

Why Color Perception?

The development of an infant's visual system is not only tied to physiological development but also to visual cognitive training. Similarly, the photoreceptors and perception of neonatal are progressively mature over the first 3 months¹ and might potentially contribute to effective visual training. During this period, the photoreceptors are largely susceptible to red and less to the blue wavelength. Tests conducted by Adams et al. reveal that newborns primarily fail to discriminate achromatic blue and all the blue-constituent (e.g. yellow, green, etc.) patches while having less error in distinguishing red colour². The difference in error rate was almost 60%. In the experiment of Adams R. J. et. al., infants between 0 and 3 months were presented with pairs of colour cards. The colour cards contained a certain hue and an achromatic background of equivalent luminosity. Accordingly, for the age groups 0, 1, 2 and 3 months, if less than 50% of infants of a certain age group distinguished the shown colour of a particular wavelength, the age category was insensitive(Fail) to this colour, as in Table 1. If more than 50% could find the difference, the age category is considered sensitive(Pass) to this colour. If the proportion is around 50%, the results are considered inconclusive and the sensitivity is transitive(Transitory).

Table 1. Concluded chromatic stimulus of infants²

Age group	Chromatic Stimulus			
	Blue	Green	Yellow	Red
Newborns	Fail	Transitory	Fail	Pass
1 month	Transitory	Transitory	Fail	Pass
2 months	Pass	Transitory	Transitory	Pass
3 months	Pass	Pass	Pass	Pass

Algorithm

Relying on the experimental data, we interpreted the wavelengths of light used in the experiment as a colour to corresponding hue angles on the HSL colour wheel: Blue (475 nm) → 225°; Green (520 nm) → 135°; Yellow (580 nm) → 60°; Red (660 nm) → 33°. Each of these hue angles represents the central point of a colour region. A symmetrical region around these hue angles defines the region of influence for each colour: Bluish region: 180° –

270°; Greenish region: Symmetrically centred around 135°; Reddish region: Extending from 270° – 30° and spanning across the 0° boundary.

- **Insensitivity (Blue)**

If an infant of a certain age is insensitive to blue, its sensitivity will be lowest (zero) at the centre of the bluish region (225°), where the colour will appear greyish. Moving towards the edges of the bluish region (180° and 270°), sensitivity gradually increases, reaching full sensitivity. At these edges, colours are perceived normally.

- **Full Sensitivity (Red)**

For colours in the reddish region (270°–30°), an infant sensitive to red perceives all hues in this range with no change.

- **Transitive Sensitivity (Green)**

When sensitivity to green is transitive, the infant normally perceives colours within the greenish region only if the saturation is above 0.5 (on a 0–1 scale). Sensitivity decreases linearly for saturation values below 0.5, with zero sensitivity at the centre of the greenish region (135°) and full sensitivity at its edges. At the centre, colours appear greyish.

Since the study did not test infant colour perception in the magenta range, the magenta region on the HSL wheel is split proportionally between the reddish and bluish regions, inheriting their corresponding sensitivity properties.

Sensitivity Reduction

To imitate low sensitivity, saturation is adjusted with a Saturation Decrease Factor(SDF):

- SDF=0 at the centre of the insensitive or transitive region (where colours appear greyish).
- SDF=1 at the region's edges (where colours are perceived unchanged).
- SDF follows a linear mapping between 0 and 1 for intermediate hue angles.
- For regions of full sensitivity, SDF=1 for all hue angles, maintaining original saturation.

Each image is processed pixel by pixel, converting RGB values to HSL values. For each pixel, the hue angle determines the relevant colour region (e.g., bluish, greenish, reddish). The corresponding SDF is computed based on the hue and saturation values. Saturation is adjusted by multiplying it with the SDF, while hue and luminosity remain unchanged. The adjusted HSL values are converted back to RGB.

¹ Skelton, A. E., Maule, J., & Franklin, A. (2022b). Infant color perception: Insight into perceptual development. *Child Development Perspectives*, 16(2), 90–95.
<https://doi.org/10.1111/cdep.12447>

² Adams, R. J., Courage, M. L., & Mercer, M. E. (1994). Systematic measurement of human neonatal color vision. *Vision Research*, 34(13), 1691–1701.
[https://doi.org/10.1016/0042-6989\(94\)90127-9](https://doi.org/10.1016/0042-6989(94)90127-9)

Low Acuity Implementation

To replicate low acuity, we mapped the age of infants from 0 to 12 months according to the following: 0-2 months $\rightarrow 4\sigma$; 3-4 months $\rightarrow 3\sigma$, 5-6 months $\rightarrow 2\sigma$, 7-9 $\rightarrow 1\sigma$, from 10 months $\rightarrow 0\sigma$. Sigma(σ) indicates the variance for the Gaussian filter that mimics low acuity.

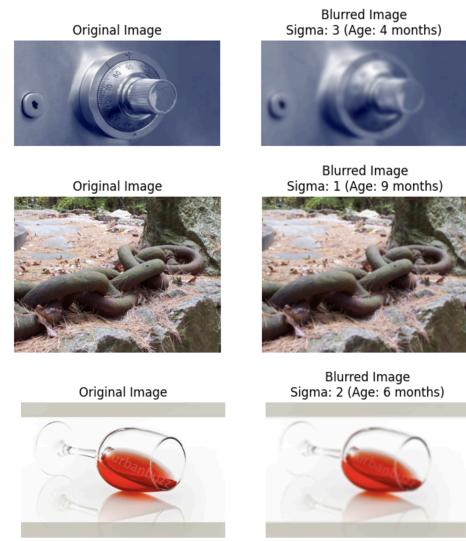
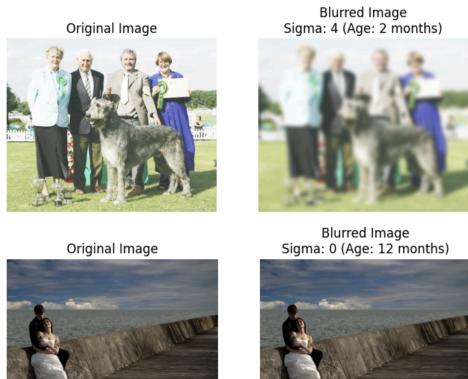
Runtime

Each image is processed pixel by pixel, converting RGB values to HSL values. For each pixel, the hue angle determines the relevant colour region (e.g., bluish, greenish, reddish). The corresponding SDF is computed based on the hue and saturation values. Saturation is adjusted by multiplying it with the SDF, while hue and luminosity remain unchanged. The adjusted HSL values are converted back to RGB. The dataloader processes images in batches of 100. At 0 months (newborn), sensitivity is limited for most colours. By 3 months, sensitivity is fully developed for all colours, requiring no image transformation. The low colour perception dataloader's runtime for each age category is compared to that for 3-month-old infants (baseline, no transformation), as in Table 2. Similarly, the low acuity dataloader applies blurring transform to images for ages up to 9 months only. So its runtime for ages below 9 months is compared to those above 9 months (baseline, no transformation), as in Table 2.

Table 2. Runtime for low acuity and colour perception transformation

	Transformations	Time per 100 images
Low acuity	≤ 9 months	1.41 sec
	> 9 months	0.29 sec
Low Colour Perception	0 month	277.42 sec
	1 month	269.64 sec
	2 months	245.72 sec
	≥ 3 months	4.28 sec

• Low Acuity Transformation Examples



• Low Color Perception Transformation Examples



• Runtime Graph for low color perception transformation

