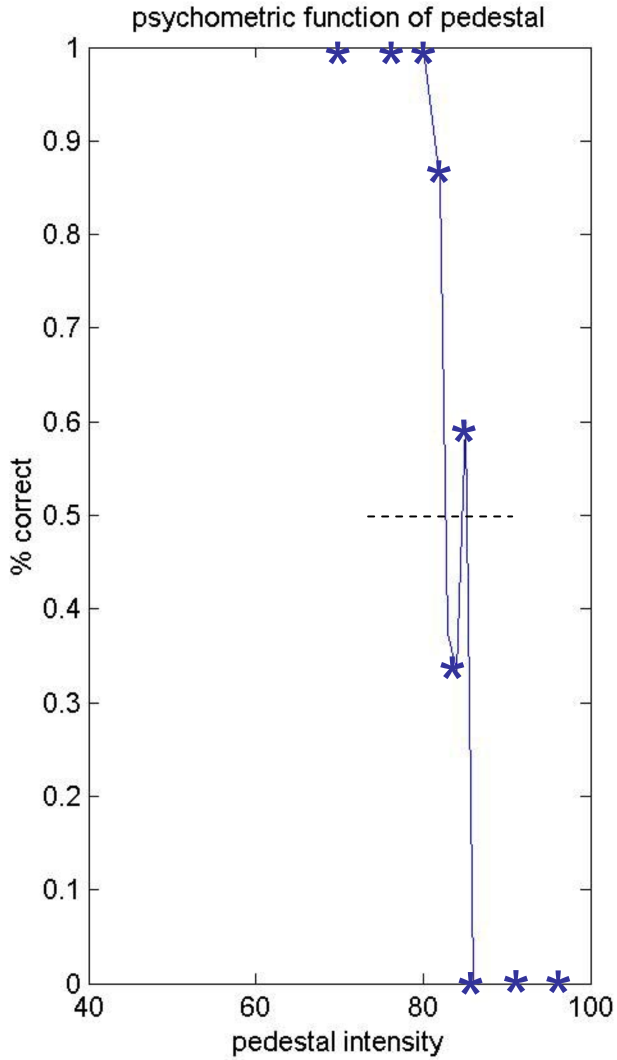
To do downstream vergence go to principal powers: M+J and M-J

Example of a staircase and psychometric function for phase 1 (glare present and vary test).



Example of a staircase and psychometric function for phase 2 (glare is not present and vary pedestal).

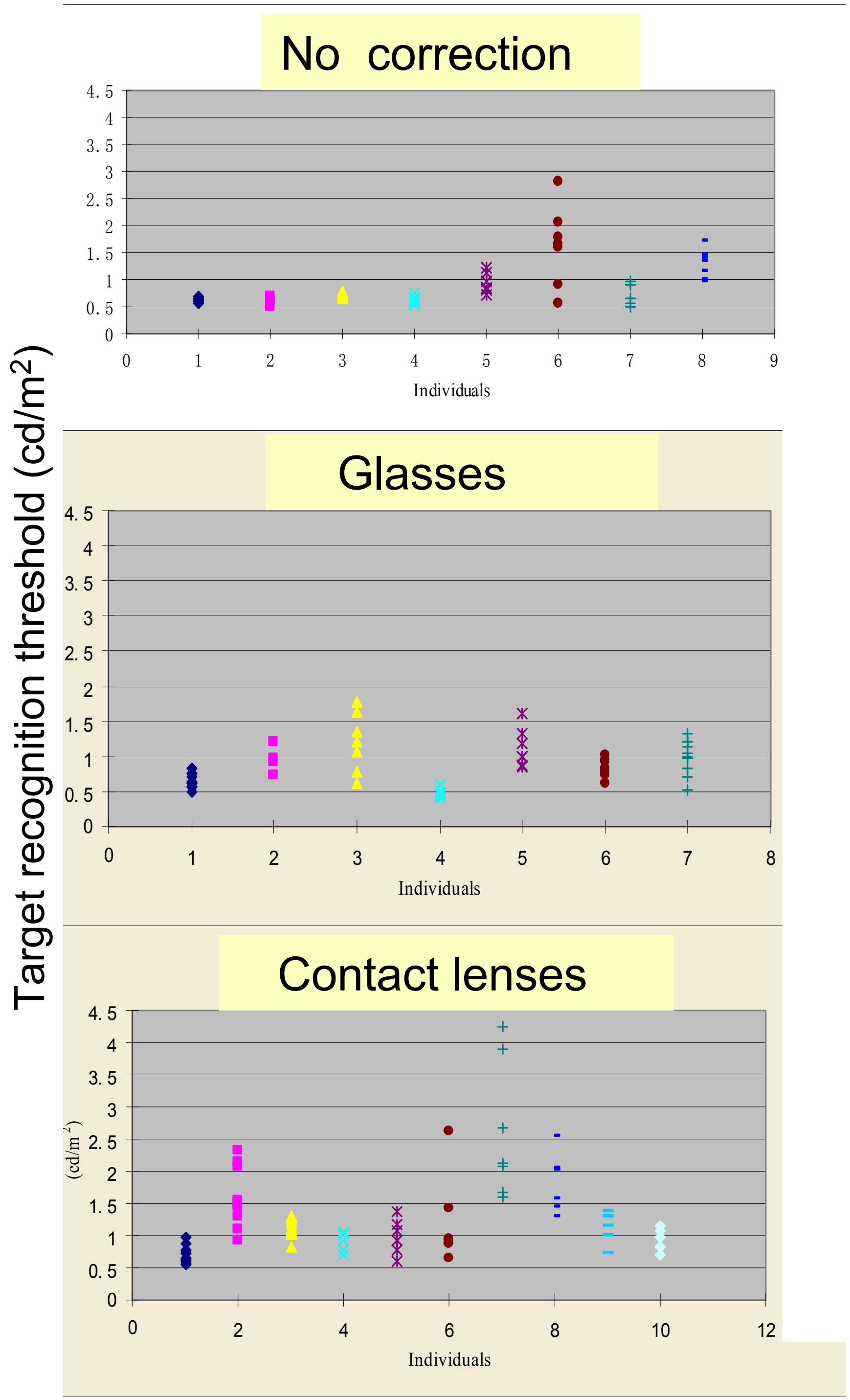




A curiousity: dependence of non-glare thresholds on whether spectacles or contact lenses were worn.

Individuals with no correction tended to have more consistent non-glare thresholds than those wearing correction. Contact lens corrections had poorest consistency.

Why??



Problems with previous glare testing

1. No good units for specifying glare.
   Glare is typically quantified by how many lines are lost with glare.
   But this is instrument dependent.

2. Glare constricts pupil so that aberrations are minimized.
   Not a good test for the night driving conditions of many complaints.

Our proposed solutions.

1. Glare index is % of photons scattered by more than ½ degree.
   Use a 1 deg diameter glare source.

2. Do test in dark room with subject given appropriate refraction.
   Flash glare and test for less that 200 msec before pupil constricts.