Development of Contrast Sensitivity in children using a novel child-friendly method

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Background

- There exists disagreements on the time course of the development of contrast sensitivity in children. This knowledge may influence decisions about when and if a treatment method is useful in children [1].
- This disagreement is due to lack of a robust, child-friendly measure of the CSF.
- Bayesian adaptive estimation (e.g., the "qCSF[2]") provides faster and more robust measures of CSF. However, this has not been tested in children yet.

Aims

- Evaluation of a novel implementation of Bayesian adaptive CSF estimation, using QUEST+: Assessment of the accuracy, speed, and test-retest reliability of this novel method in children.
- Quantifying the development of CSF in children aged 4 – 14 years.

Methods

Participants: 59 children aged 4-14 years and 28 adults (see Fig 5 for age distribution). Participants had normal or corrected-to-normal vision and had no history of non-refractive visual impairment.

Stimuli: Horizontal Gabor patches: ranging from 2 to 30 cycles per degree (cpd) in Spatial Frequency, and from 0.0001 to 1 in Michelson Contrast. The Gabor patches were presented at 3.8° eccentric.

Procedure: Four alternative forced choice (4AFC) detection. Participants completed the same test using two different algorithms: a weighted staircase (the reference standard) and QUEST+ (the novel comparison).

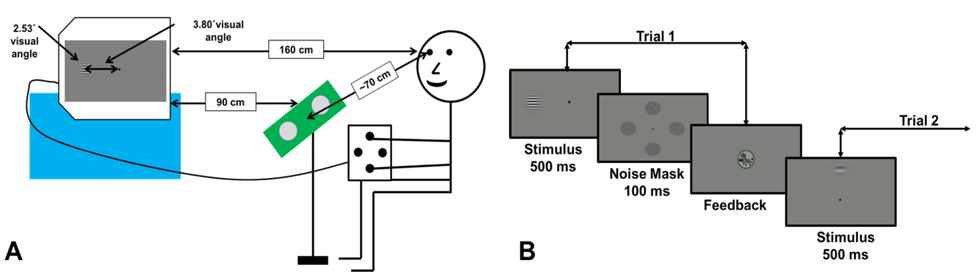

Fig 1. Experiment set-up. **A)** An eye-tracker (Tobii X120) was used to record the participant's gaze location. **B)** Each trial started with a fixation point and continued by presentation of the stimuli and presentation of feedback (i.e., happy zebra (hit) or sad face (miss)).

Reference Algorithm: 8 weighted "down-2 up-1" staircases performed independently at 8 spatial frequencies (CSF fitted post-hoc).

Test Algorithm: A 3-parameter CSF model (with a 2D stimulus space) fitted using QUEST+[3] (see Fig 2 for details). The key advantages of the QUEST+ algorithm are that it: 1. provides rapid and flexible estimation of the parameters of a psychophysical model, 2. using prior information, advises the user on the most appropriate stimuli to present and testing termination time, 3. determines the maximally informative stimulus on each trial, 4. fits arbitrarily complex models.
Our (MATLAB) implementation of QUEST+ is freely available at: https://github.com/petejonze/QuestPlus.

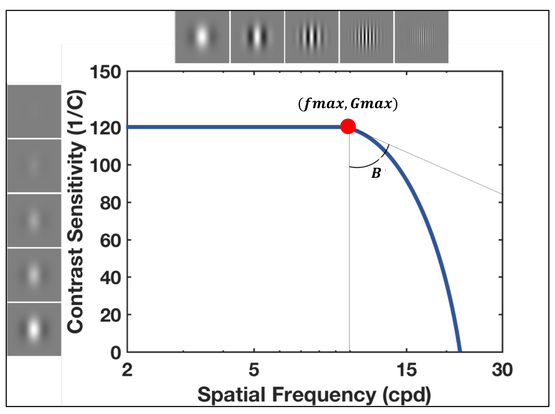

Fig 2. Our QUEST+ CSF estimation model (similar to the qCSF[2]). The model has 3 free parameters: (1) peak contrast sensitivity, G_{max}; (2) peak frequency, F_{max}; (3) rate of fall-off, B. The model also contained 3 fixed parameters: lapse rate (0.1), psychometric slope (3), and guess rate (0.25). The stimulus (i.e., Gabor patch) has two parameters: frequency and contrast.

Results

Benefits of our novel test in comparison to conventional methods

There were no significant differences in CSFs acquired using QUEST+ and the adaptive staircase after 50 trials (~2 minutes), providing substantive speed benefits in comparison to the traditional staircase method (~12 minutes). In addition, Estimates were more reliable with the QUEST+ than with the traditional staircase method. This was true for all 3 parameters and both age groups, although children's measures were consistently less reliable than adults.

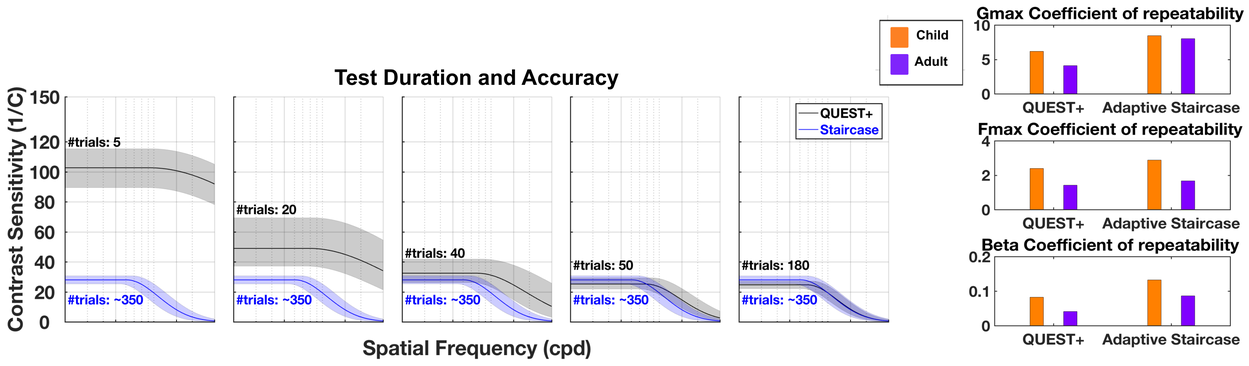

Fig 3. Test duration, accuracy and reliability. **A)** Mean ± 95%CI CSFs: the QUEST+ CSF (black) and the adaptive staircase method (blue). Each panel shows the average QUEST+ CSF estimate for all the participants obtained with different number of trials (adaptive staircase CSF estimate using all ~350 trials is shown in every panel, for reference). Shaded region: bootstrapped $CI_{95\%}$. **B)** Coefficient of repeatability for each of the three CSF estimation parameters, broken down by method and age-group (orange: child, purple: adult). **Larger values = less reliable**.

Development of contrast sensitivity

Based on the CSFs acquired using our novel child-friendly method, there were significant difference in contrast sensitivity at low frequencies (i.e., 2 to 5 cpd) across children and adults.

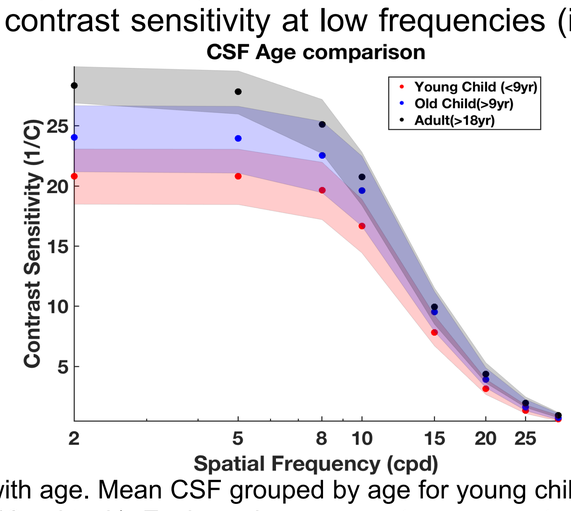

Fig 4. Development of CSF with age. Mean CSF grouped by age for young children (<9yr; red), old children (>=9yr; blue), and adults (>=18yr; black). Each marker represents mean contrast sensitivity as a function of spatial frequency: derived using the combined data from both adaptive methods (QUEST+ and Staircase). The shaded region is the bootstrapped $CI_{95\%}$.

CSF Parameters across age

Parameters f_{max} and *Beta* were not observed to change with age. However, G_{max} (peak contrast sensitivity) did exhibit a significant developmental effect (F_{112} = *23.2, p* < .001, r^2 = 0.17). Development of contrast sensitivity (7.44; mean difference between young children and adults) was larger than the individual variability between observers (4.60; median absolute deviation from the regression line shown in the left panel of Fig 5).

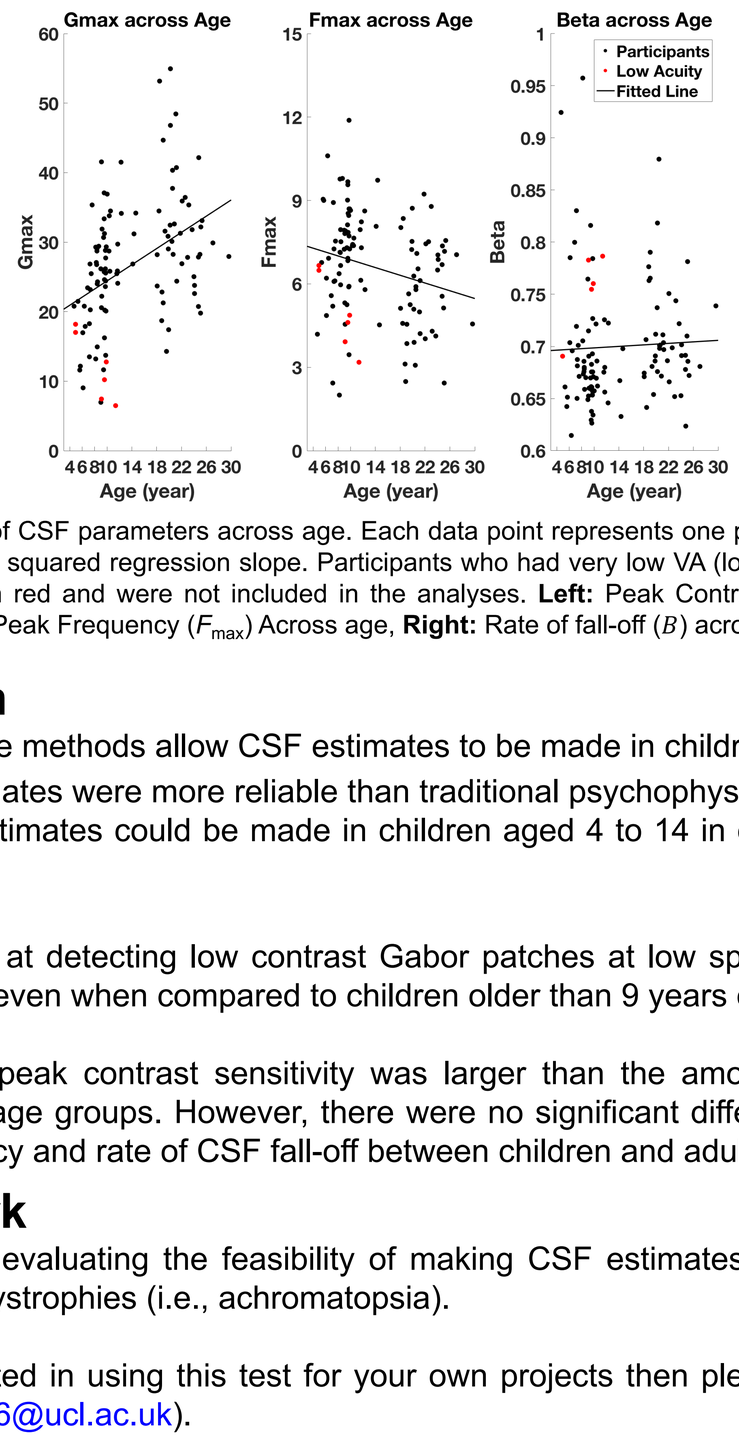

Fig 5. Development of CSF parameters across age. Each data point represents one participant. The black line is the least mean squared regression slope. Participants who had very low VA (lower than 6/9 Snellen acuity), are plotted in red and were not included in the analyses. **Left:** Peak Contrast Sensitivity (G_{max}) across Age, **Middle:** Peak Frequency (F_{max}) Across age, **Right:** Rate of fall-off (B) across Age.

Discussion

Bayesian adaptive methods allow CSF estimates to be made in children. Specifically:

- CSF estimates were more reliable than traditional psychophysical methods.
- Robust estimates could be made in children aged 4 to 14 in only 50 trials (~2 mins).

Adults are better at detecting low contrast Gabor patches at low spatial frequencies (i.e., 2 to 5 cpd), even when compared to children older than 9 years old.

Development of peak contrast sensitivity was larger than the amount of individual variability within age groups. However, there were no significant differences between the peak frequency and rate of CSF fall-off between children and adults.

Future Work

We are currently evaluating the feasibility of making CSF estimates in children with inherited retinal dystrophies (i.e., achromatopsia).

If you are interested in using this test for your own projects then please get in touch (m.farahbakhsh.16@ucl.ac.uk).

References

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

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