One of the most compelling examples of image segmentation is the perception of transparency: the visual system decomposes the 2D pattern of image intensities into the surfaces in the background and the transparent medium that partially obscures the background (see Fig. 1). How the visual system accomplishes the decomposition is not clear but it has been suggested that the link between perceived transparency and image intensities might be contrast [1], [2].

For simpler stimuli, consisting of only two luminances, perceived transmittance is reasonably predicted by Michelson contrast, defined as the ratio of contrasts in the region of transparency and in plain view \( \alpha_c = \frac{c_{\text{TRANSP}}}{c_{\text{PLAIN}}} \) [2], [3]. Each contrast is defined as \( c = \frac{l_{\text{max}} - l_{\text{min}}}{l_{\text{max}} + l_{\text{min}}} \) with \( l_{\text{max}} \) and \( l_{\text{min}} \) being the minimum and maximum luminances in each region, respectively. A so-defined contrast is invariant to changes in illumination [4], because luminances \( l \) are proportional to the reflected light \( I \ast R \), and hence Michelson contrast can be rewritten as \( \frac{I_\ast R_\text{TRANSP}}{I_\ast R_\text{PLAIN}} \), where \( I \) cancels out.

We apply a similar logic to test whether a version of \( \alpha_c \) carries information about perceived transparency in stimuli that consist of more than two luminances. Following one physical model (Metelli), luminances under transparency \( l' \) and in plain view \( l \) are related by the equation \( l' = \alpha \ast l + (1 - \alpha) \ast l_T \), where \( l_T \) is the luminance produced by the transparent medium of reflectance \( \tau \), when \( \alpha \), its transmittance, is 0. Assuming that the lightest and darkest regions are seen through the same transparent medium, then inserting the previous equation for \( l_{\text{min}} \) and \( l_{\text{max}} \) yields

\[
c_{\text{TRANSP}} = \frac{\alpha \ast (l_{\text{max}} - l_{\text{min}})}{l_{\text{max}} \ast (1 - \alpha) + l_{\text{min}} \ast \alpha}.
\]

For \( \tau > 0 \) (and thus \( l_T > 0 \)), the contrast under transparency is a decreasing function of \( \tau \). For most observers the dark transparency in Figure 1 looks indeed more transmittant than the light one of equal physical transmittance. Here we test to what extent observers’ perception of transmittance follows quantitative predictions of different contrast metrics.

Stimuli were checkerboards (Fig. 1), otherwise we closely followed the protocol in [2]. A reference stimulus had a transparent medium with fixed \( \tau \) and \( \alpha \), and a test stimulus had varying values of \( \tau \). Observers adjusted \( \alpha \) in the test stimulus (corresponding to the luminance range in the image) so as to match perceived transmittance. Figure 2A shows the mapping between check reflectances and luminances for fixed \( \alpha \) and our stimulus variations of \( \tau \). Figure 2B shows \( c_{\text{TRANSP}} \) from above as a function of \( \tau \). Figure 2C shows the luminance range (\( \alpha \)) that observers should adjust if they tried to keep \( c_{\text{TRANSP}} \) constant, together with empirical data obtained from one observer. The model based on the mean of all contrasts performed slightly better than the one based on the extreme contrasts, but neither of them fully captures the data. We also measured perceptual scales of perceived transmittance in order to get closer to the representation which is underlying transmittance matches [3]. We tested various contrast metrics [1], [2] but none of them accounted well for the data.

\[c_{\text{TRANSP}} = \frac{\alpha \ast (l_{\text{max}} - l_{\text{min}})}{l_{\text{max}} \ast (1 - \alpha) + l_{\text{min}} \ast \alpha}.
\]