(577) iPad-based quick CSF implementation to assess contrast sensitivity
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Rationale
Acuity, which describes the smallest resolvable shape at high contrast, is the current clinical standard for assessment of visual sensitivity. However, acuity is relatively insensitive to the slow progression of many neurodegenerative eye diseases. Although vision is more fully described by the Contrast Sensitivity Function (CSF), which describes stimuli along the two dimensions of scale and contrast, clinical acceptance of CSF measurements has been hindered by impractically long testing times. Recently, Lesmes et al. developed the quick CSF method that substantially reduces testing times [1]. Here, we implement the quick CSF method on a handheld device (iPad) and evaluate its reliability and sensitivity.

Our test is:
- rapid (5-5 minutes testing time)
- low-cost and portable (iPad tablet)
- flexible (different background luminance levels, stimulus sets)
- precise (44 frequencies and 96 contrast steps, 11 bits luminance resolution).

The quick CSF method
Measuring thresholds independently at multiple spatial frequencies is inefficient because it does not take advantage of the characteristic shape of the contrast sensitivity function, which can be described with four parameters: peak frequency, peak sensitivity, bandwidth, and low-bandwidth truncation. The quick Contrast Sensitivity Function method [1] is a Bayesian adaptive procedure that always picks the most informative stimulus for the upcoming trial.

Other implementation considerations
Spatial frequency of the stimuli changes with viewing distance, and therefore viewing distance needs to be monitored. We have implemented algorithms that use the iPad’s front camera and face and pattern recognition techniques to estimate viewing distance even in unsupervised settings.

Digital displays typically have only limited grayscale resolution. We have implemented novel bit-depth-extending algorithms that use spatio-temporal dithering to enable precise display of contrast levels as low as 0.1% (down from 1.2% without such algorithms).

Methods I - dioptric blur
Ten observers were tested at a viewing distance of 40cm. Tests were run at self-reported correction and additional blur conditions (+3, +2, ±1, +0D). Gratings of different frequencies (25–380 c/deg) and contrasts (0.1–100%) were presented for 250ms at 3.4deg either left or right of fixation (spatial 2AFC) and subjects used the touch screen to respond. Each condition was run twice to assess reliability of the method.

Methods II - luminance
To assess the effect of different luminance levels, six observers ran qCSF sessions at iPad backlight levels of 25%, 50%, and 85%cd/m². In this test, gratings of different spatial frequencies (45–47 c/deg) and contrasts (2–100%) and of clockwise or counter-clockwise orientation were presented at fixation for 1000ms.

Methods III - viewing distance compliance
Four observers held the device at a set of specified distances. Viewing distance was monitored either by the iPad’s integrated face tracking technology or by tracking a circular target pattern that observers wore.

See presentation 2665 (Tue 9:45am) and posters 2761 and 2762 (Tue 8:30-10:15am) for further quick CSF applications!

Results I - dioptric blur
As expected, dioptric blur primarily affected the CSF’s high-frequency region (and thus CSF acuity), and not its peak height (top panel). We reliably obtained peak thresholds <1% for six subjects, which would be impossible with a standard 8-bit display.

We further calculated the Coefficient of Reliability between the first and second measurement session, over all subjects and defocus conditions. Both peak sensitivity and qCSF acuity showed good repeatability already using the first 60 trials only (125 and 295 log units); after 120 trials, these values improved to 0.2 and 0.57, respectively.

The bottom panel shows individual data for all ten subjects.

Results II - luminance
Averaged CSFs of six observers for three different luminance levels (top panel). Luminance affects both peak sensitivity and high-frequency cutoff. Area under the log CSF scores for individual observers (bottom panel). Error bars indicate confidence intervals (±2 SEM) on the qCSF’s estimate. For all six observers, the iPad-based test is sensitive enough to reliably discriminate between the 50 and the 85%cd/m² condition; for five observers, even intermediate luminance levels can be discriminated.

Results III - viewing distance
Marker-based viewing distance estimation is highly accurate (±0.1cm error, top panel) up to a distance of about 3m. Face tracking is less accurate, and the error depends on actual viewing distance and observer (bottom panel). However, both methods are reasonably accurate for typical arm-length viewing distances of the hand-held device (50–60cm). Whereas the marker-based algorithm is slightly more burdensome for the user, it also allows for monocular tracking while the user wears an eye patch.

References

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Commercial relationship disclosure
The authors declare an intellectual property interest in USPFO 7959358 (LL, ZL) and a provisional patent and an equity interest in Adaptive Sensory Technology (MD, LL, ZL, PB).

Conclusion
The quick CSF method reliably and rapidly estimates features of the contrast sensitivity function such as peak contrast sensitivity and CSF acuity. Here, we implemented the quick CSF method on a portable tablet device and tested the effect of illumination changes and dioptric blur on contrast sensitivity. We utilized the built-in camera to monitor viewing distance compliance. Our sensitive iPad-based test allows for easy and frequent CSF assessment outside the laboratory, e.g. at home or in medically underserved areas.