Ability of Bottle Cap Color to Facilitate Accurate Patient–Physician Communication Regarding Medication Identity in Patients with Glaucoma

Pujan Dave, BA,1 Guadalupe Villarreal, Jr., MD,1 David S. Friedman, MD, PhD,1 Malik Y. Kahook, MD,2 Pradeep Y. Ramulu, MD, PhD1

Purpose: To determine the accuracy of patient–physician communication regarding topical ophthalmic medication use based on bottle cap color, particularly among individuals who may have acquired color vision deficiency from glaucoma.

Design: Cross-sectional, clinical study.

Participants: Patients aged ≥18 years with primary open-angle, primary angle-closure, pseudoexfoliation, or pigment dispersion glaucoma, bilateral visual acuity of ≥20/400, and no concurrent conditions that may affect color vision.

Methods: A total of 100 patients provided color descriptions of 11 distinct medication bottle caps. Color descriptors were then presented to 3 physicians. Physicians matched each color descriptor to the medication they thought the descriptor was describing.

Main Outcome Measures: Frequency of patient–physician agreement, occurring when all 3 physicians accurately matched the color descriptor to the correct medication. Multivariate regression models evaluated whether patient–physician agreement decreased with degree of better-eye visual field (VF) damage, color descriptor heterogeneity, or color vision deficiency, as determined by the Hardy–Rand–Rittler (HRR) score and Lanthony D15 color confusion index (D15 CCI).

Results: Subjects had a mean age of 69 (±11) years, with VF mean deviation of −4.7 (±6.0) and −10.9 (±8.4) decibels (dB) in the better- and worse-seeing eyes, respectively. Patients produced 102 unique color descriptors to describe the colors of the 11 bottle caps. Among individual patients, the mean number of medications demonstrating agreement was 6.1/11 (55.5%). Agreement was less than 15% for 4 medications (prednisolone acetate [generic], betaxolol HCl [Betoptic; Alcon Laboratories Inc., Fort Worth, TX], brinzolamide/brimonidine [Simbrinza; Alcon Laboratories Inc.], and latanoprost [Xalatan; Pfizer, Inc., New York, NY]). Lower HRR scores and higher D15 CCI (both indicating worse color vision) were associated with greater VF damage (P < 0.001). Extent of color vision deficiency and color descriptor heterogeneity significantly predicted agreement in multivariate models (odds of agreement = 0.90 per 1 point decrement in HRR score, P < 0.001; odds of agreement = 0.30 for medications exhibiting high heterogeneity [≥11 descriptors], P = 0.007).

Conclusions: Physician understanding of patient medication use based solely on bottle cap color is frequently incorrect, particularly in patients with glaucoma who may have color vision deficiency. Errors based on communication using bottle cap color alone may be common and could lead to confusion and harm. Ophthalmology 2015;122:2373-2379 © 2015 by the American Academy of Ophthalmology.

See editorial on page 2368.
vision deficiency, and a considerable proportion of male patients may have inherited color vision deficiency. Either deficiency could create confusion about differently colored bottle caps.7–10 In addition, color naming may be imprecise, and the impact of this imprecision is likely to grow as the number of differently colored bottle caps continues to increase. Therefore, it is possible that patients may not properly understand color names stated by physicians or that physicians may not properly understand color names provided by patients. Either circumstance fosters ambiguity and allows for patient–physician miscommunication.

In this study, we determined how often physicians were able to accurately identify the medication/medication class to which a patient was referring on the basis of the patient’s color description of the medication’s bottle cap. In addition, we asked whether physician–patient agreement was lower for bottle caps of specific colors and among patients with glaucoma with impaired vision. These data will help define how well the current bottle cap color system works and elucidate possible avenues for improvement to reduce patient–physician confusion regarding medication use.

Methods
Study Participants
The study protocol was approved by the Johns Hopkins Medicine Institutions’ Review Board and adhered to the Declaration of Helsinki. Study subjects were recruited from all study-eligible patients receiving care at the Wilmer Eye Institute Glaucoma Service at Johns Hopkins. All participants signed written informed consent forms before all study procedures. Subjects were recruited between June and August 2014.

Participants’ medical charts were prescreened for eligibility. Glaucoma subjects had to be at least 18 years of age and have a confirmed chart diagnosis of primary open-angle glaucoma, primary angle-closure glaucoma, pseudoexfoliation glaucoma, or pigment dispersion glaucoma. Visual acuity (VA) was required to be at least ≥20/400 in both eyes. Participants were required to have visual field (VF) testing within 6 months of study participation. Subjects with (1) neovascular glaucoma, (2) glaucoma/increased intraocular pressure secondary to other ocular conditions (e.g., uveitis, corneal surgery), (3) surgery in the 2 months before study participation, or (4) concurrent conditions that affect contrast sensitivity or color vision (e.g., significant cataract, age-related macular degeneration, other optic nerve disease) were excluded. Eligible and agreeable subjects had to pass the Mini-Cog dementia screening test.11 Participant demographic information, including date of birth, gender, race, and level of education, was collected by self-report.

Evaluation of Vision
Snellen VA was recorded as the presenting VA on the day of the patient’s most recent clinic visit and was converted to the logarithm of the minimum angle of resolution scale.13 Presenting VA was chosen to reflect real-life function of the patient and because uncorrected refractive error has been shown to affect color vision only at extreme levels.13 Severity of VF loss was quantified according to the mean deviation (MD) in the better-seeing eye (i.e., the eye with a higher [less negative] MD on SITA standard 24-2 VF testing), given prior research demonstrating that integrated VF MD and better-eye MD infrequently differ and do not predict visual disability differently across a wide range of functional metrics.14

Color vision was tested using the Richmond Hardy–Rand–Rittler (HRR) pseudosochromatic plate test and the Lanthony D15 Hue Desaturated Panel Test. Color vision testing was performed binocularly using participants’ usual (presenting) correction and under standard full spectrum lighting (OttLite Technology, Tampa, FL).

For HRR testing, plates were held approximately 25 inches from the subject and subjects were asked to trace the shapes present on each plate. Scoring of results was performed as described by Huna-Baron et al15 using HRR testing to quantify acquired dyschromatopsia. Subjects received 0 points (incorrect) or 1 point (fully correct) for screening plates, 0 points (incorrect) or 1 point (correct) for plates with 1 symbol, and 0 points (incorrect), 0.5 points (1 of 2 symbols correct), or 1 point (both symbols correct) for plates with 2 symbols. Under this scoring system, an error-free performance on the HRR test yields a maximum score of 20 points, and a lower score is associated with worse color vision.

Methods for using the Lanthony D15 test to quantify acquired color vision deficiency have been described and were used in the current study.16 The D15 testing board was positioned approximately 20 inches from the subject, and subjects were given as much time as needed to reorganize the 15 discs into the chromatic sequence that they thought best minimized hue differences between adjacent caps. The degree of color vision loss as measured by the D15 test was then scored using the Lanthony D15 color confusion index (D15 CCI).17 An error-free D15 test, occurring when all 15 caps are perfectly arranged in the correct sequence, is given a D15 CCI of 1.0. The D15 CCI increases in proportion to the number and severity of mistakes.18

Bottle Cap Description and Physician Survey
Subjects were asked to describe the color of 11 distinct medication bottle caps using their own color descriptor. Each bottle cap was held in front of the patient at a distance of 25 inches under the illumination described earlier. The following 11 medication bottle caps were used: betaxolol HCl (Betoptic; Alcon Laboratories Inc., Fort Worth, TX), dorzolamide (Trusopt; Merck and Co., Inc., Kenilworth, NJ), prednisolone acetate (generic, white-capped), brimonidine (Alphagan; Allergan Inc., Irvine, CA), brinzolamide/brimonidine (Simbrinza; Alcon Laboratories Inc.), cyclopentolate HCl (Cyclogy; Alcon Laboratories Inc.), levobunolol (Betagan; Allergan Inc.), latanoprost (Xalatan; Pfizer, Inc., New York, NY), pilocarpine (Salagen; Pfizer, Inc.), moxifloxacin (Vigamox; Alcon Laboratories Inc.), and brimonidine/timolol (Combigan; Allergan Inc.). Bottles were presented in 1 of 2 predetermined sequences (sequence 1: in the order named above; sequence 2: latanoprost, dorzolamide, brimonidine, brinzolamide/brimonidine, brimonidine/timolol, prednisolone acetate, pilocarpine, levobunolol, cyclopentolate HCl, moxifloxacin, betaxolol HCl). These patient-produced color descriptors were then presented to 3 male physicians with normal color vision (as determined by perfect HRR and Lanthony D15 scores). Physicians included 2 glaucoma faculty members at different institutions and 1 ophthalmology resident. Each physician was asked to match each color descriptor to the medication he/she thought the color descriptor was being used to describe. Physicians were given the name of the 11 medications whose caps patients had described. In primary analyses, patient–physician agreement was defined as present for a given medication when the medication name given by all 3 physicians was the same as the medication whose bottle cap color was described by the patient. Additional analyses were performed in which
patient–physician agreement was said to be present when 2 of 3 physicians provided a medication name corresponding to the medication whose bottle cap color was described by the patient. Physicians also rated the confidence of their choice as low, medium, or high.

**Statistical Analysis**

Word clouds were generated at www.wordle.net to depict the variety of color descriptors used to describe individual medications. In these word clouds, the size of the words shown corresponds with the number of times patients provided that color descriptor. Factors affecting patient–physician agreement were also analyzed using univariate and multivariate logistic regression models in which each patient–medication combination was considered to be a separate observation and generalized estimating equations were used to account for within-patient correlations. Outcomes were expressed as an odds ratio and 95% confidence interval (CI). Statistical analyses were performed using STATA 13 (STATA, College Station, TX).

**Results**

A total of 100 subjects with glaucoma were enrolled in the study and completed the study protocol. Mean participant VA (logarithm of the minimum angle of resolution) and better-eye VF MD were 0.11 (standard deviation [SD], 0.13) and −4.7 decibels (dB) (SD, 6.0 dB), respectively. Participant demographics and vision characteristics are summarized in Table 1.

**Color Vision Testing**

A total of 25 patients (25%) made no errors on D15 testing, resulting in a D15 CCI of 1.00. Mean D15 CCI was 1.46±0.48 (range, 1.00–3.45). A total of 44 patients received an error-free score of 20 points on the HRR test, and mean HRR score was 17.6±3.7 (range, 2–20). Lower HRR scores and higher D15 CCI (both indicating worse color vision) were both found at greater degrees of VF damage (Fig 1A and B), with D15 CCI scores increasing 0.21 points (95% CI, 0.14–0.29; P < 0.001) and HRR scores decreasing 2.24 points (95% CI, −2.97 to −1.51; P < 0.001) per 5 dB decrement in the better-eye VF MD.

**Bottle Color Naming**

A total of 102 unique color descriptors were used to describe the colors of the 11 tested medication bottle caps. The number of color descriptors used to describe individual medication bottle caps ranged from 2 to 19. The minimum number of color descriptors for the 11 medication bottle caps tested was 2, with all patients describing white-capped prednisolone acetate as white or off-white. The median number of descriptors was 12 (for latanoprost), and the maximum number was 19 (for cyclopentolate). The color descriptors used to describe the bottle cap colors of latanoprost and cyclopentolate are expressed as word clouds in Figure 2A and B. In many cases, color descriptors were used to describe many distinct medication bottle caps (illustrated for medication bottle caps along the blue-green spectrum in Fig 3).

**Physician Bottle Cap Survey**

Three physicians spanning 2 institutions and varying levels of training (1 resident physician, 2 glaucoma specialists) completed the physician bottle cap survey, matching the 102 color descriptors provided by glaucoma subjects to the 11 different medications and

![Figure 1](image1.png)

**Figure 1.** Relationship between severity of better-eye visual field (VF) loss and color vision deficiency. HRR = Hardy–Rand–Rittler; MD = mean deviation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N  = 100</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
</tr>
<tr>
<td>Age, yrs</td>
<td>68.9 (10.5)</td>
</tr>
<tr>
<td>African American, %</td>
<td>23</td>
</tr>
<tr>
<td>Female, %</td>
<td>46</td>
</tr>
<tr>
<td>Education, yrs</td>
<td>15.4 (2.1)</td>
</tr>
<tr>
<td><strong>Vision</strong></td>
<td></td>
</tr>
<tr>
<td>Better-eye acuity, logMAR</td>
<td>0.11 (0.13)</td>
</tr>
<tr>
<td>Visual field MD, better eye</td>
<td>−4.7 (6.2)</td>
</tr>
<tr>
<td>Visual field MD, worse eye</td>
<td>−10.9 (8.4)</td>
</tr>
<tr>
<td>HRR score</td>
<td>17.6 (3.7)</td>
</tr>
<tr>
<td>D15 CCI</td>
<td>1.46 (0.48)</td>
</tr>
</tbody>
</table>

Values shown for continuous variables reflect means with standard deviations shown in parentheses.

CCI = color confusion index; HRR = Hardy-Rand-Rittler; logMAR = logarithm of the minimum angle of resolution; MD = mean deviation.
rating their confidence of their choice. Overall, physicians rated their confidence as low for 108 of 306 assignments (35.3%), medium for 92 of 306 assignments (30.1%), and high for 106 of 306 assignments (34.6%).

Patient–physician agreement was determined in a 2-step process. First, patients observed a topical ophthalmic medication bottle and described the color of its bottle cap. Next, 3 physicians surmised to which medication a patient was referring on the basis of the cap color provided. If the medication name provided by all 3 physicians matched the medication whose bottle cap was initially described by the patient, then patient–physician agreement was defined as present.

For individual patients, the mean number of medications with patient–physician agreement was 6.1/11 (55.5%; SD, 1.09 medicines [9.9%]) (Fig 4). Among the medications studied, the degree of patient–physician agreement was lowest for betaxolol, prednisolone acetate, and brinzolamide/brimonidine, and highest for brimonidine/timolol, dorzolamide, and pilocarpine (Table 2). When the definition of agreement was loosened such that patients and physicians were in agreement if the medication bottle cap color provided by patients was deemed to be referring to the same medication by at least 2 of the 3 queried physicians, the mean number of medications demonstrating patient–physician agreement increased to 9.27/11 (84.3%; SD, 1.3 medicines [11.8%]). Under this new definition, the degree of patient–physician agreement was lowest for betaxolol, brinzolamide/brimonidine, and cyclopentolate, and highest for pilocarpine, brimonidine, and prednisolone acetate. The sequence with which the medications were presented to patients did not alter patient–physician agreement. When patients were required to agree with each of

![Figure 2. Distribution of words used to describe representative medication bottle caps. Representations are shown as word clouds for the medication bottle caps with the (A) median number of color descriptors (latanoprost, n = 12) and the (B) highest number of color descriptors (cyclopentolate, n = 19). The size of each word in the word cloud is proportional to the frequency with which it was used to describe the medication bottle color. The color of each word is depicted via a typical representation of the color as found on http://rgb.to.](image)

![Figure 3. Distribution of medications being referenced by commonly used patient color descriptors along the blue-green spectrum. This figure shows how patients with glaucoma attributed 5 common colors to distinct medications whose bottle cap colors lie in the spectrum between blue and green, highlighting potential areas of confusion and ambiguity. A, “Blue” and “green” contain only patient responses “blue” and “green,” respectively (i.e., deep blue and kelly green are not included). B, “Light blue” includes patient responses “light blue,” “baby blue,” “pale blue,” and “sky blue.” C, “Blue-green” includes patient responses “blue-green,” “teal,” “aqu,” “turquoise,” “dark teal,” and “aquamarine.” D, “Light green” includes patient responses “light green” and “pale green.” *One patient attributed the color “green” to describe the bottle cap color of moxifloxacin.](image)

![Figure 4. Distribution of patient–physician agreement per patient. Per-patient patient–physician agreement is defined as the percentage of the 11 patient-produced color descriptors that are accurately matched to the correct medicine by all 3 physicians.](image)
Patients—physician agreement was defined as present if all 3 physicians correctly matched a bottle cap color provided by a patient to the proper medication whose bottle cap the patient had described. In column 2, this definition was loosened such that patient—physician agreement was present if at least 2 of the 3 physicians made the accurate identification, as described.

Factors predicting the likelihood of poor patient—physician agreement in univariate analyses included severity of better-eye VF loss, extent of color vision loss (reflected by a lower HRR score or a higher D15 CCI), and level of heterogeneity of color descriptors (i.e., number of color descriptors provided per bottle) (Table 3). In multivariate analysis, lower HRR score (odds ratio, 0.90; 95% CI, 0.86–0.95; P < 0.001) and high heterogeneity of patient-produced color descriptors (≥11 descriptors) (odds ratio, 0.30; 95% CI, 0.12–0.71; P = 0.007) were the only significant predictors of patient—physician agreement.

Table 3. Factors Affecting Likelihood that All 3 Physicians Match a Color Descriptor to the Correct Medicine

<table>
<thead>
<tr>
<th>Variable</th>
<th>Interval</th>
<th>OR (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>10 yrs older vs. &lt;10 yrs</td>
<td>0.93 (0.83–1.05)</td>
<td>0.24</td>
</tr>
<tr>
<td>Gender</td>
<td>Male vs. female</td>
<td>0.98 (0.77–1.25)</td>
<td>0.88</td>
</tr>
<tr>
<td>Race</td>
<td>African American vs. non-African American</td>
<td>1.15 (0.87–1.53)</td>
<td>0.34</td>
</tr>
<tr>
<td>Education</td>
<td>4 yrs less vs. ≥5 yrs</td>
<td>1.02 (0.82–1.29)</td>
<td>0.84</td>
</tr>
<tr>
<td>Vision</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VA, better eye</td>
<td>0.1 logMAR worse vs. better</td>
<td>1.08 (0.98–1.18)</td>
<td>0.13</td>
</tr>
<tr>
<td>VF MD, better eye</td>
<td>5 dB worse vs. better</td>
<td>0.90 (0.81–0.99)</td>
<td>0.03</td>
</tr>
<tr>
<td>HRR score</td>
<td>1 point lower vs. better</td>
<td>0.96 (0.93–0.99)</td>
<td>0.01</td>
</tr>
<tr>
<td>D15 CCI</td>
<td>0.1 points lower vs. better</td>
<td>1.03 (1.02–1.05)</td>
<td>0.04</td>
</tr>
<tr>
<td>Color Descriptors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High heterogeneity*</td>
<td>vs. low heterogeneity</td>
<td>0.23 (0.18–0.29)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Values in boldface were regarded as statistically significant.

CI = confidence interval; dB = decibel; D15 CCI = Lanthony D15 color confusion index; HRR = Hardy–Rand–Rittert; logMAR = logarithm of the minimum angle or resolution; MD = mean deviation; OR = odds ratio; VA = visual acuity; VF = visual field.

*High heterogeneity is defined as ≥11 color descriptors for a presented bottle cap color.

Discussion

Color descriptors used to describe ophthalmic bottle caps are heterogeneous and numerous, and physician understanding of patient medication use based solely on bottle cap color is frequently incorrect. The likelihood of misinterpreting a medication class on the basis of cap color alone varied significantly across the spectrum of medications we evaluated. Greater disease severity (as defined by the extent of VF loss or color vision loss) and greater heterogeneity of color descriptors used to describe a bottle cap color were associated with an increased likelihood of misinterpretation. These findings provide strong evidence that clinicians, particularly those treating patients with more advanced glaucoma, should not rely exclusively on cap color descriptions when communicating with patients and assessing their medication use.

The focus of this study was to define the accuracy of patient—physician communication solely on the basis of medication bottle cap color. Overall patient—physician agreement was poor (agreement among all 3 physicians on 56% of tested medications for the average patient) and particularly poor (<15%) for 4 medications: betaxolol, prednisolone, brinzolamide/brimonidine, and latanoprost. Three of these 4 medications’ cap colors lie along the blue-green spectrum, where overlapping color descriptors were frequent (Fig 3). High heterogeneity of color descriptors (≥11 color descriptors for a given medication) also significantly decreased patient—physician agreement. Indeed, in our study, patients produced approximately 10 times as many unique color descriptors as the total number of medications. Medications that exhibited high heterogeneity included (number of color descriptors provided in parentheses) latanoprost (12), levobunolol (13), betaxolol (14), brinzolamide/brimonidine (15), moxifloxacin (18), and cyclopentolate (19).

We hypothesized that communication based solely on cap color information may be worse in patients with more advanced glaucoma as a result of acquired color vision deficiencies. As a first step toward testing this hypothesis, we investigated whether greater glaucoma severity was associated with worse color vision. Our work corroborated prior studies that found that color vision deficiencies worsen with increasing glaucoma severity. A challenge inherent to this research is that acquired color deficiencies can be mild and of a different pattern compared with inherited deficiencies, and thus require specialized methods for evaluation using standard tests (e.g., the D15 CCI and an HRR scoring metric used in the current report), especially given that these standard tests were originally designed to detect inherited defects. The majority of patients with glaucoma in this cohort showed at least some evidence of color vision changes based on HRR score and D15 CCI, although some errors in color vision testing will be observed even in patients with no ocular disease (mean D15 CCI = 1.04 in prior reports, compared with 1.46 in the current report). Moreover, a greater degree of color vision loss...
correlated with increased VF damage, suggesting that glaucoma was responsible for the observed color changes. In multivariate models, only color vision deficiency (defined by lower HRR score) increased the likelihood of poor patient—physician agreement. Severity of VF loss did predict poor patient—physician agreement in univariate models and may be a useful tool to gauge the ability to describe bottle cap color given that color vision is not routinely tested among patients with glaucoma. Our findings strongly reinforce that patients should be asked to bring their medications with them to appointments, particularly when there is a possibility of confusion (i.e., multiple medications, bottle cap colors consistent with multiple types of medications). In addition, these findings also support the practice of encouraging patients to know the names of their medications, checking medication bottle labels before using the medications, and opening one medication bottle at a time to reduce the likelihood of accidentally switching the bottle caps of different medications. Moreover, given that color vision loss was associated with increased glaucoma damage, another option is for physicians to test the color vision of patients with glaucoma or to discuss proper medication use with the aid of sheets containing colored images associating medications with the color of their caps.

Although these clinical changes may help reduce some miscommunication, systemic changes are likely needed to reduce confusion and maximize patient safety. Systemic changes may include instituting more unique or differentiated bottle cap colors (particularly along the blue-green spectrum), altering bottle shape or feel, creating multicolored medication bottles and caps, or using other changes that may help further delineate medications. In particular, it may be important to introduce cap colors that would elicit fewer descriptors, because color descriptor heterogeneity (greater number of descriptors per bottle cap) predicted reduced patient—physician agreement on both univariate and multivariate analyses.

Is systemic change feasible? The current color-coding system was created in 1983 by the American Academy of Ophthalmology out of concern for patient safety and is a purely voluntary system without formally published guidelines. The colors used today were selected from the Pantone Matching System because they were thought to be sufficiently distinguishable by patients (although no work validated this process). Although the system is not enforced, both brand name and generic manufacturers generally have adhered to this system. Notable challenges to change exist, however, despite the low level of regulation. For instance, the dyes/resins used to achieve cap colors can potentially leach into the product and are relevant in the stability experiments that precede medication release. As a result, manufacturers must be told the color of a medication class years in advance of release, and changing medication bottles/caps in any way may necessitate additional multi-year stability experiments. The required stability testing is costly, and changes may result in additional costs (e.g., remarketing) that are ultimately borne by patients using the drops. Thus, desirable or necessary system-wide modifications may be difficult to achieve and must balance safety/quality considerations with cost considerations.

Study Limitations
One limitation of our study was that physicians were forced to choose a medication purely on the basis of the bottle cap color. Other potentially identifying clinically relevant metrics that may be present during regular patient—physician interactions, such as dosing or size/shape of the bottle, were not available to the physicians. Likewise, physician clinical judgment (i.e., probability weighting of medications most likely to be used by patients) could not be incorporated. In practice, physicians may integrate their knowledge of which medications are commonly used to correctly identify medications (e.g., because light blue-capped bevacizumab is rarely used, it is less likely a patient is referencing it). However, our study did not include medications with the same bottle cap colors (e.g., dorzolamide/timolol [Cosopt; Merck & Co., Inc.] and brimonidine/timolol), which also must be distinguished in practice, and are bound to result in disagreement not captured in the current study. Although medical records may contain medication information of return patients, miscommunication may still occur when modifying treatment regimens just as it may when communicating with a new patient whose history is unknown. Future studies are needed to investigate direct, in-person patient—physician interactions to capture communication in a more clinically applicable context.

In summary, there is a substantial need for a practical, better system by which patients with glaucoma can discern their many medications and accurately communicate their medication use with physicians. Individuals with color vision deficiency have been noted to have difficulty recognizing a variety of colored objects (e.g., signal colors, wires, systemic medications), and our work demonstrates that topical ophthalmic medication bottle cap recognition also may be impaired. Miscommunication between patients and providers may foster confusion, resulting in inaccurate and potentially harmful changes in treatment regimens, and ultimately worsen health outcomes. Given the poor accuracy, reliability, and specificity of the current system, it is vital that changes are considered and introduced, although significant barriers exist that may hinder systemic change. An improved system would integrate dosing and entail the addition of more identifiable features to supplement bottle cap color, and may benefit from being enforceable. Most important, ophthalmologists and other healthcare providers must be cognizant of potential errors in communication that is based on bottle cap color alone (particularly for medications with bottle cap colors along the blue-green spectrum) to protect patients from both confusion and harm.

References
Footnotes and Financial Disclosures

Originally received: January 17, 2015.
Final revision: June 8, 2015.
Accepted: June 9, 2015.

1 Wilmer Eye Institute, Johns Hopkins University, Baltimore, Maryland.
2 Department of Ophthalmology, University of Colorado School of Medicine, Aurora, Colorado.


Financial Disclosure(s)
The author(s) have made the following disclosure(s): D.S.F.: Consultant—Alcon, Allergan.
M.Y.K.: Consultant—Aerie Pharma; Grant support—Alcon, Allergan.
P.Y.R.: Grant support—National Eye Institute and Research to Prevent Blindness; Personal fees—Tissue Banks International, Carl Zeiss Meditec.

Funded by a Research to Prevent Blindness Special Scholar Award and National Institutes of Health grant no. EY02976. The sponsor or funding organizations had no role in the design or conduct of this research.

Author Contributions:
Conception and design: Dave, Friedman, Kahook, Ramulu
Data collection: Dave, Villarreal, Friedman, Kahook, Ramulu
Analysis and interpretation: Dave, Ramulu
Obtained funding: Not applicable
Overall responsibility: Dave, Villarreal, Friedman, Kahook, Ramulu

Abbreviations and Acronyms:
CI = confidence interval; D15 CCI = Lanthony D15 color confusion index; dB = decibels; HRR = Hardy–Rand–Rittler; MD = mean deviation; SD = standard deviation; VA = visual acuity; VF = visual field.

Correspondence:
Pradeep Y. Ramulu, MD, PhD, 600 N. Wolfe Street, Maumenee B110, Johns Hopkins Hospital, Baltimore, MD 21287. E-mail: pramulu1@jhmi.edu.