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Empirical validation of Quest+ in PSE and JND estimations in visual discrimination tasks

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Introduction

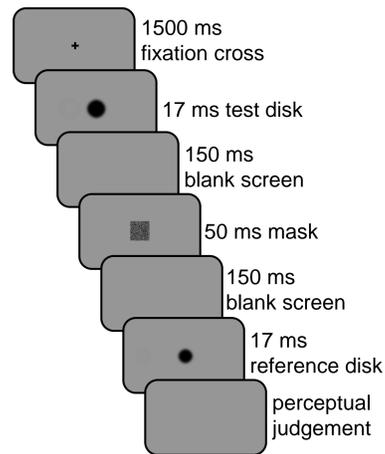
Compared to the gold-standard Constant Stimuli (CS) procedure, adaptive procedures enable reliable threshold estimation while reducing the number of trials by concentrating stimulus presentations around observers' supposed threshold. Here, the stimulus value for the next trial depends on observer's responses to the previous trials.

One recent substantial improvement of Bayesian procedures is to also enable slope estimation^[1] (related to discrimination sensitivity). The Bayesian Quest+ procedure (Watson, 2017)^[2], a generalization and extension of Watson and Pelli's^[3] Quest procedure, includes this refinement. Surprisingly, this procedure is barely used.

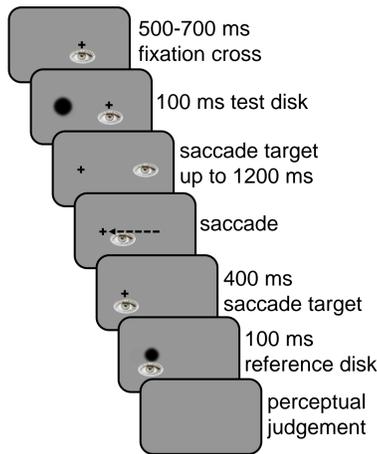
The goal of the present study is to assess the efficacy of this procedure empirically. We compared points of subjective equivalence (PSEs) and discrimination sensitivity (JNDs) obtained in four visual discrimination tasks with the **Quest+**, **Constant Stimuli** and **simple up-down staircase procedures**. We expected to find comparable threshold and slope estimates between procedures.

Methods

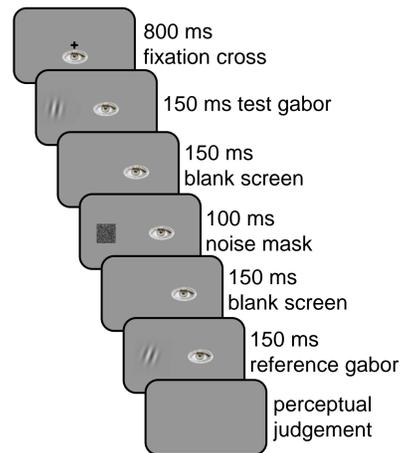
Expt. 1A: size discrimination in central vision N=21



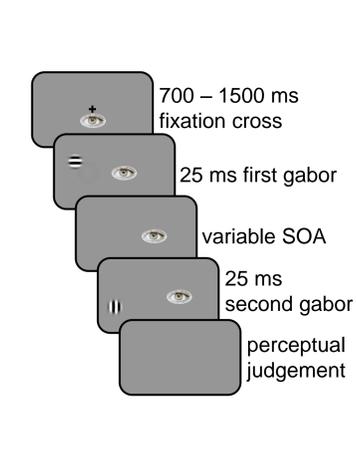
Expt. 1B: size discrimination in peripheral vision^[4] N=19



Expt. 2: feature orientation discrimination in peripheral vision N=20

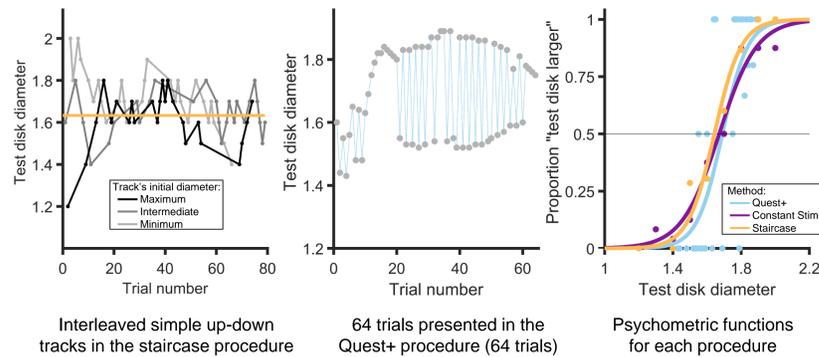


Expt. 3: time perception in peripheral vision N=21



Results

Data of one representative participant (in Expt. 1A)



Pairwise Pearson (r_p) or Spearman (r_s) correlations between PSE values and between JND values of the different procedures, for each experiment

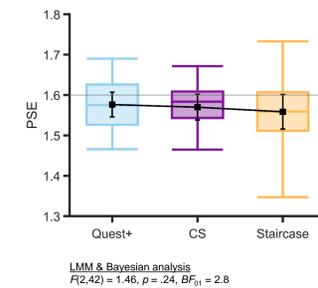
		Expt. 1 (N=21)	Expt. 1B (N=19)	Expt. 2 (N=20)	Expt. 3 (N=21)
PSE (PSS)	Q+ and CS	$r_p(19) = .85 (p < .001)**$	$r_p(17) = .54 (p = .017)*$	$r_p(18) = .69 (p < .001)**$	$r_p(19) = .25 (p = .271)$
	Q+ and Staircase	$r_s(19) = .86 (p < .001)**$		$r_p(18) = .45 (p = .046)*$	$r_p(19) = .42 (p = .057)$
	CS and Staircase	$r_s(19) = .79 (p < .001)**$		$r_p(18) = .45 (p = .045)*$	$r_p(19) = .46 (p = .036)*$
JND	Q+ and CS	$r_p(19) = .75 (p < .001)**$	$r_s(17) = .52 (p = .024)*$	$r_s(18) = .62 (p = .005)**$	$r_p(19) = .40 (p = .073)$
	Q+ and Staircase	$r_p(19) = .32 (p = 0.16)$		$r_s(18) = .42 (p = .065)$	$r_p(19) = -.14 (p = .055)$
	CS and Staircase	$r_p(19) = .19 (p = 0.41)$		$r_s(18) = .59 (p = .007)**$	$r_p(19) = .46 (p = .035)*$

** p -value is less than .001; * p -value is less than .05

Note: In Expt. 1B, only the Quest+ and Constant Stimuli procedures were compared.

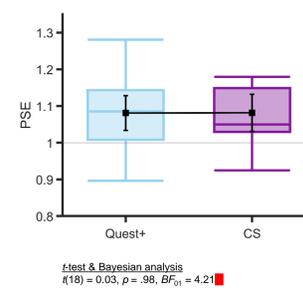
PSEs did not differ between procedures:

Expt. 1A: size discrimination in central vision



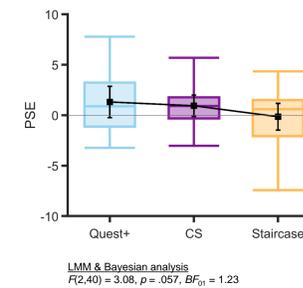
LMM & Bayesian analysis
 $F(2,42) = 1.46, p = .24, BF_{01} = 2.8$

Expt. 1B: size discrimination in peripheral vision



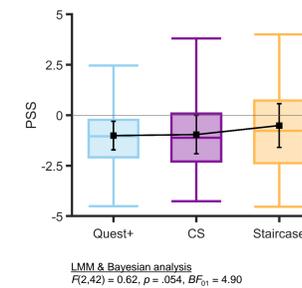
t-test & Bayesian analysis
 $t(18) = 0.03, p = .38, BF_{01} = 4.21$

Expt. 2: feature orientation in peripheral vision



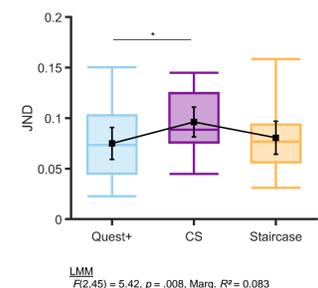
LMM & Bayesian analysis
 $F(2,40) = 3.08, p = .057, BF_{01} = 1.23$

Expt. 3: time perception in peripheral vision

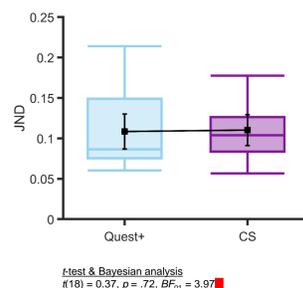


LMM & Bayesian analysis
 $F(2,42) = 0.62, p = .534, BF_{01} = 4.90$

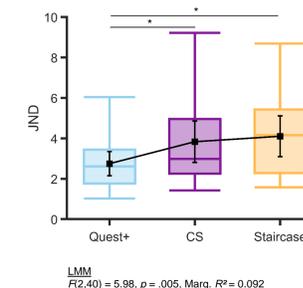
JNDs obtained with the 64-trials Quest+ procedure were smaller than the JNDs obtained with the ~180 trials of the Constant Stimuli procedure



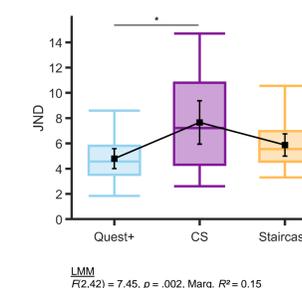
LMM
 $F(2,45) = 5.42, p = .008, Marg. R^2 = 0.083$



t-test & Bayesian analysis
 $t(18) = 0.37, p = .72, BF_{01} = 3.97$

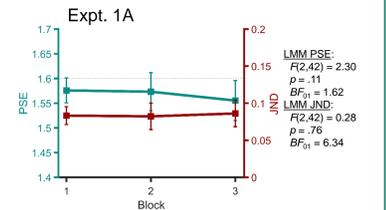


LMM
 $F(2,40) = 5.98, p = .005, Marg. R^2 = 0.092$

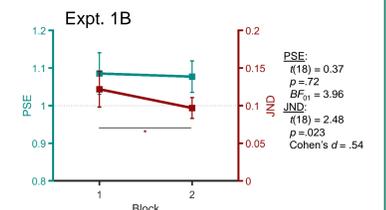


LMM
 $F(2,42) = 7.45, p = .002, Marg. R^2 = 0.15$

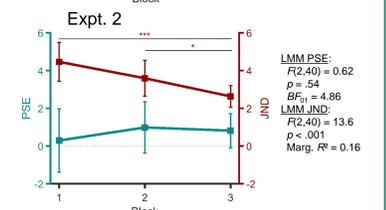
Learning effects: sensitivity increased in peripheral vision



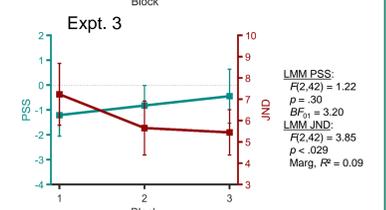
Expt. 1A
LMM PSE:
 $F(2,42) = 2.30, p = .11, BF_{01} = 1.62$
LMM JND:
 $F(2,42) = 0.28, p = .76, BF_{01} = 6.34$



Expt. 1B
PSE:
 $t(18) = 0.37, p = .72, BF_{01} = 3.96$
JND:
 $t(18) = 2.48, p = .023, Cohen's d = .54$



Expt. 2
LMM PSE:
 $F(2,40) = 0.62, p = .54, BF_{01} = 4.86$
LMM JND:
 $F(2,40) = 13.6, p < .001, Marg. R^2 = 0.16$



Expt. 3
LMM PSS:
 $F(2,42) = 1.22, p = .30, BF_{01} = 3.20$
LMM JND:
 $F(2,42) = 3.85, p < .029, Marg. R^2 = 0.09$

Conclusion

The present study empirically validates the Quest+ as an efficient and quick method to determine perceptual thresholds. Quest+ threshold estimations were as precise as the estimations obtained with the gold-standard Constant Stimuli procedure or the widely used staircase procedure. Sensitivity estimations were however overestimated. This issue might be overcome by increasing the number of trials (beyond 64) and/or by using appropriate priors.

Quest+ has proved to be generalizable to different stimulus dimensions involved in perception: size, orientation and temporality. These findings incite us to use this Bayesian method in other psychophysical tasks and sensory modalities.

References

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- Watson, A. B. (2017). QUEST+: A general multidimensional Bayesian adaptive psychometric method. *Journal of Vision*, 17(3), 10-10.
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