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Colored Glasses to Mitigate Photophobia Symptoms Posttraumatic Brain Injury

Joseph Clark, PhD, ATC*; Kimberly Hasselfeld, MS†; Kathryn Bigsby, PT, DPT‡; Jon Divine, MD†

*Department of Neurology and †Division of Sports Medicine, Department of Orthopaedic Surgery, University of Cincinnati, OH; ‡NovaCare Rehabilitation, Cincinnati, OH

Context: After a concussion or mild traumatic brain injury (mTBI), patients often suffer from light sensitivity, or photophobia, which contributes to decreased quality of life post-mTBI. Whereas sunglasses may provide some relief from photophobia, they are not practical indoors or in low light. A light-mitigation strategy can be easily used indoors as needed to optimize the relief. We have found that many photophobic patients experience relief using colored sunglasses.

Objective: To provide the athletic trainer with a means and method to assess whether an athlete is suffering from photophobia after concussion and to determine if colored glasses provide relief.

Design: Cross-sectional study.

Setting: Rehabilitation clinic.

Patients or Other Participants: Fifty-one patients being treated after concussion.

Intervention(s): We assessed postconcussion patients for visual symptoms including photophobia and photosensitivity. Off-the-shelf glasses were used to determine whether specific colors provided relief from photophobia. Screening was done using a penlight and multiple pairs of colored glasses.

Main Outcome Measure(s): Self-reported mitigation of photophobia symptoms and the specific color frequency that reduced symptoms in each individual.

Results: Of the 39 patients studied who had visual symptoms, 76% complained of photophobia. Using glasses of 1 or more colors, symptoms were relieved in 85% of patients reporting photophobia. The colors that provided the most relief were blue, green, red, and purple. No adverse events were reported.

Conclusions: An empirical assessment of frequency-specific photophobia is easy to perform. A traditional penlight is used to elicit photophobia and then the colored glasses are tested for optimal relief. Frequency-specific photophobia can be reduced with a strategy of light-mitigation therapy, including colored glasses, sunglasses, hats, and light avoidance. This, we believe, helps to improve the patient's quality of life and may aid in the recovery process. More work is needed to identify the best colors and methods of mitigating frequency-specific photophobia.

Key Words: concussion, photosensitivity, rehabilitation, therapy, light, cones, rods, opsins

Key Points

- Many individuals suffer from debilitating photophobia after a concussion.
- Specific colors of glasses may help individuals mitigate photophobic symptoms and assist in the return to normal daily function.
- Athletic trainers, in consultation with team physicians, can initiate this photophobia-mitigation strategy in the acute and subacute settings.

At least 3.8 million persons in the United States sustain a concussion every year, many of whom have experienced a previous concussion.[1] As with a number of other health conditions, the presentation of concussion symptoms can vary greatly among the concussed population.[2,3] Some individuals exhibit very little to no change in function and might report no symptoms at all. Others experience confusion, headache, decreased balance, and vision disturbances including blurry vision, trouble focusing, and sensitivity to light.[4] Short-term changes in day-to-day function are a concern, as is the possibility of long-term dysfunction.[5,6] Sensitivity to light is common and can affect activities of daily living (ADLs),[7,8] suggesting that light mitigation might improve the quality of life for many of these patients.

Photophobia is a common symptom in patients after traumatic brain injury (TBI).[5,9–11] In fact, it is so common that standard operating procedure in most neurosurgical intensive care units is to keep the lights dimmed in the rooms of patients with TBI. Patients with a mild TBI (mTBI; concussion patients) often arrive at the clinic for their appointments wearing dark sunglasses or brimmed hats (or both) to protect against bright light and sun. This light sensitivity can be so great that indoor lighting, looking at a computer screen, and even standard visual and funduscopic examinations can cause significant discomfort. We have observed that examining the pupillary response or using an ophthalmoscope can be unbearable for certain patients. As a result, they often avoid lights and experience concomitant visuosensory deprivation. The sensitivity can affect ADLs as well as trigger or exacerbate a headache.[6,8,12]

Conversely, in environments where lights cannot be avoided, discomfort can persist long after the light stimulus is removed. Patients who work in a well-lit, indoor environment frequently feel very fatigued after leaving that setting. Relatively constant photophobia at a patient's workplace or in a classroom may be a contributing factor to end-of-day fatigue, headache, and other symptoms. Therefore, methods to mitigate photophobia are needed to provide patients with a comprehensive strategy for managing their photophobia and allowing them to continue functioning and engaging in ADLs at the highest possible level.

To our knowledge, at this time no peer-reviewed research publications have reported the incidence of wavelength frequency- (color-) specific photophobia in postconcussion syndrome. In addition, no validated method has been presented to aid athletic trainers (ATs) in screening for the optimal colored glasses to mitigate the photophobia. Our goals were to obtain data concerning the incidence of photophobia in patients with visual symptoms postconcussion; determine the incidence of frequency-specific photophobia in this cohort as well as the colors that seem to provide benefits; and provide a methodologic paradigm to help in choosing the appropriate colored glasses.

METHODS

This was a retrospective chart analysis of consecutive concussion patients who presented to a university-based concussion clinic with a complaint including vision symptoms. The protocol for this study was reviewed and approved by the local institutional review board.

Inclusion Criteria

We examined the charts of 51 concussion patients who presented with visual disturbances as one of their chief complaints and were seen by a single provider (J.F.C.). Patients with photophobia are generally assessed for frequency-specific photophobia if they are able and willing to tolerate the photophobia assessment. Any patient with symptoms lasting more than 3 weeks, which may or may not meet the conventional definition of postconcussion syndrome,[6] was eligible for inclusion.

We assessed the baseline severity of the photophobic discomfort with a light-emitting diode penlight (model EVEPLED23AEH; Eveready Battery Company, St Louis, MO) that is described as providing 21 lumens using no filter. Then, we repeated the penlight exposure using different colored glasses (ColorGlasses.com, Preston, WA) and assessed the patient's discomfort level with each colored lens; about 15% of participants had no relief. Patients who were photophobic but did not want to have a light shined in their eyes were not assessed for frequency-specific photophobia and were excluded from the study.

Sequence of Events for Frequency-Specific Photophobia Assessment

1. A standard penlight is shined in each eye with no glasses on. This is performed inside with normal indoor lighting.
2. Observe responses to the light.
3. Wait for the patient's photophobia to abate and ask him or her to recall the discomfort or pain experienced. This is a subjective measure of *better*, *worse*, or *the same*.
4. Have the patient put on a pair of colored glasses.
5. Shine the light into each eye.
6. Note the response.
7. Have the participant report whether the colored glasses made the light discomfort better, worse, or the same.
8. Place the glasses in 1 of the 3 categories: better, worse, or the same.
9. Repeat with the other colors.
10. Colors tested are red, green, blue, violet, rose, indigo, orange, yellow, aqua, turquoise, pink, plum, and magenta. (These colors are presented here as a list and not in the order followed.)
11. At the end of the examination, there should be 2 or 3 groups of glasses: glasses that had no benefit, glasses that made the photophobia worse, and glasses that made it better.
12. Note the colors that mitigated photophobia symptoms.
13. Have the patient wear each pair of colored glasses that provided some relief and perform activities such as walking around in a well-lit room, looking at electronic media, or reading from a book. Choose appropriate ADLs for the patient to test.
14. Alternate the colored glasses with another pair that provided relief and repeat the process from step 13.
15. Have the patient report whether any of the colors were more or less objectionable when executing ADLs.
16. Recommend the patient consider purchasing glasses in 1 or more colors that provided relief. Remind the patient that environments can be lit differently and, therefore, suitable colors for each environment may also differ, so it is beneficial to have more than 1 color option available. Also recommend that the purchased glasses should provide the maximum amount of physical coverage of the eyes and not just the visual fields. Thus, wide-rimmed glasses that cover the peripheral visual fields are recommended. Colored glasses can fit over prescription glasses as needed.

Colored glasses were assessed beginning with red, blue, and green because these are the 3 colors sensed by the cones. The remaining colors (listed in item 10) were tested in no particular order.

For our patients who needed to work at a computer for a prolonged period of time, we repeated this test using a computer screen or other medium to determine which colors mitigated symptoms during that activity. This essentially meant repeating steps 1 through 12 but using the medium in place of the penlight. Alternatively, the computer-screen test can be done as part of the ADL assessment. Often patients have already dimmed their phone and computer screens, but the colored glasses allow them to operate these devices much more comfortably. Colored screens can be purchased to act as a filter for media use.

Many computers and phones have hue settings, and phone apps can mitigate certain hues that cause discomfort. Mitigation of media light to manage photophobia and photosensitivity may allow the patient to continue some level of media use.

Typical Instructions for an Athlete With Photophobia

Typical instructions given to an athlete with frequency-specific photophobia are as follows:

Table 1. Participants' Demographics[a]

Code Number	Sex	Age[b]	Weeks Postinjury[c]	Photophobia?	Colors Mitigating Photophobia
1	F	25	50	Yes	Red, green, purple
2	F	27	150	Yes	Green, purple
3	M	22	0.17	No	
4	F	75	2.5	Yes	Green, magenta, purple
5	F	53	9.5	Yes	Blue, purple, green
6	F	53	25	Yes	Red, green
7	M	17	4	No	
8	F	15	104	Yes	Red, blue
9	F	49	125	Yes	ND
10	M	17	2	No	
11	M	18	4	Yes	Rose
12	M	53	12	Yes	Green
13	F	30	52	Yes	Blue, indigo, magenta
14	M	65	156	No	
15	F	47	40	Yes	Blue
16	F	26	156	Yes	Green, purple
17	M	30	7	No	
18	M	22	12	Yes	ND
19	F	17	1	Yes	Green
20	F	42	6	Yes	ND
21	F	20	4	Yes	Violet, indigo, magenta
22	F	54	12	Yes	Aqua
23	M	17	2	Yes	Resolved before evaluation
24	F	16	5	Yes	Purple, orange
25	F	45	6.5	No	
26	F	49	12	No	
27	F	75	14	Yes	Some relief with all colored glasses
28	F	19	0.4	Yes	Green, blue
29	F	14	19	Yes	Rose, turquoise
30	M	22	0.17	Yes	Resolved before evaluation
31	F	17	40	Yes	Green, blue
32	M	18	1.5	No	
33	M	17	68	Yes	Violet, orange, magenta
34	M	41	11	Yes	ND
35	F	59	3.5	No	
36	F	29	250	Yes	Green, blue
37	M	43	15	No	
38	F	48	4	Yes	Violet, pink, magenta
39	M	27	18	Yes	Red, blue
40	F	20	24	Yes	Red, pink
41	M	21	20	Yes	Blue, purple
42	F	55	10	No	
43	F	49	32	Yes	Purple
44	F	19	0.35	Yes	Blue, turquoise
45	F	28	6	Yes	Blue
46	F	19	0.17	Yes	Blue
47	F	30	8	Yes	Purple, blue, red
48	M	28	12	Yes	Blue, purple
49	F	19	200	Yes	Red, blue, indigo
50	F	19	12	Yes	Red, purple
51	M	15	52	No	

Abbreviations: F, female; M, male; ND, no difference.

[a] Of the 51 total participants (33 F, 18 M), 76% (39 of 51) had photophobia; of those, 85% (33 of 39) had relief with colored glasses.

[b] Mean age = 32.4 ± 16.9 years.

[c] Weeks after concussive event = 35.5 ± 56.5.

Table 2. Frequency and Percentage of Relief From Photophobia by Color (n = 33)

Color	Frequency (Percentage)[a]
Blue	15 (45)
Green	10 (30)
Red	9 (27)
Purple	9 (27)
Magenta	4 (12)
Indigo	4 (12)
Violet	3 (9)
Aqua	3 (9)
Orange	2 (6)
Rose	2 (6)
Pink	2 (6)

[a] Multiple colors often provided relief. Yellow provided no relief.

1. Wear dark sunglasses at all times when outside during daylight.
2. Wear the recommended colored glasses when inside or using a computer or bright electronic device. If multiple color options were useful, try to rotate through the colors that provide the best benefit and symptom mitigation on the basis of the environmental lighting. Colored glasses should not be worn while driving.

   If practical, apply translucent screen covers in the same colors as the glasses to serve as an additional filter or to replace colored glasses entirely when using electronic media. For example, in some settings (eg, schools), it is more socially acceptable to use a screen cover than to wear colored glasses. Modifying the hue using electronic settings is also an option.
3. If possible, when using computers and other light-emitting media, dim the light intensity without decreasing the contrast. The dimming level is appropriate when an asymptomatic individual can easily read the screen.
4. Wear wide-brimmed hats at all times when outside during daylight.
5. Avoid wearing dark sunglasses (traditional sunglasses) when inside.

RESULTS

A total of 39 patients (33 females [60%] and 18 males [40%]; mean age = 32.4 ± 16.9 years [range, 14–75 years]) were included in this analysis. The 12 participants who did not have visual symptoms were not included in the analysis. Participant age, sex, and photophobia symptoms are presented in Table 1. None of the patients demonstrated color blindness on testing using standard Ishihara plates.

Of the patients who had visual symptoms, 76% had photophobia; 33 (85%) experienced relief with 1 or more colors of glasses. Blue was the most common color that produced relief (in 15 of 33 patients), followed by green, red, and purple. The other colors provided relief less frequently and always in combination with the primary colors (red, blue, and green; Table 2); no adverse events were reported. The only color that never provided relief in this cohort was yellow. Twenty-five (75%) of the patients had relief with more than 1 color of glasses. Three patients (9%) were photophobic but did not report a benefit from any of the colored glasses.

DISCUSSION

The use of color filters for other neurologic and ophthalmologic conditions is not new.[13–16] A common example is migraine with visual aura; light mitigation can alleviate the migraine and is a practical intervention.[15,16] Thus, we believe that many neurologic and ophthalmologic practitioners are already familiar with the use of colored glasses and willing to work with ATs to benefit patients.

Colored glasses help to decrease discomfort from many sources of bright light (sun, indoor lights, and screens) while maintaining contrast and retaining the details of sensory information. Of the 39 patients who had visual symptoms, 76% complained of photophobia. We found that 85% of patients reporting photophobia had relief from symptoms with 1 or more colors of glasses. The colors that provided relief most often were blue, green, red, and purple, with no reported adverse events.

We believe that ATs, in consultation with team physicians, will find it useful to apply this photophobia assessment and recommend colored glasses to the athlete after concussion. Wearing colored glasses in the high school, collegiate, or other setting may allow a person to engage in medically approved activities while minimizing the risk of symptom exacerbation. We believe that colored glasses mitigate photophobia and have added benefits that make them superior to dark sunglasses, especially with indoor lighting.

Most traditional sunglasses diminish all frequencies of light: hence, the dark blackish hue. However, dark sunglasses often decrease contrast and make detailed visual observations difficult, especially indoors. Thus, they are not practical inside. The result is less visuosensory input to the brain via the eyes.

Photophobia (light-induced pain) and photosensitivity (light-induced discomfort) are different conditions. Separating the two is a semantic question beyond the scope of this article. Furthermore, mitigating both pain and discomfort eliminates the need to distinguish between the conditions. We believe that prolonged decreases in visuosensory input from wearing traditional sunglasses constantly (inside and outside) do not help the brain manage and process sensory information.[17] Symptoms may be mitigated, but there is a risk that recovery could be slowed. The use of dark sunglasses indoors decreases contrast and visuosensory input. We think the objective should be to expand the visuosensory system to work more normally. In treating these patients, we try to avoid treatment methods that might restrict the visuosensory system's input. For example, patients without photophobia were not instructed to wear either standard or colored sunglasses. Patients with photophobia who did not report frequency-specific benefits (9% of this cohort) were advised to engage in light-mitigation therapy using sunglasses inside and out. However, the inside glasses are of a hue lighter than standard dark sunglasses to avoid altering the contrast of visuosensory input.

With colored glasses, the color(s) or frequencies of light that stimulate symptoms are mitigated, but full visuosensory information for the other colors is available. We often demonstrate this to patients by having them try to read text in a low-light environment wearing sunglasses, which is difficult, versus colored glasses, which is easier. With colored glasses, the brain receives more information but at less disruptive frequencies. Therefore, the brain is 1 step closer to working normally compared with sunglasses but with less discomfort.

Obviously, pain and discomfort from photophobia have a negative effect on quality of life. This is why we advocate for sufficient mitigation of bright light that elicits photophobia symptoms and discomfort while maintaining visual contrast, detail, and neurosensory input. A student-athlete may be cleared to attend class before returning to activity, but the classroom lighting may evoke symptoms. Colored glasses may prevent symptom exacerbation when in class.

Frequency-specific photosensitivity in the postconcussion patient can be due to damage to either the eyes (specifically, the photo-sensing cells within the retina) or the more central neuropathways within the brain.[18,19] Given that our patients had all sustained concussions and improved with colored glasses, it seems logical that the brain's ability to process visual information may be more involved in the symptom of photophobia. Furthermore, because the rod cells within the retina can become saturated,[20,21] they may have an intrinsic ability to prevent overstimulation of the brain's processing ability. Thus, the rods have a natural filter that makes it less likely they cause photophobia.[21,22]

Processing of signals to the brain by the other color-sensing retinal cells, the cones, may be affected in postconcussion patients with frequency-specific photophobia.[23] This supposition is supported by the finding that 85% of the patients in this study had frequency-specific photophobia. For the brain to perceive color, the visuosensory pathways for the color signals must be kept separate and initially processed separately.[19,21,22] This separation would provide an opportunity by which certain pathways could be affected more or less than others post-TBI. Damage to the retinal ganglion cells has been reported previously in animal models after simulated blast injury. These cells do not sense light but serve as a conduit between the photoreceptive cone cells and lateral geniculate area within the thalamus in the midbrain.[19,22,23] Because the brain's perception of color requires that information sent via these pathways remain separate before arriving at the brain for processing, distinct differences in processing could lead to different photophobic responses. Differences in the cones' color populations would make people more or less sensitive to various colors. We believe that more needs to be learned concerning color vision, color-vision processing, and photophobia post-TBI.[12] We have had great success with an aggressive light-mitigation therapy using colored glasses with our patients. These therapeutic successes are accomplished without the need to put the patient in a dark room. Using our protocol allows patients to engage in activities indoors and outdoors with minimal discomfort from light.

In a post hoc examination of sex and photophobia, 9% of females versus 38% of males did not report photophobia (Table 1). Whether sex differences exist for photophobia and frequency-specific photophobia is yet to be determined.

Using a monochromatic light challenge to assess the populations of cones involved would be relatively straightforward, so it may be advisable to select a light that specifically stimulates a narrow frequency range to identify the pathways or cone populations involved. Such work might be coupled with methods to assess the populations of cones because this would indicate the light "load" being transmitted to the brain.[12] Whereas that information would be beneficial for understanding the mechanisms involved, our goal when working with patients was to provide a strategy for mitigating symptoms and recommendations for self-management. We performed the assessments to identify the appropriate glasses for mitigation. We thought that if patients experienced relief with the glasses, they might be more compliant concerning our recommendations. Indeed, for some patients, the relief was so profound that they wanted to keep the test glasses and not wait to purchase their own. Future studies are needed to determine the extent to which patients with photophobia who are color-blind might benefit from this work.

LIMITATIONS

Our assessment of frequency-specific photophobia was an empirical method based on the subjective responses of the patients when challenged with a standard penlight. Therefore, the method is limited to the ability of the patients to subjectively assess and report the pain or discomfort they are experiencing and any mitigation with the colored glasses. The patients also need to be willing to undergo the photophobia challenge, which involves some discomfort. In addition, the sample was small and limited to patients with mTBI.

It is not clear if the results extend to other conditions associated with photophobia or patients with more severe TBI. The data we presented were from participants with concussion who reported photophobia and experienced mitigation using colored glasses (Table 1). However, our intent was to provide a method with medical evidence to indicate that assessing and using color glasses for symptom mitigation may be beneficial.

The colored glasses used in this study are commercially available, but the manufacturer did not provide their precise frequency ranges. Therefore, a detailed analysis of the frequency components that mitigated symptoms is beyond the scope of this article. We report the glass colors as they were described by the manufacturer. The glasses can fit over prescription glasses, and style-related options make them attractive to and functional for the patients. However, colored glasses should not be worn while driving.

In conclusion, we believe that photophobia may have a frequency-specific component that ATs can assess and that patients can mitigate somewhat by using appropriate colored glasses. More work is needed to determine the mechanisms by which frequency-specific photophobia occurs and whether there are better ways to assess and manage it. Future study will help us to better understand the mechanisms of and incidence rates for frequency-specific photophobia and how to assist in patient recovery.

REFERENCES

1. Faul M, Xu L, Wald MM, Coronado VG. Traumatic brain injury in the United States: emergency department visits, hospitalizations, and deaths 2002–2006. Centers for Disease Control and Prevention Web site. https://www.cdc.gov/traumaticbraininjury/pdf/blue_book.pdf. Accessed February 20, 2017.
2. Lynch JM, Anderson M, Benton B, Green SS. The gaming of concussions: a unique intervention in postconcussion syndrome. *J Athl Train*. 2015;50(3):270–276.
3. Lynch JM, Stanley Green S. Do the eyes have it? Can consideration of concussion variants improve management? *Curr Res Concussion*. 2015;2(2):61–63.
4. Concussion (mild traumatic brain injury) and the team physician: a consensus statement. American Academy of Orthopaedic Surgeons Web site. http://www.aaos.org/uploadedFiles/PreProduction/About/Opinion_Statements/advistmt/1029%20Concussion%20%28Mild%20Traumatic%20Brain%20Injury%29%20and%20the%20Team%20Physician%20-%20A%20Consensus%20Statement.pdf. Accessed February 20, 2017.
5. Master CL, Balcer L, Collins M. In the clinic. Concussion. *Ann Intern Med*. 2014;160(3):ITC2-1.
6. Jotwani V, Harmon KG. Postconcussion syndrome in athletes. *Curr Sports Med Rep*. 2010;9(1):21–26.
7. Master CL, Scheiman M, Gallaway M, et al. Vision diagnoses are common after concussion in adolescents. *Clin Pediatr (Phila)*. 2016;55(3):260–267.
8. Waddell PA, Gronwall DM. Sensitivity to light and sound following minor head injury. *Acta Neurol Scand*. 1984;69(5):270–276.
9. Alla S, Sullivan SJ, Hale L, McCrory P. Self-report scales/checklists for the measurement of concussion symptoms: a systematic review. *Br J Sports Med*. 2009;43(suppl 1):I3–I12.
10. Laker SR. Sports-related concussion. *Curr Pain Headache Rep*. 2015;19(8):41.
11. Zuckerman SL, Yengo-Kahn AM, Buckley TA, Solomon GS, Sills AK, Kerr ZY. Predictors of postconcussion syndrome in collegiate student-athletes. *Neurosurg Focus*. 2016;40(4):E13.
12. Fimreite V, Willeford KT, Ciuffreda KJ. Effect of chromatic filters on visual performance in individuals with mild traumatic brain injury (mTBI): a pilot study. *J Optom*. 2016;9(4):231–239.
13. Takahishi Y, Sato T, Goto K, et al. Optical filters inhibiting television-induced photosensitive seizures. *Neurology*. 2001;57(10):1767–1773.
14. Wilkins AJ, Baker A, Amin D, et al. Treatment of photosensitive epilepsy using coloured glasses. *Seizure*. 1999;8(8):444–449.
15. Evans BJ, Patel R, Wilkins AJ. Optometric function in visually sensitive migraine before and after treatment with tinted spectacles. *Ophthalmic Physiol Opt*. 2002;22(2):130–142.
16. Wilkins AJ, Patel R, Adjamian P, Evans BJ. Tinted spectacles and visually sensitive migraine. *Cephalalgia*. 2002;22(9):711–719.
17. Lebensohn JE, Bellows J. The nature of photophobia. *Arch Ophthalmol*. 1934;12(3):380–390.
18. Baylor DA, Lamb TD, Yau KW. Responses of retinal rods to single photons. *J Physiol*. 1979;288:613–634.
19. Kandel ER, Schwartz JH, Jessell TM. *Principles of Neural Science*. 4th ed. New York, NY: McGraw-Hill; 2000:507–513.
20. Adelson EH. Saturation and adaptation in the rod system. *Vision Res*. 1982;22(10):1299–1312.
21. Purves D, Augustine GJ, Fitzpatrick D, et al. *Neuroscience*. 2nd ed. Sunderland, MA: Sinauer Associates; 2001.
22. Kolb H, Nelson R, Fernandez E, Jones B. *Webvision: The Organization of the Retina and Visual System*. Bethesda, MD: National Library of Medicine; 2007. http://webvision.med.utah.edu/book/part-vii-color-vision/color-vision/. Accessed February 21, 2017.
23. Mustafi D, Engel AH, Palczewski K. Structure of cone photoreceptors. *Prog Retin Eye Res*. 2009;28(4):289–302.

Address correspondence to Joseph Clark, PhD, ATC, Department of Neurology, University of Cincinnati, ML 525, 231 Bethesda Avenue, Cincinnati, OH 45267-0525. Address email to joseph.clark@uc.edu.