Visual Space in the Control Room

Optimizing Visual Information

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For a seated control room operator, their visual space is the space they can comfortably see without moving their head significantly. This is in the range of 70 degrees horizontally and 60 degrees vertically. Since about 15 degrees is typically reserved for the desktop work space (e.g. the computer keyboard), this leaves the upper 45 degrees available for display. (Use your index finger on your outstretched hand to trace out your visual space, comfortably moving your head and eyes but not your body).

At the very center of our eye's visual field is a narrow region of 100% visual acuity. This region, just three degrees of the entire visual arc, is called our foveal vision. In this region, the human eye, with 20/20 vision, can resolve a single point or "pixel" in the space of 1/60th of a degree of the visual arc, the best test of which is being able to clearly see two distinct black lines, each one pixel wide and one pixel apart at a distance just before they begin to blend together as a single line. So for each of the three degrees of foveal vision, vertically and horizontally, the eye can resolve 60 distinct pixels. We use the term pixel because we are going to relate this to display technology. Measuring visual acuity is a bit more complicated, but 'pixel' works well for the purpose of this discussion.

Beyond the foveal vision region, the eye's resolution falls off dramatically and is thereafter more able to detect movement than detail. This was useful to our ancestors when a sable toothed tiger might be lurking in their peripheral vision and very useful today when we are adjusting the radio or looking at our GPS while driving.

Try this: hold a printed page at arm's length, focus on a single word and you will see that the words on either side are barely readable until you move your eye. Indeed, we are always subconsciously scanning our visual space, using our very narrow foveal vision to see the detail.

Quantifying Visual Space

We can easily calculate a control room operator's available visual space in terms of pixels. If their usable visual space is in the range of 70 degrees horizontally and 45 degrees vertically and their foveal resolution is approximately 60 pixels per degree, then their useable visual space for display purposes will be in the range of 4,200 by 2,700 pixels - around eleven million pixels in all. Keep in mind that we have defined a pixel in terms of angular resolution and not absolute size and the operator's visual space consists of the same number of pixels regardless of whether they are located on personal desktop displays or on a distant, shared wall display. In a control room, it is typically a combination of the two. In order for an operator to see pixels located further away as clearly as those located closer, the pixels must be proportionally larger.
So to fully utilize an operator's visual space one should ideally present around 11 million pixels of information with all pixels properly scaled to be just viewable.

Using a little trigonometry, one can calculate the optimal pixel size for a given viewing distance or the optimal viewing distance for a given pixel size. At the 'optimal' viewing distance, a single pixel will just fit within an arc of 1/60th of a degree (a unit of measurement also known as one "minute"). Using this 1/60th of a degree angle and knowing the pixel size, the Tangent function provides us this simple formula: 'optimal' viewing distance = pixel size divided by 0.00029.
So if a display has a pixel size of 1mm (such as a 50" XGA resolution projection cube), the optimal viewing distance = 1/0.00029 = approx. 3,450mm or 3.45 meters = approx. 136 inches or 11 ft 4 in, meaning that if the closest operators are seated at least that distance from the display wall there would be no benefit to using a more costly, higher resolution (i.e. higher pixel density and smaller pixel size display) element.

These are typical screen pixel sizes for current generation displays along with the associated optimal viewing distances. This is for data display, not video where viewing a single pixel is not so critical.

Display Pixel Size and Optimal Viewing Distance

Notebook Screen	0.20 – 0.25mm	27" - 34"
Desktop Screen	0.25 – 0.3mm	34" – 41"
Projection Cube	0.7mm – 1.33mm	8ft – 15ft.

Note: for those wearing corrective lenses, 'optimal' close viewing distance, i.e. for viewing notebook and desktop screens, will be a function of the lens prescription and may be much closer.

Of course, operators are not typically viewing single pixels, just larger characters. But ideally, you would want a display with a resolution roughly matching the visual acuity of the closest viewers.

This is why we use the term 'optimal' viewing distance. It is the distance at which the pixel size and operator's visual acuity (assuming 20/20 vision) are perfectly matched.

In movie theaters the middle rows fill up first. This is because the screen resolution and size is optimized for that viewing location. For people forced to sit in the front rows, the movie experience can be quite uncomfortable: the screen's visual space is uncomfortably large and you are forced to turn your head to follow the action and the pixel size is uncomfortably large also, causing the movie to look grainy and less realistic.

The same holds true in a control room, except that the operator can't typically choose their seat. The appropriate display technology should be chosen by taking into account operators' visual space and visual resolution (both constants) and viewing distance (a variable) and designing a display system with the appropriate density of information that can be comfortably viewed by each operator.

Certainly as the control room size and average viewing distance increases the wall display should be larger, ceiling height permitting, and the pixel density should be lower (and the pixel size correspondingly larger) to accommodate the operators' viewing distance.

And if the control room has rows of operators the display wall will typically be longer, with each section viewed by different groups of operators, and have many more pixels in aggregate.

But each seated operator has only around 11 million pixels of comfortable visual space to fill and this is worth bearing in mind when choosing the appropriate wall display technology.