We have measured the relative perceptual scales for chromatic and luminance blur in dense textures comprised of color and luminance Gabors, using a modification of the method of paired comparisons. We find that the rate at which perceived blur grows with physical blur, when normalized to 1.0 for luminance, is 0.2 for red–green and 0.06 for blue–yellow blur. It is argued that the relatively severely compressed perceptual scales for red–green and blue–yellow blur are a contributary factor to the observation that when the color but not luminance layer of an image of a natural scene is blurred, there is little or no impression of blur (Wandell, 1995).

Introduction

The perception of blur is important for depth perception and for providing feedback about the eyes’ state of accommodation (Mather, 1997; Mather & Smith, 2002). Since most objects in the natural visual world are defined by suprathreshold differences in both chromatic (“color” from now on) and luminance contrast, it is important to know whether color vision contributes to our perception of blur, in line with its contribution to other spatial tasks (for a review, see Shevell & Kingdom, 2008). The role of color vision in blur perception has primarily been studied by measuring blur detection and blur discrimination thresholds using isoluminant gratings (Wuerger, Owens, & Westland, 2001), checkerboards (Webster, Mizokami, Svec, & Elliott, 2006), and images of natural scenes (Sharman, McGraw, & Peirce, 2013; Webster et al., 2006). In general, these studies show that blur defined along the red–green axis can be detected almost as easily as when luminance defined, but when defined along the blue–yellow axis, thresholds are somewhat worse. In the only study to date of color-blur appearance, Webster et al. (2006) required observers to adjust the amplitude spectra of isoluminant images until they appeared correctly focused, and repeated these measurements both before and after adaptation to blurred or sharpened images. Prior adaptation induced large and distinct changes in perceived focus for the color patterns, suggesting that color mechanisms are able to adjust to changes in the level of blur.

A different picture of the role of color in blur perception emerges from a compelling demonstration by Wandell (1995, plate 7). Wandell’s image is of a strikingly colored fish, in which the luminance, red–green, and blue–yellow layers of the image have been separately blurred. Yet only the image in which the luminance layer is blurred appears blurred. Figure 1 provides a version of this demonstration in which the luminance and color layers have been separately blurred to two different degrees, and suggests that the growth of perceived blur with physical blur is highly impoverished when only the chromatic layer is blurred.

Why is there so little impression of blur in the color-blurred image even when the color layer is severely blurred? One possibility is poor color resolution. Blurring an image removes the fine detail—if we are relatively insensitive to color fine detail, removing it
will not be noticed. However, in Figure 1 the color layer in the bottom right image is blurred well below the resolution limit, so poor color resolution would seem to be insufficient as an explanation. Another possibility is that the luminance layer masks the perception of the color blur. Both possibilities were recently tested by Sharman et al. (2013). They measured the minimal detectable blur in the color layers of images of natural scenes, presented either alone or in the presence of the luminance layer. They found that when the contrasts of the color and luminance layers were equated behaviorally, blur detection thresholds were similar for the color and luminance layers. However, when the two layers were combined, the color-blur thresholds were about 1.5 times greater. Sharman et al. suggested that the lack of perceived blur in Wandell’s (1995) as well as their own stimuli was not due to poor color resolution but instead due to luminance masking. They opined that the sharp edges in the luminance layer acted as boundaries that constrained the spread of color information, reducing the magnitude of the gradients associated with blur and hence making them less detectable. They argued that the effect was similar to the well-known Boynton effect, whereby the yellow of a straight yellow–white edge appears to spread into the concavities of a wavy black line positioned on the white side of the edge (Boynton, 1978). This explanation from Sharman et al. seems plausible given that in natural scenes, color and luminance edges tend to be spatially coaligned (Fine, MacLeod, & Boynton, 2003; Johnson, Kingdom, & Baker, 2005), minimizing the distance over which color spreading has to occur before making an impact on blur thresholds.

The effects in Figure 1, however, can also be seen in images that are devoid of both sharp luminance edges and between-layer spatial correlations. Figure 2 comprises nine Gabor textures, each constructed from a large number of Gabors with a range of orientations, spatial frequencies, and phases. In the top left this results in a “pink noise” texture—i.e., a texture with the characteristic $1/f$ amplitude spectrum of natural scenes.
but devoid of their characteristic structure (Kingdom, Hayes, & Field, 2001). Each texture comprises two layers, a luminance and a color layer. The Gabors are spatially uncorrelated, both within and between layers. The textures have been blurred to different degrees by removing increasing numbers of Gabors starting from the high-spatial-frequency end of the spectrum, which simulates the effect of Gaussian blurring (see later). As in Figure 1, only when the luminance layer is blurred (along the horizontal dimension) does one obtain a significant impression of blur.

Both Figures 1 and 2 appear to show that with mixed color-and-luminance stimuli, the rate at which perceived blur increases with physical blur is much greater for luminance than for color. Put another way, a given difference in physical blur translates to a large difference in perceived luminance blur but only a small difference in perceived color blur. The aim of the present study is to quantify this effect, specifically to establish the relative scaling of luminance and color blur when both dimensions are present in the stimulus, and in stimuli that possess natural-scene statistics yet are devoid of sharp edges and between-layer correlations.

Scaling methods such as partition scaling and difference scaling, when applied to a single stimulus dimension, provide interval perceptual scales—that is, they capture the relative but not absolute perceived levels with the dimension of interest (see Kingdom & Prins, 2010, for a review). They therefore do not lend themselves to a comparison of perceptual scales between two, simultaneously present, stimulus dimensions both signaling the same image attribute. We have employed a novel (we think) version of the method of paired comparisons to deal with this scenario. In our method, each stimulus comprises different relative amounts of luminance and color blur. The stimuli are presented in pairs on each trial, and the subject is required to indicate which member of the pair appears more blurred. Example pairs are shown in Figure 3. It is important to emphasize that like most scaling methods, the method here is based on stimulus appearance, not performance, in that there is no correct and incorrect response on each trial. One feature of the method is that the results can be divided into two groups of trials.

The second group of trials consists of those trials in which both the color and luminance blurs are different between the members of each forced-choice pair, as in Figure 3a. These are generically termed “luminance and color” trials. It is the data from these trials that can be used to determine the relative perceptual scales of color and luminance blur, as it is in these trials that the two dimensions are in competition.

The second group of trials consists of those trials in which one or the other, but not both, of the color and luminance blurs differ between the members of each forced-choice pair, as in Figure 3b and c. We term these “luminance or color” trials. For these trials there is in principle a correct answer, as only one of the two dimensions is differently blurred in the pair. The data from these trials can be compared to data obtained when the other dimension is altogether absent, in order to determine the effect of that other dimension on perceived blur even when it is ostensibly irrelevant to the task.

Methods

Subjects

Six subjects participated. FK and AB were authors, while EC, EM, GC, and DW were undergraduate
volunteers who were naïve as to the purpose of the experiment. All observers had normal or corrected-to-normal visual acuity and normal color vision.

Stimuli: Generation and display

The stimuli were generated by a ViSaGe graphics card (Cambridge Research Systems, Rochester, UK) and displayed on a Sony Trinitron F500 flat-screen monitor. The R (red), G (green), and B (blue) gun outputs of the monitor were gamma-corrected after calibration with an OptiCAL photometer (Cambridge Research Systems). The spectral emission functions of the R, G, and B phosphors were measured using a PR-640 spectroradiometer (Photo Research, Chatsworth, CA), with the monitor screen filled with red, green, or blue at maximum luminance. The CIE coordinates of the monitors’ phosphors were R: $x = 0.624$, $y = 0.341$; G: $x = 0.293$, $y = 0.609$; B: $x = 0.148$, $y = 0.075$.

In the combined color and luminance stimuli, the two components were generated on separate pages of the ViSaGe’s video memory, along with their own lookup tables. During stimulus presentation, the two video pages (and corresponding lookup tables) were alternated at the monitor frame rate of 120 Hz, resulting in a stimulus refresh rate of 60 Hz. For the conditions in which only one component (color or luminance) was presented, the component frame alternated with a blank screen. This method of display ensured that there were no within-frame interactions between the components and that any measured interactions were of a perceptual origin. The method of frame alternation meant that the contrasts of the components were half of that specified in the stimulus generation program, and are reported as such.

Stimuli: Gabor textures

Example stimuli are shown in Figures 3 and 4. Each texture was $192 \times 192$ pixels, subtending 3.65° at the viewing distance of 110 cm. The method for generating the Gabor textures is detailed elsewhere (Kingdom, Hayes, & Field, 2001), so only key points will be made here. In the baseline zero-blur condition, the Gabor textures approximated pink or $1/f$ noise. This was achieved by (a) setting the number of each spatial frequency of Gabor (all with a bandwidth of 1.6 octaves) to be proportional to the square of their spatial frequency, and (b) by making the texture very dense, by using a total of 36,864 Gabors per color layer. There were eight spatial frequencies of Gabor, ranging from 0.27–13.2 c/° at equal geometric intervals. There were 10 orientations (spaced evenly around the clock) and four phases (0°, 90°, 180°, and 270°) of Gabor. The Gabors were randomly positioned.

Blur was accomplished by removing Gabors beginning at the high-spatial-frequency end of the spectrum; examples are shown in Figure 4c through f. There were four levels of blur, obtained by removing zero, two, four, and five of the Gabor spatial frequencies. This resulted in the cutoff Gabor spatial frequencies given in Table 1 for each of the four levels of blur. The values were chosen from inspection of the luminance textures to give four distinct levels of perceived blur.

Removing Gabors from the textures to achieve different levels of blur is virtually identical to blurring the textures with a 2-D (two-dimensional) Gaussian kernel. This was confirmed by convolving the baseline Gabor texture (the one with all Gabors present) with a 2-D Gaussian kernel, then adjusting the standard deviation of the kernel until it maximized the correlation between the logarithms of the Fourier amplitude.
spectra of the Gaussian-filtered and Gabor-removed textures. For the four textures generated by Gabor removal, Table 1 gives the blur index (0–3), cutoff frequency, equivalent standard deviation of the Gaussian kernel, and log Fourier amplitude spectra correlations (all \( R > 0.995 \)).

Gabor textures were either single or double layered. Examples of each are given in Figures 3 and 4. For the single-layered textures there were four levels of blur, as already described. For the double-layered textures, each texture comprised two layers, either S and LUM or L – M and LUM. Since there were four levels of blur for each layer, this means that for each double-layer texture there were 4 \( \times \) 4 = 16 blur-level combinations. The two layers of each texture were presented on alternate pages of the ViSaGe’s video memory with their associated lookup tables.

### Stimuli: Colors

Each component pattern comprised two colors, defined as points straddling the midpoint of an axis in a modified version of the MacLeod–Boynton (MB) color space (MacLeod & Boynton, 1979). In this version of the MB color space, points are defined by combinations of long-wavelength-sensitive (L), middle-wavelength-sensitive (M), and short-wavelength-sensitive (S) cone contrasts. The three cone contrasts are defined as \( L_c = \Delta L/L_h, M_c = \Delta M/M_h, \) and \( S_c = \Delta S/S_h \) (Cole, Hine, & McIlhagga, 1993; Norlander & Koenderink, 1983; Sankeralli & Mullen, 1997; Stromeyer et al., 1985). The denominator in each cone-contrast term refers to the cone excitation produced by the background, which was a midgray color with CIE coordinates \( x = 0.282, y = 0.311, \) and luminance 40 cd/\( \text{m}^2 \). The numerator in each cone-contrast term represents the difference in cone excitation between the texture layer and background. The LMS cone excitations assigned to the texture layer were converted to RGB phosphor intensities using the cone spectral sensitivity functions provided by Smith and Pokorny (1975) and the measured RGB spectral functions of the monitor.

The three types of texture layer were defined along the three cardinal axes, termed here S, L – M, and LUM (luminance). The term “cardinal” implies that the colors uniquely stimulate one of the three post-receptoral mechanisms (Cole et al., 1993; Derrington, Krauskopf, & Lennie, 1984; Krauskopf, Williams, & Heeley, 1982; Norlander & Koenderink, 1983; Sankeralli & Mullen, 1997; Stromeyer et al., 1985). The relative cone-contrast inputs to the three post-receptoral mechanisms have been estimated to be as follows: \( kL_c + M_c \) for the luminance mechanism, \( \text{LUM} \) for the mechanism that differences L and M cone contrasts, and \( S_c - (L_c + M_c)/2 \) for the mechanism that differences S from the sum of L and M cone contrasts (Cole et al., 1993; Sankeralli & Mullen, 1997; Stromeyer et al., 1985). The parameter \( k \) determines the relative weightings of the L and M cone-contrast inputs to the luminance mechanism, varies between observers, and was established for each subject (see later). In order to isolate the three cardinal mechanisms, the stimuli must be constructed such that the L – M stimulus does not activate either the LUM or the S mechanism, the S stimulus neither the LUM nor the L – M mechanism, and the LUM stimulus neither the S nor the L – M mechanism. Kingdom, Rangwala, and Hammanji (2005) used the following combinations of \( L_c, M_c, \) and \( S_c \) to achieve this:

\[
\begin{align*}
\text{LUM} &= L_c + M_c + S_c \quad (1a) \\
L - M &= L_c - kM_c + S_c(1 - k)/2 \quad (1b) \\
S &= S_c. \quad (1c)
\end{align*}
\]

For the Gabor textures used in the experiments reported here, the contrasts of the S and L – M layers were set to the maximum possible for the CRT monitor such that <2% of pixels exceeded the lookup table. Clipping ensured that these pixels did not result in spurious colors. The contrast of the LUM texture was then adjusted downwards to produce a texture with roughly the same apparent contrast as that of the L – M texture. It proved difficult for our naïve subjects to reliably equate the perceived contrasts of the L – M, S, and LUM textures, so this was done by the senior author. However, as will be argued later, the conclusions of our study are not compromised by the precise contrasts employed. The resulting contrasts, defined in terms of the cone contrast of the maximum variation in the texture, are as follows: \( \text{LUM} \) (the contrast assigned to each of the three cones, i.e., \( L_c = M_c = S_c = 0.18; L - M (the \text{difference between } L_c \text{ and } M_c) = 0.18; S \text{ (the \text{contrast } S_c) } = 0.88. \)
Procedure: Measurement of isoluminance

Because of intersubject variation in the relative weightings of the L and M cones that feed the luminance mechanism, it was necessary to ensure that the colors combining L and M cone modulations were isoluminant. Although S cones have a negligible input to the luminance mechanism (Eskew, McLellan, & Giuliani, 1999), we also set the S stimuli to isoluminant in case of any calibration error. For both the L – M and S stimuli, we used the criterion of minimum perceived motion for a 0.5-° sinusoidal grating drifting at about 1.0 Hz. Previous studies have shown no significant variations in the isoluminant point for sinusoidal gratings with spatial frequency (Mullen & Boulton, 1992), so we assume that the isoluminant settings made here with gratings are valid for our spatial-frequency broadband Gabor textures. The contrasts of the L – M and S gratings were 0.025 and 0.25, respectively. Subjects pressed a key to add or subtract luminance contrast to the grating until the perceived motion was at a minimum. Each subject made between 20 and 30 settings. For the L – M stimuli, the average amount of luminance contrast added (or subtracted) was used to calculate the parameter $k$ in Equation 1b, which is the ratio of $L_c$ to $M_c$ in the putative luminance mechanism. For the six subjects, $k$ was determined to be EC = 0.79; EM = 0.96; GC = 0.83; AB = 0.68; FK = 1.61; DW = 0.93. For the S stimuli, the ratios of luminance contrast added to the S stimuli to achieve isoluminance were EC = 0.078; EM = 0.041; GC = 0.05; AB = 0.06; FK = 0.083; DW = 0.077.

Procedure: Paired comparisons

As already described, for each double-layered texture there were 16 blur-layer combinations. On each trial two double-layer textures were presented, which meant that there were altogether $16 \times 16 = 256$ possible pairings. However, identical pairs were not presented, and only one instance of each pair was presented per session, making the total number of trials 144 per session. On each trial, the two textures were presented side by side in the middle of the screen separated by 0.5°. Stimulus exposure duration was 500 ms, and the computer waited for a key press before commencing the next trial, so the session was self-paced. The task on each trial was to indicate by key press the stimulus that appeared more blurred. There were four sessions for each of the two double-layer conditions. For the single-layer textures there were just four conditions—the four different blur levels. Thus there were 24 combinations of blur level, excluding identical pairings. For these conditions a single session of 48 trials was employed.

Results

Figure 5 shows the results from one of the naïve observers, EC. For ease of exposition, the four levels of blur are indexed 0, 1, 2, and 3, and the cutoff frequencies and equivalent Gaussian standard deviations of the four blur levels are given in Table 1. Consider the top left graph, which shows the results for the trials in which both the LUM and L – M blurs were different between the two members of the forced-choice pair—call these the “LUM and L – M pairs. The black circles show the proportion of trials in which the stimulus with the physically more blurred LUM layer was chosen as the more perceptually blurred stimulus, as a function of its blur. The red circles show the proportion of trials in which the stimulus with the physically more blurred color layer was chosen as the more blurred, as a function of its blur. Straight lines have been fitted to both plots. The theoretical limits of these data are the diagonal and flat dashed lines. If a set of data fell perfectly along the diagonal line, this would mean that on every “both different” trial, the stimulus with the physically more blurred layer in question was chosen as the more perceptually blurred. At the other extreme, if a data set fell along the horizontal dashed line, it would mean that the layer in question did not contribute at all to the perception of the blur difference, with subjects choosing an equal number of times the more physically blurred and the less physically blurred stimulus as the perceptually more blurred stimulus.

The top middle panel shows the results for those trials in which only one or the other but not both LUM and L – M blurs were different in the forced-choice pairs—call these the “LUM or L – M” trials. Finally, the right-hand panel shows the results from two additional experiments. The red triangles are for a separate experiment in which the L – M layer was presented on its own, while the red circles are for a separate experiment in which only the trials from the main experiment were presented for which the L – M but not the LUM blurs were different—i.e., trials represented by the red circles in the middle panel. We collected data for this condition in a separate experiment in order to determine whether removing these trials from the context of “both different” trials had any impact on the results.

What do the data from this subject reveal about color-blur processing? First, compare the data in the top left and middle panels. For the trials shown in the top left panel, in which the LUM and L – M blurs were in competition, the subject almost always chose the stimulus in which the LUM blur was the greater, as evidenced by the fact that the black line is nearly diagonal and the red line almost flat. The middle panel, however, shows that when the LUM and L – M blurs were not in competition, because only one of the two
layers differed in blur, the subject tended to choose the physically more blurred stimulus as the more blurred, irrespective of whether it was LUM or L – M. However, the slope of the L – M data is still slightly lower than that of the LUM data, meaning that the subject did not designate the physically more blurred L – M layer as the more blurred quite as many times as she did for the LUM layer. This suggests a small amount of masking by the luminance layer, or rather that the L – M layer was masked by the LUM layer more than the other way around. The masking effect of the LUM layer is revealed more directly in the right-hand panel, which compares L – M alone with L – M in the presence of LUM layers with identical blurs in each forced-choice pair. One can see that in the absence of the LUM layer, L – M blur discrimination is close to perfect, and that the addition of the irrelevant LUM layer slightly reduces discriminability.

Moving onto subject EC’s S results (lower panels), a similar pattern can be seen, except that the data are all-around flatter than the L-M data: EC was worse at discriminating the S blurs compared to the L – M blurs. However, the reduced discriminability of S blur, made worse by the presence of an irrelevant LUM layer, is not sufficient to explain the complete absence of any contribution of S blur to perceived blur when in competition with the LUM blur.

Figure 6 plots the slopes of the fitted straight lines for the conditions shown in Figure 5 for all six subjects. Note that a slope of 0.3 corresponds to the gray diagonal dashed line in Figure 5, whereas a slope of 0 corresponds to the gray flat dashed line. The results are generally consistent across all six subjects, with the one exception of EM’s results for the conditions shown in the right-hand panels, in which the slopes for the with-LUM-mask and color-alone conditions are reversed in magnitude. This result appears to be an anomaly for which we confess to not having an explanation.

If we calculate the ratios of the slopes between the two conditions in each of the graphs in Figure 6, and average these (geometrically) across subjects, the values are as follows: For the L – M data (top panels), the ratio of L – M to LUM slopes is 0.193 for the “LUM and L – M” condition (left panel) and 0.675 for the “LUM or L – M” condition (middle panel). The comparable ratios for the S data (bottom panels) are 0.061 for the “LUM and S” condition (left graph) and 0.314 for the “LUM or S” condition (middle graph).
The ratio of slopes for color plus irrelevant LUM mask to that of color alone (right-hand panels) is 0.845 for the L/C0M and 0.507 for the S data.

### Discussion

The results from the modified paired-comparison experiment show that when two Gabor textures with a $1/f$ characteristic differ in both color and luminance blur, it is the latter that dominates the perception of blur difference. This demonstrates that the perceptual scale that relates perceived blur to physical blur is relatively compressed along the perceptual axis for color compared to luminance. To measure this quantitatively, we took the average L/C0M and S slopes of the “color and luminance” trials shown in the left panels of Figure 6 and normalized them to the LUM slopes. Figure 7 shows a schematic of the resulting relative slopes, calculated as 1.0 for LUM, 0.2 for L – M, and 0.06 for S. To facilitate comparison, the figure also shows perceived blur differences for two blur values (green lines) applied to all three slopes.

There are three caveats to the interpretation of Figure 7. First, our paired-comparison method only tells us about the relative contribution of color and luminance to perceived blur across a particular range of physical blurs that have been applied equally to the color and luminance layers of our textures. Had we used textures with a narrower range of luminance blurs and/or a wider range of color blurs, and indexed them as having the same ranges, then the slopes of the color and luminance blurs in the “color and LUM” trials would inevitably be closer. So our results are only relevant to the situation in which the same physical blurs are applied to the same physically defined textures. Second, had we used color and luminance layers with very different relative contrasts, the slopes in Figure 7 would also likely be different. For example, if the luminance contrasts had been much lower, the slopes of the color data would almost certainly be higher. In fact, however, the method we used to match the saliency of the color and luminance layers—i.e., matching their apparent contrasts when presented separately—may well have underestimated the relative saliency of the color layer when combined with the luminance layer: Kingdom, Bell, Gheorghiu, and Malkoc (2010) recently showed that when suprathreshold color and luminance stimuli that had been matched in saliency were combined, their relative saliencies shifted significantly in favor of color. Thus, if anything, we underestimated the relative saliency of the color layer in our stimuli and hence overestimated the slope of the perceptual scale for color blur relative to that of luminance blur. The third caveat is that the plots in Figure 7 must only be regarded as crude approximations.
to the functions relating perceived blur to physical blur, which are almost certainly not straight lines as shown. Four discreet levels of blur spread across the range of physical blur is not sufficient to derive the precise shapes of the transducer functions for blur.

How do our findings relate to the question of why there is only a minimal impression of blur when the luminance layer of Figure 1 is blurred? The results of the present study suggest a number of possibilities. Consider first the suggestion by Sharman et al. (2013) that the sharp luminance edges in the image constrain the spread of color information that on its own could effectively signal color blur. There are no sharp edges in our Gabor-texture stimuli, and the color and luminance layers are not spatially correlated, so it seems unlikely that luminance edges are the cause of the perceptual-scale compression for color blur found using our stimuli. However, we cannot rule out a contributory effect of luminance edges, given the small effect of luminance masking of color blur that we found (see right-hand panel of Figure 6). In the main, however, our results suggest that the perceptual scales for color and luminance blur in densely textured stimuli are simply very different. In turn, this suggests that the effects in Figure 1 in part result from a relatively compressed perceptual scale for color blur.

Georgeson, May, Freeman, and Hesse (2007) have recently advanced a model of luminance-edge blur coding in which blur is encoded as the scale of visual filter most responsive to the edge. In order for a filter-response peak in scale space to occur, the gains of the filter responses in their model are set to monotonically decrease with scale, in a manner somewhat akin to the low-frequency falloff observed in the contrast sensitivity function. According to the model, as the edge becomes increasingly blurred, the scale of the peak filter response shifts to lower spatial frequencies, signaling an increase in blur. One possible reason why the color system has a more compressed representation of blur is because the gain function that in Georgeson et al.’s model results in pronounced peaks in scale space is much shallower, resulting in poorly defined peaks in scale space and/or peaks that barely shift with changes in physical blur.

Conclusion

Using a modified method of paired comparisons, we have determined the relative perceptual scales for chromatic and luminance blur in dense textures made from spatially uncorrelated color and luminance Gabors. Relative to the perceptual scale for luminance blur, the scale for chromatic blur is markedly compressed. While the relative compression of the perceptual scale for chromatic blur appears to be in part due to masking from the luminance layer, it is primarily a property of the internal representation of chromatic blur itself. We argue that the relatively compressed perceptual scale for color is a contributory factor to the apparent lack of perceived blur in images of natural scenes in which only the color layer is blurred. Finally, our modified method of paired comparisons has general applicability for deriving relative perceptual scales for image attributes signalled by more than one dimension.

Keywords: blur, color vision, perceptual scale, fractal textures, modified method of paired comparisons

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