Neutral-Density Filters Are Not a Patch on Occlusion

A number of studies over the past decade have shown that a neutral-density (ND) filter placed in front of an eye of a healthy adult can mimic certain aspects of amblyopic function,[1,2] particularly those related to contrast sensitivity loss,[3] binocular summation,[4] and interocular imbalance.[2,5,6] Furthermore, wearing a ND filter over the fellow eye of an amblyope can rebalance the dominance[1,2,6] and, in some cases, recover stereoscopic function.[7] Neutral-density filters reduce the mean luminance of scenes without perturbing the physical contrast. However, the contrast gain of visual neurons from retinal to cortex[8–10] is dependent on the mean luminance. What this means is that the visual systems' contrast sensitivity is modulated by the mean luminance even though the physical contrast is itself unaltered.[11] Because it has recently been demonstrated that a rebalancing of the contrast between the eyes of amblyopes can lead to a restoration of binocular function,[12] one might reasonably conclude that the rebalancing effects reported in amblyopes as a result of changes in interocular mean luminance (i.e., use of ND filters) are simply due to indirect changes in contrast sensitivity. This leads to the expectation that occlusion with a ND filter might provide a way to treat amblyopia and recover binocular function based on the contrast rebalancing principle.[13–15] This could provide a simple alternative to that of lens blur if occlusion was the preferred approach over the alternative of contrast rebalancing using the dichoptic videogame training.

This proposal has merit if, and only if, the rebalancing effect produced by a ND filter over one eye is simply dependent on the relative luminance seen by the two eyes (as is the case for contrast), a point recently made by Ding and Levi.[6] However, if on the other hand, it depends on the absolute luminance seen by the occluded eye, this approach is doomed to failure because the luminance can vary by more than 100,000:1 (5 log units) between indoor and outdoor conditions across the day. The effectiveness of ND occlusion would be constantly varying and could not provide a stable level of binocular balance.

We measured how ocular dominance varies with the absolute interocular luminance when the relative interocular luminance ratio is kept constant in five adults (age, 29.2 ± 2.9 years), who have normal or correct to normal (20/20) visual acuity in both eyes and normal stereopsis. Ocular dominance was measured using the binocular phase combination task.[2] This result is seen in the Figure, where the average ocular dominance for healthy subjects is plotted against the ND filter values in front of each eye. There is an interocular ND difference of 2, meaning a constant relative interocular luminance ratio of 100. This ratio is constant while the absolute levels of luminance seen by each eye are varied, mimicking what would occur throughout the day. There was a systematic relationship between eye dominance and the absolute luminance while the relative interocular luminance ratio was kept constant ($F(2,8) = 16.85$, $P = 0.001$).

These results suggest that ocular dominance changes induced by a ND filter over one eye not only depend on the interocular luminance ratio[2,5,6] but also on the absolute luminance. Because the light levels can vary across the day by as much as 100,000:1, the effectiveness of a particular ND occluder that is set within the clinic would vary continually throughout the day in an uncontrollable fashion, which would render it impractical as a solution for amblyopic therapy based on rebalancing the inputs from the two eyes.

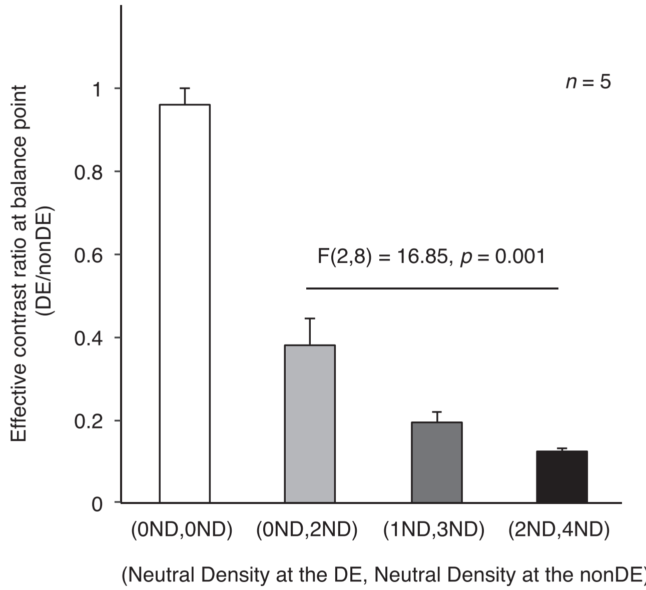

FIGURE. The effect on ocular dominance as reflected by our balance point measure of the effect of the same interocular luminance ratio (i.e., 2ND; ×100) at different absolute viewing luminance (×100). Ocular dominance change (results for 0/2ND; 1/3ND; 2/4ND are all significantly different; $F(2,8) = 16.85$; $P = 0.001$) depends not only on the relative luminance between the two eyes but also on the absolute luminance levels. *Error bars*, SEM. DE, dominant eye; nonDE, nondominant eye.

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