Defining Threshold Display Resolution

Shun-nan Yang, PhD
Vision Performance Institute
Pacific University, Oregon, USA
Psychophysical limit of visual acuity

![Diagram showing the relationship between blur level, physical distance, focal distance, and threshold.](image)
Limiting Factors

- Retinal density
- Optical aberration
- Accommodation/convergence lag
Critical Questions

• What is the threshold display resolution allowing full visual functions?
• How does it differ for different display platforms?
Benefits of High Display Solutions

• Eliminate the need of anti-aliasing/subpixel rendering and color fringe
• Allow smaller image size and farther viewing distance
• Permit richer image content but smaller screen
• Mitigate motion smearing (streaking)
Critical Display Resolution

PPI = 132

PPI = 163

PPI = 264

PPI = 326

Central human retina

iPad “Retina” display

cone size: 2.5 microns
New iPad (10.4 p/mm)

pixel size: 96 microns
iPad2 (5.2 p/mm)

Pablo Artal blog (http://pabloartal.blogspot.com/)
Quantifying Display Resolution

- Diagonal screen size
- Numbers of available pixels
- Viewing distance (VD) & extend of viewing angle

*Example:*

Diag. = 12”;
Screen pixels = 1280 (w) x 800 (h);
VD = 50 cm;
PPI (pixel per inch) = 126; \[ \frac{\sqrt{w_p^2 + h_p^2}}{\text{diag.}} \]
PPD (pixel per arcmin) = 1.07; \[ \tan^{-1}\frac{VD}{ppi} \]
Meta-analysis of Present Data

- Children reading (Yang et al., 2010a, 2010b)
- Smart Phone displays (Yang et al., in revision)
- Currently popular devices with proportionally scaled viewing distance.
Observed VD with different PPD

Pixel Size, Display Size and Viewing Distance

PPD (arcmin*10)

Diagonal Size (inch)

Viewing Dist. (inch)
Display platforms re. PPD

Display resolution adjusted by Viewing Distance

Pixel per degree (arcmin)

Diagonal screen size (inch)

1 arcmin threshold

3D

2D

Smart Phone

Tablet

Laptop

Desktop

55" HDTV
Mediating Display Factors

- Subpixel structure (vertical strip vs. PenTile)
- W/H ratio (16:9 vs. 4:3)
- Surface reflectancy (glossy vs. matte)
- Luminance source (OLED vs. LED)
- Viewing angle (orthogonal vs. oblique)
- Contrast/luminance/illuminance
Research Directions

• Test the threshold PPD (1 arcmin?) re. visual abilities.
• Determine how font size and screen size alter VD and threshold stimuli size.
• Assess how to vary image size and VD based on visual abilities.
• Examine task-specific (reading, acuity testing, & search spreadsheet) effects on threshold PPD.
• Develop standards and software to calibrate VD and font size, based on PPD and screen size.
Measure Threshold Display Resolution

• Distant step-forward method
  – Eliminate accommodation/convergence influence
  – Constant image size and screen size
Measure Effects of Image/Screen Sizes

• Proportionally scaled image size or screen size with freely-adjusted VD and constant PPD
Measure Effects of Visual Acuity on VD and Image Size Threshold

• Viewing distance and image size adjusted to visual abilities for seeing threshold stimuli.
Develop Standards for VD and Screen Size

**Viewing Distance When Resolution Becomes Important:**
Screen Size vs. Viewing Distance

- 480p, 720p, 1080p, 1440p all appear to be equivalent at these "far" viewing distances.
- Benefit of 720p starts to become noticeable.
- Benefit of 1080p starts to become noticeable.
- Benefit of 1440p starts to become noticeable.
- Resolutions higher than 1440p would start to become noticeable.

- Full benefit of 480p is visible.
- Full benefit of 720p is visible.
- Full benefit of 1080p is visible.
- Full benefit of 1440p is visible.
### Automated Calculation of VD and Screen Size

**VIEWING DISTANCE CALCULATOR**

1. Distance to main viewing location: ______ feet

2. Choose Screen Shape:  
   - [ ] 4:3 *(Standard TV Shape)*  
   - [ ] 16:9 *(Widescreen TV Shape)*

3. Choose Screen Size: *(Enter either a diagonal screen size or width):*
   - Choose [ ] Diagonal Size = ______ inches
   - or  [ ] Width = ______ inches

**Calculate**

**RESULTS:**

<table>
<thead>
<tr>
<th></th>
<th>Current Viewing angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>deg.</td>
<td></td>
</tr>
<tr>
<td>Feet</td>
<td>Maximum recommended viewing distance</td>
</tr>
<tr>
<td>Feet</td>
<td>Maximum recommended SMPTE viewing distance <em>(30 degree viewing angle)</em></td>
</tr>
<tr>
<td>Feet</td>
<td>Maximum THX viewing distance <em>(26 degree viewing angle)</em></td>
</tr>
<tr>
<td>Feet</td>
<td>Recommended THX viewing distance <em>(36 degree viewing angle)</em></td>
</tr>
</tbody>
</table>

**Screen size to achieve SMPTE minimum viewing angle**

```
"" = " 4:3 diagonal or " 16:9 diagonal
```
Limitations of Present Analysis

- VD is inferred based on limited observations.
- Testing conditions are varied.
- Subject age and visual ability are not systematically sampled.
Conclusions

• Threshold display resolution is defined by visual acuity, pixel size.

• Viewing distance, screen type, and screen size must be considered when choosing threshold resolution.

• Systematic measurements of VD and threshold resolution for optimal visual performance is sorely needed.