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Guest Editorial ▶ Irwin Suchoff, a Mensch’s Mensch
Paul A. Harris, OD, Southern College of Optometry, Memphis, Tennessee

“Mensch” – a person of integrity and honor
On March 21, 2018, the world lost a great man, Dr. Irwin B. Suchoff, a man who did what he did for others. He brought out the best in those around him. He bettered the lives of all he touched and all they touched throughout their lives. To many, he was a particular person or served a particular role in their lives and development, which was key to their development at that time. Most had no idea the number of different hats he wore or the varied roles he played over his illustrious career.

Irwin was a clinician, teacher, mentor, researcher, writer, editor, administrator, and so much more. Most of all, Irwin was inquisitive; he wanted to understand. Throughout the learning process, he stopped and took time to write and publish so that others could be part of his journey. As his knowledge base grew and the number of individuals he shared with expanded, their combined growth was synergistic in nature. He stated, “My patients, particularly the special populations I worked with, taught me about vision.” And, “My publication showed my life.”

He became an optometrist due to a question that came to him early in life. He pursued the answer his entire career. The question essentially was, Why do all the diagrams of vision start with arrows showing light going into the eye, into the system, but what we perceive are objects out there in space? Yes, it also took a chance meeting with Second Lieutenant Norman Haffner at an Army hospital in Europe, while serving in the Army himself as a pharmacist involved with supply lines, to turn his interest into reality.

Irwin got his BS from the Massachusetts College of Optometry in 1959 and his OD degree a year later. He then came to the New York area and began working for Dr. Haffner at the Optometric Center of New York (OCNY) part time. At the time that Dr. Harold Solan made a shift from the Bronx to New Jersey, Irwin partnered up with Dr. Dick Kavner to buy the practice in the Bronx. As Irwin tells it, he and Dick met with Harold at 9:00 AM and decided on the spot to buy the practice. As they were leaving, they ran into Dr. Harold “Hal” Friedman, who had a 10:00 AM appointment and who never got a chance to make an offer on the practice. Well, Dick and Irwin involved Hal in the practice, and Irwin credited him not only with teaching them how to run the practice but also with a different way to do VT, aimed at results, changes in behavior. They practiced together for 12 years.

Irwin cited his time at OCNY as a magic time. He worked for 7-8 hours once a week in the VT clinic with Dr. Marty Birnbaum for years. He also did perceptual evaluations at the St. Joseph’s School for the Deaf, which was a great learning experience for him. As OCNY was maturing, Norman asked Irwin to begin teaching some courses on child development and vision development. Well, in typical Irwin style, as he learned he wrote, and this led to one of his first publications, which became a textbook for his class at SUNY.

Irwin came on full time as SUNY was forming as a college of optometry in 1971. Unknown to many of his students and colleagues,
throughout his time at SUNY, he continued to see patients a minimum of one day a week in private practice. During his time at SUNY, he was involved with the summer internship program. This program was so highly regarded that he helped to establish a 3-month post-graduate program at first. This didn’t last long, though. Because of the positive experiences had by all, he went to Norman with the idea of expanding the program to become a one-year residency. Norman agreed but told Irwin that they needed to have four positions to make the program fly. The SUNY program is now called the Dr. Irwin B. Suchoff Residency in Vision Therapy and Rehabilitation.

This led to a new page in Irwin’s dedication to the profession and to those it serves. He began a long involvement with the ACOE. At first, he assisted in the accreditation of residencies and eventually served to accredit optometry school programs in North America.

Irwin stated, “I worked with dedicated persons who gave of themselves, unbelievably in terms of how much they gave.” Those who knew Irwin frequently said the same thing of him. How could one man give so much? But he did, and he wasn’t finished, not by a long shot.

In 1990, he became the founding editor of the Journal of Behavioral Optometry (JBO), published by the Optometric Extension Program Foundation (OEPF). He was the editor in chief for 17 years. All articles and editorials from these journals are online at oepf.org/journals. This depository of knowledge is a treasure for all optometrists. Irwin had a vision, and he brought it to reality through the JBO. He wanted the articles to be more clinical in nature. Irwin, rather than just managing the publication, served as what he called a developmental editor. He worked closely with authors who he deemed to have a message to deliver to the world, but who had not perfected the ability to communicate through writing. Irwin would work the piece, and through extensive back-and-forths with the author, help them find their voice.

The last 15 years of his time at SUNY and in practice was devoted exclusively to working with patients with head trauma, as he liked to call it. He taught for many years an Applied Concepts course for COVD with Dr. Allen Cohen, which helped many optometrists to enter the field and have the tools necessary to help those patients who had suffered a head trauma. Again, he took to the pen and authored or co-authored several landmark publications that are still relevant today.

Two lighter notes. In the early days, Dick Kavner, also known according to Irwin as “Cha Cha” Kavner, was a dance teacher. One day, several other dance teachers called in sick, and Dick reached out to Irwin and asked for his assistance as a dance instructor. We all would have loved to have been a fly on the wall that day in the dance studio. Also, many who will read this know the one and only Bubba, Dr. Glen Steele. Most I am sure think that the moniker Bubba must have come from something early in Glen’s childhood, but no. It was Irwin who first called Glen “Bubba,” and boy oh boy, has it stuck.

Irwin inspired many. He never sought recognition. He was recognized by others. Irwin, thank you for all you have done. This profession and this world are better for having had you, the mensch you were and will continue to be in our minds.
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Article: Baseball Seam Recognition Under Temporal Constraints

Daniel Hagee, OD, MS, The Ohio State University College of Optometry, Columbus, Ohio
Nick Fogt, OD, PhD, The Ohio State University College of Optometry, Columbus, Ohio

ABSTRACT

Background: Different pitch types produce different patterns on a baseball as balls spin toward the batter. Batters have only about 250ms to examine and make use of these patterns in determining pitch trajectory. The purpose of the current study was to measure subjects' ability to determine seam orientation on spinning baseballs with and without temporal constraints.

Methods: Two separate studies were performed, with ten subjects in each study. In both studies, subjects were asked to determine one of three possible seam orientations of a spinning baseball. In the first study, subjects viewed baseballs monocularly under two conditions. In one condition, subjects were given unlimited time to determine the seam orientation. In the other condition, subjects were given 286ms to determine the seam orientation. In the second study, subjects viewed baseballs monocularly in one condition and binocularly in the second condition, with unlimited time to determine the seam orientation. Each subject gave 63 responses in all conditions.

Results: In Study 1, seam recognition performance was significantly better (p=0.015) with unlimited viewing time (52.06% correct) compared to limited viewing time (37.62% correct). In Study 2, no significant difference (p=0.52) between binocular and monocular viewing (76.03% and 74.29% correct, respectively) was observed.

Conclusions: The difference in seam recognition performance for the limited versus unlimited viewing times (28% reduction with limited viewing) was significantly greater than the difference in performance in comparing binocular and monocular viewing.

Keywords: baseball, batting, seam recognition, temporal constraints

Background

Baseball batting is extremely difficult due to the temporal and spatial constraints of the task. A pitch thrown at 90mph will reach a batter in less than half a second, so the batter may only have about 250ms (or less) to decide when and where the ball will arrive and whether to swing the bat. Batters then attempt to strike the ball at or near the center of percussion or “sweet spot” on the bat, an area only about 4-6 inches in length and 1/3-1/2 inch in the vertical dimension.1

To determine when and where a pitched ball will arrive at the plate, the batter could make use of information before and after a pitch is released.2-5 Pre-pitch predictive information might be gained from contextual cues such as the pitch count or the presence of baserunners, knowledge of a pitcher’s capabilities and

Figure 1. Two-seam (1a) and four-seam (1b) grips.
tendencies, or assessment of the pitcher’s arm angle upon pitch release.

Once the pitcher releases the ball, time-to-contact with the ball can be estimated from the change in both the retinal image size and retinal disparity as the ball approaches the plate.\textsuperscript{6,7} Regarding retinal image size, the ratio (termed tau) of the current retinal image size of the pitched ball to the rate of image size expansion may be used to estimate time-to-contact. Regarding retinal disparity, the ratio of the current (horizontal) convergence angle of the ball to the rate of change of relative (horizontal) disparity of the pitched ball may also be used for time-to-contact estimations. On the other hand, to make judgments of where a pitched ball will arrive, batters could use contextual and visual cues to estimate the speed of the ball, which is proportional to the height of the ball when it reaches the batter.\textsuperscript{2}

Another visual cue that batters might potentially use in determining the ball’s trajectory is the appearance of the seams on the ball as it spins toward the plate.\textsuperscript{8-10} For example, the seam appearance of a curveball can differ from that of a fastball, and a curveball is slower and demonstrates more downward deflection than a fastball. Further, fastballs delivered using different grips (described below) may drop at different rates.

Bahill and colleagues\textsuperscript{8,9} have detailed the appearance of pitched baseballs thrown using different grips and releases. Here we focus only on fastballs and curveballs. A fastball can be thrown using a two-seam or four-seam grip (Figure 1). The two-seam fastball is said to drop more rapidly than a four-seam fastball. In the case of the two-seam pitch, the ball is gripped so that the index and middle fingers are oriented with the seams (see \url{bit.ly/2qlMfZR}). The four-seam pitch is gripped so that the index and middle fingers are perpendicular to the seams. Upon release, backspin is applied to the ball. Therefore, the two-seam fastball results in the appearance of two red vertical (overhand delivery) or diagonal seams (non-overhand delivery).\textsuperscript{8,9} The four-seam release, on the other hand, results in thinner and more numerous red vertical (or diagonal) lines compared to the 2-seam release. These thin lines are superimposed on a blurry gray background.\textsuperscript{8,9} In the case of a curveball, topspin is applied to the ball. This can result in a similar appearance to that of a four-seam fastball, with the possible inclusion of a red dot or a red annular circle on the ball.

While it is known that these lines or dots on the ball will appear, the question that arises is whether baseball batters can and do make use of these cues in batting.

There have been few studies investigating the ability of a batter to recognize seam orientation or to perform the related task of determining the rotational direction of a spinning baseball.

Hyllegard\textsuperscript{10} examined the role of the seam pattern in pitch recognition. He asked college-level baseball players and college (non-baseball playing) students to identify the direction of spin (topspin or backspin) of pitches seen on video. In some cases, the ball had no visible seams, while in other cases, normal or enhanced seams were used. While pitch recognition performance was lower for the non-baseball players, for both the baseball players and the non-baseball players, the presence of seams had a statistically significant effect on subjects’ ability to determine the spin type. The duration of pitch exposure (initial 200ms or the entire pitch) did not have a statistically significant effect on pitch recognition. This latter result is similar to the findings of Burroughs, who showed that college baseball players could accurately differentiate breaking pitches from straight pitches exposed for only 170ms.\textsuperscript{11}

Gray\textsuperscript{2} investigated the ability of six experienced college baseball players to “hit” simulated pitches displayed on a computer monitor. Batters were exposed to pitches with and without rotational cues. Rotational
The purpose of the studies described here was to measure subjects’ ability to determine the orientation of the seams on a rotating baseball with and without temporal constraints similar to those encountered by baseball batters.

Methods
These studies and the associated consent forms were approved by The Ohio State University Biomedical Institutional Review Board. Data were collected on 20 adult subjects (male and female) across two studies. All subjects signed the informed consent document prior to data collection. To be eligible for the study, subjects had to be between 18 and 40 years of age, as this is the typical age range of baseball and softball players. Additionally, subjects were required to have best-corrected visual acuity of 20/20 in each eye. Data on refractive error were not collected.

Subjects who wore refractive correction were not required to wear the same type of correction (contact lenses or spectacles) at the two study visits. Contrast sensitivity under conditions where subjects are presumably given unlimited time to respond has been compared many times between spectacles and contact lenses. In those studies in which statistical comparisons of contrast thresholds between spectacles and contact lenses were performed, some have found a reduction in contrast sensitivity with contact lenses compared to spectacles, while others have reported a relative reduction with spectacles. Still others have reported no difference in contrast sensitivity between contact lenses and spectacles. Most of these studies have been performed using spherical contact lenses, although one study involved toric contact lenses. In any event, the preponderance of differences reported in these studies would not be expected to change the contrast threshold to such an extent that vision cues (topspin and backspin) resulted in a reduction in spatial error in 4 of the 6 batters and a reduction in temporal error for 3 of the 6 batters. In another study, Gray and Regan demonstrated that rotational cues influenced subjects’ perception of the vertical motion of a (simulated) pitched baseball.

While these studies demonstrate that the presence of seams improves pitch recognition and can positively affect batting in experienced batters, a question that remains unanswered is how various contextual and visual cues to pitch trajectory are weighted to determine when and where the pitch will arrive. In order to improve batting, it may be useful to focus one’s training on those cues that are weighted most strongly. Perhaps rotational cues related to seam direction are relativity weak or unreliable in isolation, but the reliability of these cues is improved when presented in conjunction with other cues, such as the increase in retinal image size of the approaching ball or the pitcher’s arm angle when the pitch is released.

There are only two studies in which the ability to detect the seams on a spinning baseball have been assessed independent of other cues to trajectory. Bahill et al. tested the detection of seams on a four-seam fastball and a two-seam fastball and concluded that a non-athlete with normal vision could see the seams created by a two-seam fastball at 16 feet (4.88m) and the thin lines on a four seam fastball at 10 feet (3.05m). Such distances are most likely too short to provide information that could influence the trajectory of the batter’s swing. On the other hand, a pilot study from our laboratory suggested that seam recognition performance was substantially better than that found by Bahill et al. Finally, at least in the case of this latter study, subjects were given unlimited time to assess the seams on the spinning baseballs. The effect of temporal constraints on seam recognition performance is not known.
of the seams on a baseball would be precluded with either refractive modality.

In addition to static comparisons of contrast sensitivity with spectacles and contact lenses, short-term changes in contrast sensitivity with contact lenses after blinks have been examined. Contrast thresholds largely stabilized in less than 200ms after the blink for both spherical soft contact lenses and rigid gas permeable lenses. Contrast thresholds for soft toric contact lenses stabilized about 200ms after the blink. Since the stimulus exposure duration in these previous studies was very short (16ms), these results suggest that blink-induced changes in contrast threshold would not influence the results of the current experiments (even under conditions where the stimulus duration was limited) regardless of refractive correction.

Two separate studies were performed. Ten different subjects participated in each study.

**General Experimental Set-up**

All studies were performed indoors under ballasted fluorescent lights. A photodiode placed near the location of the ball was used to measure the flicker from these lights. Flicker at a frequency of 120Hz could be found, but the percent flicker was very low (<2%).

A drill press (Sears Craftsman, model #E148193) was used in both experiments. The drill press was mounted on an adjustable table, which could be moved vertically and horizontally for alignment. A black background was placed behind the baseball to reduce distractions and to provide a uniform background.

Subjects were asked to view a baseball (glued to a drill bit) after the drill bit was inserted into the drill press. The baseballs were Rawlings (Town and Country, MO, Model OLB3) balls. A label on these balls states that they are 5 ounces in weight and 9 inches in diameter. In comparison, according to the 2017 Official Rules of Baseball (atmlb.com/2qAPjr2), the acceptable range of baseball weights is 5 to 5.25 ounces, and the acceptable range of baseball diameters is 9 to 9.25 inches.

There were black labels near the top, in the center, and near the bottom of the ball. For each presentation, the ball was spun in the drill press at a rate of 1358rpm. This spin rate is similar to that used by Bahill et al. and results in an apparent smearing of the individual seams of the ball, but this spin rate is lower than that of a typical fastball thrown by a Major League Baseball pitcher. The rotational velocity used in this experiment could result in a “flickering” effect in the case of one or both of the two-seam orientations described below. For a typical two-seam fastball, for most of a revolution two red seams are apparent, but once during this revolution the seams approach one another, and it is possible that only one seam is briefly seen. This flicker would probably not be evident with the four-seam orientation.

The horizontal illumination was measured at a location close to that of the ball using a LiteMate (Model 504) photometer (Photo Research, Burbank, CA). This illumination was found to be about 400 lux.

**Study 1: The Effect of Temporal Constraints on Seam Recognition**

Two shutters (Melles Grillot, Rochester, NY, model #04 IES 003) were used in the first study. One shutter was placed 7.6cm from the subject’s eye. This shutter (diameter 1.9cm) remained open for all trials and so effectively served as an aperture to assist in aligning the subject’s eye on the baseball. A second shutter was placed 4m from the subject’s eye. The diameter of the aperture produced when this latter shutter was opened was 3.5cm. This equated to a visual angle of about 0.50deg. The purpose of this shutter was to limit the time over which the subject could observe the spinning baseballs.

Each subject was tested on two different days. These testing sessions were separated...
by a minimum of two days. Subjects performed one of two randomly selected trials on each day.

On both testing days, the subject first sat about 11 ft (3.35 m) from the spinning baseballs mounted in the drill press. The subject was then asked to observe (binocularly) a spinning ball at three possible orientations (Figure 2). For each orientation, the subject was told in which orientation the baseball was spinning.

The three orientations of the baseball used in this experiment were as follows:

1. “Two Far” (Figure 2a). This orientation to some extent simulated a two-seam fastball (although the rotational axis was 90 degrees away), such that the spinning ball produced two relatively wide horizontal red stripes that were relatively far from one another. The dark label in the center of the ball produced a somewhat dark horizontal stripe in the center of the ball when the ball was spun.

2. “Two Close” (Figure 2b). This orientation was produced by inserting the drill bits into the spinning ball at an angle of approximately 30 deg relative to the angle of drill bit insertion used for the “Two Far” orientation. The spinning baseball produced two relatively wide (red) horizontal stripes separated by a lesser vertical extent than those in the “Two Far” orientation. The labels produced a somewhat dark horizontal stripe that was

![Figure 2. Two Far (2a, left), Two Close (2b, middle), and Zero (2c, right) seam orientations.](image)

![Two Far (2a, left), orientation video.](image)

![Two Close (2b, middle) orientation video.](image)

![Zero (2c, right) seam orientation video.](image)
near or just below the upper horizontal stripe.

3. “Zero” (Figure 2c). This orientation simulated that of a four-seam fastball to some extent. Thus, when the ball was spun in the drill press, the pattern was of many very thin red horizontal lines on a blurred grey background. The black labels on the ball produced a somewhat wide and somewhat dark horizontal stripe near the top of the ball.

Next, subjects were seated at a distance of 36ft and 1in (11m) from the ball. The subject’s left eye was patched. Subjects placed their chin in the chin rest and looked through the two shutters at a ball mounted in the drill press. The cart holding the drill press was then moved to center the mounted baseball in the opening of the shutter at 13.1ft (4m). While the entire baseball was visible through this shutter, the background of the ball was obscured by the shutter aperture. After the subject was properly aligned, he or she was again shown one spinning baseball at each of the three seam orientations described previously and informed as to the orientation of these balls. On those days when exposure duration was limited by the shutter at 13.1ft (4m), this shutter was opened and closed three times to demonstrate the exposure duration. The subjects were not provided with any practice trials beyond these just-described demonstrations. By providing similar demonstrations in the two studies (described below), differences in the results of these two studies were not likely to be the result of subjects misunderstanding the requirements of the task.

A total of 63 balls were presented to each subject on each day. Three balls were available for each of the three seam orientations. Each of these nine balls were presented randomly 7 times. This yielded 21 presentations of each of the three orientations for each trial. For every presentation, a black curtain was used to obscure the ball from the subject prior to exposing the ball. After the ball was mounted in the drill press and the drill press was turned on, the curtain was moved to the side to allow the subject to view the ball.

Limited Exposure Duration Trial

During the trials in which the shutter at 4m was used to control the exposure duration, the subject was notified that the shutter was about to open, and then the shutter was promptly opened via a push-button on the shutter control box. After viewing the baseball, subjects were given unlimited time to report the number and location (Far or Near for the two seam orientations) of any seams detected on the ball. Fixation was not monitored in this experiment or in Study 2 (described below). The largest fixation error for these subjects was likely to be <1deg, and this would have occurred only if subjects fixated the outside edge of the shutter. While it has been shown that contrast sensitivity decreases linearly with eccentricity from the fovea, fixation errors of <1deg would result in very minimal effect on contrast sensitivity.38

Exposure duration was determined based on a 90 mile per hour (40.2m/s) fastball. For a 90 mile per hour pitch, and assuming the ball is released about 55 feet (16.76m) from the batter, the batter has approximately 420 milliseconds (assuming a constant linear velocity) until the baseball arrives. However, a swing requires 160-200 milliseconds to complete, so the batter has only about 220-260 milliseconds to determine when and where the ball will arrive. Therefore, in order to simulate the time a batter has to make these temporal and spatial decisions, we wanted the duration of ball exposure to be close to this time window.

A shutter controller (Melles-Grillot, Rochester, New York, #04ISC001) was used to open the shutter. The duration that the shutter remained open was assessed using a laser and photocell. For 13 measurements, the mean exposure...
duration was found to be 286.6ms (the standard deviation of this mean was far less than 1ms).

Over a period of 286ms, a pitch traveling at a constant linear velocity of 90 miles per hour (40.2m/s) would traverse a distance of 37.8 feet (11.51m). Subtracting this value from 55 feet (16.76m) (the distance from the release point of the pitch to the batter) yields 17.2 feet (5.26m). This means that in 286 milliseconds, a 90 mile per hour pitch travels from the pitcher’s hand at 55ft (16.76m) to a location 17.2ft from the batter. Subjects were therefore situated 36.08ft (11m) from the spinning baseballs, as this is midway between the distance at which the pitcher releases the ball and the distance of the ball from the batter 286ms after the pitch is released.

Unlimited Exposure Duration Trial

For the trials where exposure duration was not limited, the shutter near the eye and the shutter at 4m remained in place and open. The procedures in this trial were otherwise identical to those in the limited exposure duration trial.

Study 2: Monocular vs. Binocular Seam Recognition

Because the seam recognition performance in Study 1 was lower than expected, a second study was completed. In this study, the effect on seam recognition of binocular viewing versus monocular viewing was examined. In these experiments, no apertures were present between the subject and the mounted baseball.

Testing in this study was very similar to that in Study 1. Ten subjects were tested. Each subject returned for testing on two different days, separated by a minimum of two days. Subjects performed one of two (monocular or binocular) randomly selected trials on each day of the study; by the end of the second day, every subject had completed both trials.

Subjects were given unlimited time to view the baseball in both the monocular and binocular conditions. After viewing the baseball and determining the seam orientation, subjects were given unlimited time to give their response to the examiner.

Results

Study 1 (Unlimited Viewing Time vs. Limited Viewing Time)

In the trials with limited viewing time, subjects responded correctly on a total of 237 of the 630 presentations (37.62%). The mean number of correct responses per subject was 23.7 ± 6.02 (range 13 to 34). In the trials with unlimited viewing time, subjects responded correctly on a total of 328 of the 630 presentations (52.06%). The mean number of correct responses was 32.8 ± 8.01 (range 19 to 48). The mean (absolute) difference between the number of correct responses in the limited and unlimited viewing time conditions was 9.30 ± 9.36, with 9 of the 10 subjects demonstrating a larger number of correct responses in the unlimited viewing time condition. Thus, reducing the exposure duration resulted overall in a 28% [1-(237 correct (limited time)/328 correct (unlimited time))] reduction in correct responses. Comparing the total number of correct responses in each scenario (paired t-test), performance was significantly better (p=0.015) with the unlimited viewing time.

Study 2 (Monocular Viewing vs. Binocular Viewing)

In the monocular trials for Study 2, subjects responded correctly on 468 out of 630 baseballs presented (74.29%). The mean number of correct responses per subject was 46.8 ± 4.13 (range 37 to 50). In the binocular trials of Study 2, subjects responded correctly on 479 out of 630 baseballs presented (76.03%). The mean number of correct responses was 47.9 ± 3.57 (range 42 to 54). The mean (absolute) difference between the number of correct responses in the binocular and monocular viewing time conditions was 3.3 ± 4.06 (4 subjects had more correct responses under monocular conditions, 4 had more correct under binocular conditions,
and 2 had an equal number of correct responses in the two conditions). Comparing the total number of correct responses in each scenario, there was no significant difference in performance (paired t-test: p = 0.522) between the binocular and monocular conditions.

As mentioned in the introduction, it is possible that subjects could distinguish between the two-seam (i.e., Two Far) orientation and the Zero seam orientation by looking for flicker associated with the two-seam orientation.\(^8\) The Two Close orientation also produced some flicker, in that in each rotational cycle, the top seam would reach a point near the top of the ball and nearly disappear from view. Further, in each rotational cycle, the bottom seam would reach a point near the bottom of the ball, mostly disappearing from view. The extent to which the flicker was apparent for the Two Close orientation compared to the flicker for the Two Far orientation is not clear. If subjects utilized flicker to differentiate the seam orientations, then one of two things would be expected. If the flicker was apparent for both the Two Far and Two Close orientations, one would expect that subjects would be less likely to confuse the Zero seam orientation with either the Two Far or Two Close orientations, while the Two Far and Two Close orientations would more likely be confused for one another. On the other hand, if flicker was apparent for the Two Far orientation but not for the Two Close or Zero seam orientations, then one would expect that subjects would be equally likely to confuse the Two Far orientation with the other orientations. To address this, incorrect responses in Study 2 were examined.

In both the monocular and binocular conditions, the percentage of correct responses was similar between the different seam orientations. For the monocular condition, the percentage correct was 76.67% (Two Close), 72.38% (Two Far), and 73.81% (Zero). For the binocular condition, the percentage correct was 80.00% (Two Close), 71.43% (Two Far), and 77.14% (Zero). As shown in Tables 1 and 2, if subjects reported the wrong orientation when the Two Far orientation was presented, then they were far more likely to report the Zero seam orientation than the Two Close orientation. Similarly, if subjects reported the wrong orientation when the Zero seam orientation was presented, then they were far more likely to report the Two Far orientation than the Two Close orientation. These results do not support the supposition that subjects made use of the presence of flicker in judging seam orientation. These data instead suggest that the darker line produced by the labels at the top of the Zero seam orientation (Figure 2c) likely resulted in some difficulty in distinguishing the Two Far orientation from the Zero seam orientation.

**Comparisons between Study 1 and Study 2**

A t-test was used to compare the mean difference in correct responses for the limited versus unlimited viewing times (Study 1) to the mean difference in correct responses for the binocular and monocular viewing conditions (Study 2). The mean differences for the two studies were significantly different (t-test: p=0.037).

<table>
<thead>
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<th>Table 1. Monocular Results for Study 2</th>
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The mean number of correct responses in all four conditions (Study 1 and Study 2) is shown in Figure 3. When comparing the total number of correct responses under monocular conditions and unlimited viewing time in Study 1 (apertures present) and the total number of correct responses under monocular conditions in Study 2 (no apertures), it can be seen that the number correct is lower for Study 1. A t-test between these results demonstrated that the two were significantly different (p<0.001).

**Discussion**

Baseball pitches are usually thrown such that they spin, potentially producing red stripes, red dots, or red circles from the seams that are characteristic of different pitch types. Furthermore, the labels on a baseball can also create patterns on the spinning ball. Once the pitch is released, in addition to properties such as the change in retinal image size and the change in binocular disparity of the approaching ball, these stripes, dots, or circles might be used to determine the pitch trajectory and ultimately to improve batting.2,6,8-10 A Pritchard Photometer (Model 1980A, Photo Research, Burbank, CA) was used to measure the luminance from the top stripe created by the seam on a baseball and the adjacent white area (closer to the ball’s center) as the ball spun in the drill press in the Two Far orientation. The Michelson contrast for these two adjacent areas was found to be about 4%, which is expected to be visible to the subjects. (If one calculates the spatial frequency using the average separation of the two red seams, the spatial frequency for this target is about 4 cycles/degree.)39 However, batters have only about 250ms to assess these post-release visual cues and to decide when and where a pitch will arrive and whether to swing the bat.

The results of this study demonstrate that in determining the presence and location of the stripes on a spinning ball, limiting the viewing time of subjects (Study 1) has a much more substantial effect on performance than does monocular compared to binocular vision (Study 2). Combining all of the subjects in each condition together, the percentage of correct responses with no temporal constraints was 28% greater than that with temporal constraints.

While it is expected that the negative influence of temporal constraints on seam recognition will hold up under different conditions of illumination, the percentage of correct responses under different experimental conditions could vary.

In comparing monocular performance between Study 1 and Study 2, performance levels with unlimited viewing time in Study 1 were much lower than those of Study 2 (Figure 3). This suggests that some feature of Study 1 (other than the monocular testing conditions) influenced the result. It might be the case that the shutter at 13.1ft (4m) in Study 1 influenced seam recognition. For example, subjects may have accommodated on the shutter (instead of the baseball). However, the accommodative demand of this shutter was only 0.16 diopters more than that of the ball. Another possibility that must be considered is that the shutter at 13.1ft (4m) eliminates the background, and although unintended, possibly also eliminates small portions of the edge of the ball. Perhaps there are subtle cues obtained from viewing the edge of the ball (against the background)
that improve the subject’s ability to discern the stripes on the ball.

In addition to the potential influence of the shutter aperture on the results, different illuminants such as stadium lighting or sunlight may differentially affect the results when compared to the indoor lighting used in the current experiment. For example, scattering by the atmosphere could create glare in bright sunlight that might reduce the contrast of the seams on the ball.

The reduction in seam recognition performance under temporal constraints in the current experiment stands in contrast to the results of previous investigations. Hyllegard and Burroughs reported that when seams were apparent on the ball, experienced baseball players could discern the type of pitch (topspin or underspin) under temporal constraints. There are some potential explanations for the discrepancies in the results of the current studies and these previous studies. First, in the previous studies, the pitcher was presumably in view when the pitch was released. Batters may consider seam direction cues to be more reliable in the presence of other visual cues to pitch trajectory such as the pitcher’s arm angle or the pitcher’s release point. Second, precession, the wobbling of a spinning object about a second axis, might provide some clues as to the pitch type that would not be evident in the current experiment. Finally, although the baseball experience of the subjects in the current studies was not recorded, it is likely that these individuals were not as experienced or accomplished as were the participants in previous studies.

Perhaps accomplished players are more efficient at seam orientation tasks under temporal constraints than are less accomplished players. It is difficult to draw definitive conclusions from the results of studies comparing novice and expert performance under temporal constraints in baseball-related tasks. In Hyllegard’s pitch recognition task, for both novices and experts, performance was similar whether the pitch was exposed for the first 200ms or for the entire pitch.

Paul and Glencross compared the length of time required for expert and novice baseball players to decide the likely location of baseball pitches (seen on video) at the time these pitches arrive at home plate. The experts demonstrated faster decision times than the novices. The experts’ faster decision times were associated with better estimates (compared to the novices) of the location of the ball at the time the pitch reached the batter. However, in a second study, these investigators found that experts were only modestly better than novices at determining pitch trajectory over the first 240ms of the pitch. Reichow and colleagues found a positive correlation between the batting average of college players and the ability of these players to identify the type of pitch being thrown by a pitcher seen in a picture when these pictures were exposed for 200ms. This latter study suggests that temporal processing is correlated with proficiency in baseball batting. If experts are indeed more efficient at pitch recognition tasks under temporal constraints, one of the cues of which experts might make more efficient use is the flicker cue mentioned in the methods. This cue may allow a batter to differentiate pitches thrown using a two-seam grip from those thrown using a four-seam grip. The subjects in the current study did not make use of the flicker cue, but it could be that more accomplished players do make use of this cue.

A recent paper by Fadde describes studies on occlusion-based training for baseball pitch recognition. This training is at least partially based on previous results demonstrating that experts recognize pitch trajectories more quickly than do novices and that hitting can be improved if pitch recognition time is shortened. The methodology is such that subjects are exposed to pitches over short time periods, and then subjects are asked, for example, to indicate the type of pitch. Subjects are then
given feedback as to their performance. In future studies, subjects could be provided with more practice trials in the limited exposure duration trial (and perhaps given feedback as to their performance), as this may reduce the discrepancy in seam recognition performance between the limited and unlimited duration trials found in Study 1.

Conclusion

In summary, subjects in this study performed well on a seam recognition task under both monocular and binocular conditions in the absence of temporal constraints, while the addition of temporal constraints resulted in a much more significant reduction in performance.

Acknowledgments

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References


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The Effect of Relaxation Techniques and Visual Training on Peripheral Vision in U.S. Collegiate Soccer Players
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ABSTRACT

Background: Injuries are common among soccer players in the United States. A possible causative factor is stress-induced peripheral vision narrowing, causing reduced awareness of other players on the field. This pilot study sought to measure peripheral visual attentive fields during non-stress and stress conditions in healthy young collegiate soccer players before and after training techniques (stress reduction or vision training).

Methods: Single-blind, randomized pilot study. Athletes were recruited from soccer teams at a National Association of Intercollegiate Athletes (NAIA) Division 1 school. Athletes were randomized into two groups for one month of training in relaxation (n=9) or peripheral vision exercises (n=8). Peripheral visual attentive fields were measured using Bernell Color Campimetry (white, red, green, and blue) under stress and non-stress conditions.

Results: 16 athletes (14 male) completed the study. Athletes initially had a statistically significant stress-induced reduction in visual attentive fields for certain colors, including both colors white and blue (p<0.05). After training, a statistically significant decrease in narrowing was shown for the color white for the combined results of both training groups (p<0.05).

Conclusions: Color campimetry was effective for measuring baseline peripheral visual attentive fields, with no significant learning effect. Participants demonstrated stress-induced peripheral field narrowing in the laboratory setting, which was reduced after intervention.

Keywords: athletic performance, soccer, sports vision, sports injury prevention

Background

The popularity of soccer is on the rise in the United States; the Federation Internationale de Football Association (FIFA) reports that over 24 million Americans currently play this sport. In addition, soccer was ranked in a 2011 Entertainment and Sports Programming Network (ESPN) sports poll as the second most popular sport in the country for 12-24 year-olds. Unfortunately, this increase in popularity carries an increase in the injury rate, with 22% of athletes ages 5-14 years are injured while playing the sport. Soccer injuries vary from orthopedic injuries, such as sprains and strains, to more serious neurologic injuries, including concussion. Concussions range from mild to severe and can cause athletes serious health problems. Additionally, injuries can...
cause athletes to be out of play for weeks or longer, depending on the severity. In a 10-year prospective study of collegiate soccer players, head-to-head contact was the primary cause of concussion, with authors speculating that injury severity could be mediated by contact anticipation, allowing for muscle contraction to reduce cranial acceleration and shearing forces. Determining the mechanism of injuries is an essential first step towards prevention of injuries in soccer players.

As the role of vision in sports performance is becoming appreciated, and the concept of sports vision is better defined, visual training is becoming more common in athletics. Peripheral vision is motion sensitive, warning of potential contact with other players on the field. Athletes have increased peripheral retinal sensitivity as compared to non-athletes, which aids in the motion detection of both teammates and obstacles. With impaired peripheral vision, athletes may not see the incoming object or person in time to respond, and therefore, they may sustain injury from avoidable contact. Peripheral vision is reduced in stressful situations. This visual attentive field narrowing may contribute to injuries during the game.

Injuries are higher among athletes with greater perceived life stress, with possible factors including reduced attention, decreased peripheral vision awareness, increased muscle tension, and fatigue. Relaxation techniques have been used effectively to reduce the stress response. Relaxation techniques address the physiologic response to stress by decreasing oxygen consumption, decreasing heart rate and blood pressure, improving attention, decreasing muscle tension, and decreasing peripheral narrowing. Techniques shown to reduce stress and to increase relaxation include diaphragmatic breathing, biofeedback, and guided imagery. These commonly used techniques are considered safe and effective. The purpose of this study was to examine peripheral vision narrowing from stress in soccer players and to determine whether it was possible to reduce peripheral narrowing through training in either visual strategies or stress reduction.

Methods

Seventeen intercollegiate soccer players (13 male and 4 female) were recruited from the men’s and women’s soccer teams at a National Association of Intercollegiate Athletes (NAIA) Division 1 school. All were pre-screened for visual defects, ocular disease, vestibular impairments, and recent concussion. Vision pre-screening was performed or supervised by a licensed clinical optometrist and included static visual acuity, cover test, near point of convergence, accommodative facility, binocular smooth pursuits, binocular saccadic movements, stereo acuity, retinoscopy, monocular visual attentive field screening using the HMP-200 (NovaVision, Inc), and contrast sensitivity. Vertigo pre-screening included the Vertigo Symptoms Scale in order to identify signs of vertigo dysfunction that could impair vision. Athletes were excluded if they had best-corrected visual acuity worse than 20/40, presence of strabismus, presence of phoria (worse than 5 exo, 4 eso, or any vertical), uncorrected refractive error (greater than -0.50 D or more than +2.00 D), visual field defects reducing the horizontal field to less than 40 degrees with each eye, convergence worse than 7 cm from the nose, accommodative facility worse than 8 cycles per minute binocularly and 11 cycles per minute monocularly, any abnormality in smooth pursuit or saccadic eye movements, stereoacuity worse than 40 seconds of arc, contrast sensitivity worse than 1.72 log, active pathology potentially affecting visual function (determined by subject interview), glasses worn during sports (athletes wearing contact lenses were included), vestibular impairments, or concussion in the previous 2 months. In addition, all potential participants completed the Depression-Anxiety-Stress scale to identify depression or anxiety symptoms and the Holmes
and Rahe Stress Scale screening for negative life events. Athletes who passed the pre-screening had the opportunity to participate in the study. Participants were randomly assigned to one of two groups and were free to leave the study at any time. This protocol was approved by the primary investigator’s university Institutional Review Board, and the tenets of the Declaration of Helsinki were followed.

**Visual Attentive Field Assessment**

All participants completed color campimetry by a certified ophthalmic technician using the Computerized Functional Color Field Tester (Bernell; Figure 1) under both stressed and non-stressed conditions prior to beginning training and after training was completed. The examiner was blinded to the intervention group designation. The test incorporates 4 different-colored targets that are 1 mm in size. This test was chosen as a way to determine the difference in color perception in the periphery for athletes. Color perception is a result of the stimulation of three types of cone photoreceptors in the eye. Because these photoreceptors change in structure and function with increasing eccentricity from the fovea, color perception in the periphery is present but decreases in response, with a greater decrease in red/green sensitivity. Each participant was seated comfortably, with neutral spine position, and 23 centimeters from a 42.72 cm flat-screen computer monitor (Acer) wearing either contact lenses or no correction if none was needed. In the non-stressed situation, each eye was tested separately across 8 different peripheral meridians for each of the following target colors: white, blue, red, green. During the testing, the athlete was instructed to identify the color of a target that moved from a peripheral area of non-seeing into an area of seeing while maintaining central fixation. To maintain central focus, participants had to call out a number that flashed in the center of the screen; the examiner also watched to ensure that they were maintaining continual focus on the central image during testing. Each trial was terminated by the examiner when the participant correctly identified the color. Next, each participant repeated the test under a stressful condition created with a cognitive task using the intermittently flashing numbers on the middle of the screen. Athletes were asked to take the original number, subtract 2 and then multiply by 3, and call this final number out loud during testing. Participants needed to process the mathematical problem accurately and quickly. This created the need for divided attention and presumably reduced peripheral visual awareness.

**Vision Training**

Athletes in the vision training group were taught three vision therapy techniques to release central field focus and to expand peripheral visual perception: the modified MacDonald card, central-peripheral saccades, and central fixation release using the Padula Transformation Cube.29

The McDonald card has a central red dot surrounded by letters at various distances across the card. The athlete was instructed to affix the card to a wall at eye level and to stand about 3 feet away from the card with good posture. The athlete focused on the red dot while simultaneously reading letters in alphabetical order in expanding distance from the center.
Athletes performed the central-peripheral saccades both monocularly and binocularly. All were instructed to put a small target (Post-it® note) at eye level in the center of a wall, and then to put colored or numbered targets elsewhere on the board. Participants held a stick of about 3 feet in length with both hands and were instructed to look at the center target and to use the stick to tap the targets that they viewed with their peripheral vision. After they tapped a peripheral target, the participant would then look at the target to check for accuracy.

For the central fixation release task, participants were instructed to place four of the Padula Transformation Cubes directly in front of themselves in a vertical line: on the floor 3 feet in front of the standing position, on the floor at the edge of a wall 6 feet in front of the standing position, 3 feet up the wall, and 6 feet up the wall. The transformation cube is a green/red box, and the athlete practices either viewing the box as red or green. Participants were instructed to view the box as green, to begin to move their arms in a circle for 3 arm rotations, then to view the box as red. The athlete would then proceed by looking at the next of the four transformation cubes.

**Relaxation Training**

Athletes in the relaxation training group were instructed in relaxation techniques to be performed in a quiet area. These exercises included diaphragmatic breathing and guided imagery. Diaphragmatic breathing requires deep breaths through the abdomen, a slower respiratory rate, and results in decreased stress on the system. Guided imagery involves visualizing a positive, safe environment in which the individual performs at his/her optimal level. Participants were instructed to visualize doing exceptionally well on the soccer field.

Athletes in both intervention groups were issued a calendar to track compliance and were instructed to perform the exercises for 10 minutes daily, as well as before practice and games for the most benefit. After two weeks, athletes participated in separate group review sessions in order to ensure that they were performing techniques correctly, to answer any questions, and to promote compliance. After a total of 4 weeks of intervention, athletes returned to complete post-intervention color campimetry under both stressed and non-stressed situations, as described above. In addition, the compliance calendars were reviewed.

All potential participants were given a thorough explanation of the study and the choice of whether or not to participate. Those who agreed read and signed informed consent forms prior to any testing.

**Statistical Analysis**

The Wilcoxon Signed Ranks Test was used to determine whether there were statistically significant differences in color campimetry for both the left and right eye of each individual. This test was used because data were not normally distributed. First, in order to evaluate whether changes in visual attentive field were due to repeated testing, learning effect was assessed by comparing the non-stressed condition pre- and post-intervention. Next, in order to determine whether a stressed condition was actually created, stressed and non-stressed conditions were assessed before and after intervention. Finally, assessing the stressed condition before and after an intervention was done to look for a training effect from the interventions. Data were analyzed for all four colors under all four conditions for each eye: stress/no stress pre, stress/no stress post, pre/post no stress, pre/post stress. Statistics were generated using the International Business Machine Statistical Package for the Social Sciences (IBM SPSS Statistics) 22.0 and are reported using the Z statistic.

**Results**

Sixteen of the original 17 enrolled athletes completed the study, ranging in age from 18
to 23 years (20.53 ± 1.41 years). Vision therapy group (n=8) data is presented parenthetically. Fourteen (6) of the athletes were male; 12 (7) were Caucasian, 2 (0) were African American, and 2 (1) were Hispanic. See Table 1 for demographic information.

Our first aim was to measure athletes’ peripheral vision in a laboratory setting, in both non-stressed and stressed conditions, in order to create stress-induced peripheral visual attentive field narrowing. To determine whether there were practice effects from repeated testing, we compared the pre-intervention non-stressed color campimetry to the post-intervention non-stressed color campimetry results for all participants. Analysis showed no significant changes between pre- and post-training sessions for any color, indicating no significant learning effect from testing (results ranged from $Z=-1.706, p=0.088$ to $Z=-0.220, p=0.826$).

Next, we wanted to create a stressful condition through dual cognitive task- and time-urgency and to measure the stress response in peripheral vision. We determined that participants initially had a statistically significant reduction in visual attentive field for certain colors (white right eye $Z=-3.413, p=0.001$; white left eye $Z=-2.379, p=0.017$; blue right eye $Z=-3.471, p=0.001$; blue left eye $Z=-2.432, p=0.015$; red right eye $Z=-3.129, p=0.002$; green left eye $Z=-2.485, p=0.013$), but no significance was found for other colors (red left eye $Z=-1.035, p=0.301$; green right eye $Z=-1.590, p=0.112$). Only white and blue had statistically significant reduction in visual attentive fields for both eyes (Table 2).

Our final aim was to determine whether the stress-induced peripheral narrowing could be changed with training, using either relaxation or visual training techniques. All colors for each eye of the post-training stressed visual attentive fields were compared to the same color and same eye of the pre-training stressed visual attentive fields for the relaxation group, and there was no significant change found ($p=0.898$ left eye, $p=0.166$ right eye). This comparison was also done for the vision therapy group, and no significant change was found. The two groups had similar averages, so in order to increase power, we pooled the data. For example, Figure 2 shows findings of both intervention groups for left eye, white, stressed post-intervention average visual attentive field size. When the relaxation and

### Table 1. Study Demographic Information

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</tbody>
</table>

### Table 2. Z-score and p values for the right eye and left eye pre-intervention stress condition versus pre-intervention non-stress condition for each peripheral vision stimulus color, indicating that the stressed task does create peripheral narrowing in all but 2 scenarios. Asterisk (*) indicates statistically significant p value.

<table>
<thead>
<tr>
<th></th>
<th>Right Eye</th>
<th>p value</th>
<th>Left Eye</th>
<th>Z-score, p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>-3.129</td>
<td>0.002*</td>
<td>-1.035</td>
<td>0.301</td>
</tr>
<tr>
<td>Blue</td>
<td>-3.471</td>
<td>0.001*</td>
<td>-2.432</td>
<td>0.015*</td>
</tr>
<tr>
<td>Green</td>
<td>-1.590</td>
<td>0.112</td>
<td>-2.485</td>
<td>0.013*</td>
</tr>
<tr>
<td>White</td>
<td>-3.413</td>
<td>0.001*</td>
<td>-2.379</td>
<td>0.017*</td>
</tr>
</tbody>
</table>

**Figure 2.** The post-intervention average visual attentive field size for the combined left eyes in the white, stressed condition for both the vision therapy group (group 1) and the relaxation therapy group (group 2), indicating that the two groups had similar averages, so to increase power we pooled the data.
vision therapy groups were pooled, there was a significant difference in the white post-training stressed visual attentive fields as compared to the white pre-training stressed visual attentive fields (Z=-2.586, p=0.01 right eye; Z=-2.096, p=0.036 left eye), indicating a treatment effect for the stressed condition. No difference was found for any of the other colors (Table 3).

Athletes were asked to perform the task daily for one month, for a total of 30 sessions. Their compliance with performing the techniques was poor, with average reported compliance of 13.25 ± 6.11 sessions for the relaxation group and 8.88 ± 3.44 sessions for the vision training group.

Discussion

This pilot study measured peripheral visual narrowing from stress in healthy athletes and demonstrated that reduced peripheral narrowing remained with stress. We were able to replicate prior studies of stress-induced peripheral vision narrowing using a lab-based campimetry task to create stress. Further, we found no significant learning effect with the campimetry upon repeated measure under calm conditions. The sample size in each of the two groups was too small to analyze separately, so the data was pooled together for analysis; the averages of each group were similar. The resulting analysis demonstrated that intervention led to a reduction in stress-induced peripheral narrowing on post-training measurement; however, we are unable to ascertain the reason.

Study limitations included a small number of participants, limiting the power of data analysis. In addition, compliance with training techniques was poor. Simply having the knowledge that peripheral narrowing could be reduced may have been enough to change the post-intervention performance, which could be controlled with an education-only group as well as a non-intervention control in the future.

A review of the literature did not show any other sports medicine studies using color campimetry. The tool is used by two of the authors (CG, JG) to measure peripheral vision and to track recovery after neurological injury, noting clinical changes (particularly expansion of fields) across all colors during rehabilitation. In the current study of healthy, normally sighted athletes, only the color white showed significance between pre- and post-measures of both eyes, while other colors had varied responses, including visual attentive field expansion under stress, with no trend measured in our small sample.

Conclusion

The use of campimetry in this normally sighted, healthy population was effective in measuring peripheral vision, both for creating and measuring stress-induced peripheral visual attentive field narrowing for the color white. Participants demonstrated stress-induced peripheral field narrowing in the laboratory setting, which was reduced after training with either relaxation or peripheral vision techniques. The impact of training and education on reducing peripheral visual attentive field narrowing is unclear, possibly due to our small sample size with poor compliance in both training techniques. The prospect of reducing stress-induced peripheral vision narrowing is worthy of further study as a potential intervention to reduce injuries common among soccer players navigating a crowded field. We recommend further research using campimetry, with longer training periods and improved compliance.
mechanisms for compliance, as well as control groups to establish ideal training techniques that may reduce stress-induced visual attentive field narrowing in healthy college soccer players.

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References


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Article ▶ Comparison of Backlit and Novel Automated ETDRS Visual Acuity Charts
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ABSTRACT

**Background:** This study was conducted to compare two different methods and presentation systems of testing visual acuity to determine whether they are equivalent.

**Methods:** We compared the results of taking visual acuity (VA) measures with the standard backlit Early Treatment of Diabetic Retinopathy Study (backlit ETDRS) and Automated ETDRS (A-ETDRS) VA charts (M&S Technologies, Inc., Niles, IL) on 111 healthy subjects with corrected visual acuity of 20/20 or better. Testing was done under four conditions—with spectacles, uncorrected, with +1.50 blur over spectacles, and with +3.00 blur over spectacles—to assess correlation of primary outcomes between charts across a wide range of acuity measures. Visual acuity measures were recorded in letter count, logMAR, and standard Snellen measures.

**Results:** Correlations between the backlit ETDRS and the A-ETDRS chart types were 0.93 (uncorrected), 0.60 (with spectacles), 0.76 (+1.50 blur over spectacles), and 0.50 (+3.00 blur over spectacles), with all correlations statistically significant at p< 0.001.

**Conclusion:** This study shows that traditional backlit ETDRS and A-ETDRS charts are functionally equivalent to each other under a variety of testing conditions, mimicking both clinical and research applications. Additional benefits of the automated system over the backlit charts include: the ability to calibrate the system precisely, faster testing and scoring times combined, and less chance for error to enter into the conversion of the raw data into logMAR, letter, or Snellen scores. For all of these reasons, Automated-ETDRS testing is preferred.

**Keywords:** automated testing, backlit screen, digital screen display, Early Treatment of Diabetic Retinopathy Study, electronic vision chart, ETDRS, logMAR, optotype, Snellen, Visual acuity

**Background**
Visual acuity is one of the most important tools in determining visual function and has been established as the “gold standard” in prospective clinical trials, especially regarding eye disease and treatment.1,2 The assessment of visual acuity with optotype charts is the most standardized test of visual function. These high-contrast printed charts include black optotypes, letters, or symbols on a white background and are externally illuminated. The charts allow a diverse patient population to be tested. Theoretically, visual acuity testing should give a precise, reproducible, and reliable result that represents the state of macular function. The testing further implies that any acuity changes are related to disease or treatment. However, visual acuity can be influenced and altered by external factors, including but not limited to exam room lighting, contrast, design of the chart, subject motivation, and scoring technique.3,4
The Snellen eye chart is the most widely used method of visual acuity measurement in clinical practice, in part due to its ease of use and availability. Snellen’s original chart had a single large letter at the top, and with each successive row, the letters became more numerous and progressively smaller. The letters are not equal in their legibility; there is also unequal letter and line spacing. In addition, since its original conception, many variations in size, sequence, chart layout, and design of the optotypes were made; subsequently, there is no broadly accepted “standard” Snellen chart.

Most commonly, visual acuity measurements are determined under high-contrast conditions, as previously mentioned. Over time, the required contrast level for the chart can be impacted by stains and fading, which may alter reflectivity. Room position and room illumination may also introduce variability.

ETDRS Standards

The Early Treatment of Diabetic Retinopathy Study (ETDRS) chart is based on the previously designed Bailey-Lovie logMAR chart to establish a standardized measurement of visual acuity. The inclusion of administration and scoring protocols serves to improve the precision of visual acuity measurement in the range of poorer visual acuities. The ETDRS chart has been recognized to be highly reliable for vision testing and has been considered one of the standard tools for measuring acuity in prospective clinical research for more than 30 years. Each Sloan letter on the ETDRS chart (ten in total) has approximately equal legibility or difficulty, and each line has the same overall difficulty. Each row contains five letters, with the spacing between each letter being equal to the width of one letter and the space between lines being equal in height to the letters of the next lower line. The letter size from row to row changes in equal logarithmic intervals. The chart itself is non-reflective, white, high-impact polystyrene with the black letters creating a contrast level of approximately 90%. The accompanying light box produces a standardized illumination of 120 cd/m², which conforms to the ANSI specifications. All other light sources in the room should be turned off to reduce any potential glare sources.

Although considered the standard for clinical research, ETDRS and other logMAR charts are not widely used in clinical practice. As evidence of this, at Southern College of Optometry, the 90+ clinical testing lanes and the 50+ student practice lanes are equipped with computer-based chart systems, while there are only two ETDRS charts in place for compliance with specific FDA clinical protocols. This ratio is similar in most North American optometry schools. It is thought that the test format, including the length of test administration, unfamiliar scoring,
and patients memorizing letter sequences, as well as the inherent difficulty in discussing logMAR acuity with patients, contribute to the practical limitations.9,14,15

The standard ETDRS chart is a large, floor-mounted, backlit device that takes up a significant amount of space and requires manual changes amongst the three provided plastic sheets (Figure 1).

The Automated ETDRS chart (A-ETDRS; M&S Technologies, Inc., Niles, IL),5 which is part of the Clinical Trial Suite offered by M&S, has the potential to make the test more portable, more difficult to memorize, easier to score, and it may speed up testing time (Figure 2).

Computerized Testing

Technological advancements have improved the incorporation of technology, such as computer-based displays, in all facets of health care, including electronic vision testing. Various forms of electronic and automated displays exist on the market and continue to gain popularity with patients and practitioners alike. The inevitable trend towards using more computer-based displays for the measurement of visual acuity has specific research advantages that come from computer control of visual displays for measuring visual acuity.5 Computer displays can provide selectable options, such as optotypes, spacing and crowding arrangements, contrast, and color. Research has shown that another advantage of a computerized acuity system is the ability to increase the test-retest repeatability through repetition and averaging of measurements.8,16 Furthermore, a computer-based acuity chart allows random order presentation and automated processing.8

Purpose

This study was conducted to compare two different methods and presentation systems of testing visual acuity to determine whether they are equivalent. Should that aim be met, then additional benefits would accrue to the user of A-ETDRS. In many clinical studies, subjects spend a great deal of time, under many different conditions, reading the backlit ETDRS charts from top to bottom, over and over. Since there are only three different charts, which must be manually changed, there is a chance that subjects could begin to know some of the letter sequences in those charts. This could lead to an overestimation of their visual acuity, which is not related to the specific testing or experimental condition. Randomization of each “chart” in the A-ETDRS configuration would eliminate memorization from prior exposures, thus increasing the validity of the measure.

An additional benefit that would result from the aim being met is increased reliability in the calculation of the letter count, from which the logMAR and/or visual acuity measure is derived. The standard backlit ETDRS charts must be manually scored. This process is highly repetitive and adds time to the process of getting the letter count. The A-ETDRS system immediately provides the user with all of the scores needed, without the need for a separate recording system or the counting or calculation of any of the scores. This should save time and guarantee that the measures reported are indeed the measures obtained.

This study also addresses some of the issues raised in discussion of some early attempts to computerize the ETDRS testing process.17 Issues that have been raised include pixelation of the letters on the computer screen, where individual pixels are visible to the naked eye, and anti-aliasing.3 These specifically affect the ability cleanly to present letters smaller than 20/20 on older computer monitors. Smaller screens limit the size of the largest letter that can be shown to a subject. Larger computer monitors with smaller pixels, packed much more closely together on the screen in both the vertical and horizontal dimensions (dot pitch), combine to allow for much larger letters than before, while being able to present letters down
to 20/8 Snellen visual acuity levels. Aliasing occurs in computer graphics when a screen cannot render as smooth a curve as intended and it appears on the screen as jagged. When viewed extremely closely, what is seen are small steps rather than smooth curves. Anti-aliasing software has been used to attempt to minimize these effects. The typical panel displays used now in these systems do not need anti-aliasing software because of the smaller dots, which are packed much more closely together. The M&S Technologies Smart System II used in this study has a 22-inch digital flat panel screen with a resolution of 1680 x 1050.

Lastly, the new control systems, which use a separate tablet with built-in scoring, should allow for faster data collection times.

**Methods**

One hundred and eleven (N=111) second- and third-year students from Southern College of Optometry (SCO), with corrected visual acuity of 20/20 or better binocularly, had their visual acuity taken eight separate times, with each of the conditions being randomized. Visual acuity was measured four different times on each of the two different types of charts. The four conditions for each chart included: with spectacles, without spectacles, with +1.50 spheres over spectacles, and with +3.00 spheres over spectacles. For each subject, randomization was across all 8 conditions, and all testing was done on the same day at a single sitting. The randomization table was generated by research randomizer. All testing was done at 4 meters. The standard ETDRS protocol has the subject wearing a +0.25 DS lens to compensate for this distance. The +0.25 lens was not used in any of our 8 test conditions. We created the two pairs of spectacles for testing, one pair of +1.50 spheres and the other of +3.00 spheres, in frames large enough to allow them to be worn over the subjects’ own spectacles without difficulty. Those subjects who wore contact lenses were asked not to wear their contact lenses on the day of testing, but instead to wear their spectacle correction. This made the randomization of the uncorrected conditions on both the backlit and the A-ETDRS charts less time-consuming than if we had our subjects remove their contact lenses and then readapt to them for the next condition.

All testing was done binocularly in a room where the only illumination came from the two charts. Both displays were on all the time. Whenever a backlit chart was to be used for testing, one of the three charts was selected based on a randomization table. It should be noted that for each subject, four different measures were made on the backlit chart, but there are only three different charts. Each chart had an equal chance of being used at any time. Although it was time-consuming to change the charts manually, it was done to minimize any chance of a subject memorizing the charts, as well as to simulate formal research protocols. In the cases where the randomization table indicated that the same backlit chart was to be used again, the researcher went through the chart changing routine and simply put the prior chart back in position. This was to encourage the thought in the subjects that the charts were different each time.

When the backlit ETDRS charts were used, printed score sheets were available for each of the three charts. The appropriate score sheet was selected, and the subject was asked to read each letter distinctly from the top of the chart. Every letter was marked on the recording form as either correct or incorrect. The total number of letters correct was recorded, and a conversion chart was used to derive the logMAR and Snellen score for that condition.

The protocol used to measure visual acuity with these charts followed standard ETDRS research protocol, where for every measurement, letters were read at a speed of one per second, beginning at the top left of the chart and proceeding line by line, left to right, with an opportunity to correct an error only before the next letter was attempted. The
procedures for encouraging letter recognition and the stopping rule are standardized. Training materials for Ophthalmic Clinical Trial Training and Certification are available from the Emmes Corporation. The researchers did not anticipate any of the subjects triggering the standard protocol for the conditions when visual acuity was worse than 20/200. When this was encountered, the A-ETDRS program returned a standard value of 20/250 and a letter count of 34, and similar results were recorded with the backlit ETDRS chart. The portion of the standardized testing protocol used to change the working distance to one meter was not done.

The A-ETDRS uses an Android tablet with the M&S Technologies, Inc. custom control program, which synchronizes with the main Smart System through a Bluetooth connection. Each time the protocol is run, the chart provides a random sample of the 10 ETDRS letters, making memorization of the chart impossible. There are two phases of determining the endpoint of visual acuity measures, range-finding and thresholding. During the range-finding phase, the subject finds the smallest line of letters that they believe they can read completely correctly and proceeds to read them aloud. The operator presses the button on the control software that corresponds to that line of letters. Figure 3 shows the screen from the tablet. The letters shown to the subject on the display screen are also displayed to the operator on the tablet.

After the A-ETDRS testing is complete, the system saves the results and reports the test results to the main screen, which can be printed. A sample set of data includes the eye (Right, Left, or Both), test distance (4 meters in this protocol), spectacles (on or off), light level (photopic vs. mesopic), and the visual acuity results in three forms (letter score, visual acuity, and logMAR). The letter score is the total number of letters that the subject said correctly, which results in a standard Snellen equivalent and a logMAR score. For example, a letter score of 87 converts to a Snellen VA of 20/20 and a logMAR score of -0.04.

Test times were measured for all trials using a stopwatch function on the investigator’s smart phone. Timing started as soon as the A-ETDRS chart was presented and terminated when the program displayed the scores to the computer screen for recording. For the backlit chart, timing was started when the subject said the first letter and finished when they were no
longer able to get any letters correct. Time to change the plastic test cards in the backlit box was not included in the timing, nor was the time to count and score the subject’s results.

Weber Contrast was calculated for each of the targets using measurements collected with the Konica-Minolta LS-110 luminance meter, which measures the amount of reflected or emitted light from an area of 0.33 of a degree. On the backlit box, the white area was 181 cd/m², while the black was 1.35 cd/m². This produced a Weber Contrast of 99.25%. On the M&S Technologies A-ETDRS screen, the white was 120 cd/m², and the black was 0.72 cd/m², which produced a Weber Contrast of 99.4%. The backlit box was not adjustable in luminance. The M&S system was at its calibrated light value of 120 cd/m². Both are compliant with ANSI Z80.21-2010 (R2015) and ISO 8597:1994(E) standards.\(^{11,12}\)

All subjects gave informed consent after a verbal and written explanation of the experiment, which was approved by the Southern College of Optometry Institutional Review Board in accordance with the Declaration of Helsinki.

### Statistical Analysis

Measurement of visual acuity with the ETDRS charts yields two different scores. The first is a Letter Score, which is a count of the total number of letters correct from the largest letter until the subject stops getting letters correct. There is also a calculated logMAR visual acuity level assigned to this value.

LogMAR scores for both Backlit ETDRS and A-ETDRS chart types were compared under each of four testing conditions (uncorrected, with spectacles, +1.50 blur over spectacles, and +3.00 blur over spectacles) using paired t-tests. Findings were also confirmed using non-parametric alternatives (Wilcoxon sign-rank tests), as well as a repeated measures analysis of variance (ANOVA), which yielded the same conclusions. Thus, for ease of presentation, the mean comparisons of each chart type at each testing condition are shown here. Bland-Altman plots were used to illustrate agreement between A-ETDRS and Backlit ETDRS chart types. Correlations between A-ETDRS and Backlit ETDRS chart types were examined using Pearson’s \(r\).

### Results

Analyses were conducted using Stata/SE software, version 13.\(^*\) Table 1 shows means, standard deviations (SDs), standard errors (SEs), and 95% confidence intervals comparing logMAR scores on A-ETDRS and Backlit ETDRS charts for each condition. There were no significant differences between the chart types at any condition. Figure 5 shows mean logMAR values for Automated and Backlit charts graphically, with error bars. The widest standard deviations exist for the uncorrected measures.

<table>
<thead>
<tr>
<th>Table 1. LogMAR scores by condition and chart type. Note: Significance test based on paired t-tests for Automated vs. Backlit on the common sample within each condition.</th>
</tr>
</thead>
<tbody>
<tr>
<td>With spectacles (n= 110)</td>
</tr>
<tr>
<td>Automated</td>
</tr>
<tr>
<td>Backlit</td>
</tr>
<tr>
<td>Uncorrected (n= 87)</td>
</tr>
<tr>
<td>Automated</td>
</tr>
<tr>
<td>Backlit</td>
</tr>
<tr>
<td>+1.5 Blur over spectacles (n= 111)</td>
</tr>
<tr>
<td>Automated</td>
</tr>
<tr>
<td>Backlit</td>
</tr>
<tr>
<td>+3.0 Blur over spectacles (n= 102)</td>
</tr>
<tr>
<td>Automated</td>
</tr>
<tr>
<td>Backlit</td>
</tr>
</tbody>
</table>

Note: Significance test based on paired t-tests for Automated vs. Backlit on the common sample within each condition.
and here the visual acuities measured trended to be worse with the backlit ETDRS. However, the differences were neither statistically nor clinically significant. Figures 6 to 9 show Bland-Altman plots for each study condition, which plot the difference of the paired chart vs. their average. There were only very few cases where individual values fell outside the range of agreement.

Correlations between Automated and Backlit chart types were 0.93 (uncorrected), 0.60 (with spectacles), 0.76 (+1.50 blur over spectacles), and 0.50 (+3.00 blur over spectacles), with all correlations statistically significant at \( p < 0.001 \).

It was decided to eliminate any data points in the Bland-Altman plots when one or both logMAR values was greater than 1.0, because we had not anticipated that we would have significant numbers of these measures. Indeed, only 9 subjects in the +3.00 blur and 24 subjects...
in the uncorrected conditions had one or more logMAR measures greater than 1.0. This accounted for the different number of subjects in each direct comparison. Figure 6 shows the Bland-Altman plot for the “with spectacles” condition. Three of the 110 subjects (2.73%) fell outside the 95% limits of agreement.

Figure 7 shows the Bland-Altman plot for the “uncorrected” condition. Three of the 87 subjects (3.45%) fell outside the 95% limits of agreement. The number of subjects for this condition was the smallest, because 24 of the subjects had either the A-ETDRS or the backlit ETDRS visual acuity worse than 1.0 logMAR and therefore were not included in the analysis.

Figure 8 shows the Bland-Altman plot for the “+1.50 blur over spectacles” condition. Four of the 111 subjects (3.6%) fell outside the 95% limits of agreement.

Figure 9 shows the Bland-Altman plot for the “+3.00 blur over spectacles” condition. Six of the 102 subjects (5.88%) fell outside the 95% limits of agreement. The N for this condition was reduced to 102 as nine subjects had either the A-ETDRS or the backlit ETDRS visual acuity worse than 1.0 logMAR.

The authors independently took the raw scores from the A-ETDRS testing and verified that the computer algorithm indeed yielded the correct Letter and logMAR Scores for each measurement for the first 20 subjects.

Timing data for all 444 trials on the A-ETDRS chart across all conditions averaged 21.24 seconds (SD 18.6 seconds), with a range from 3 to 180 seconds. The average time varied across the conditions, with the corrected measures averaging the fastest (24.88 seconds SD 9.9 seconds) The “+3.00 blur over spectacles” condition averaged 39.1 seconds (SD 25.7). Timing data for all 444 trials on the backlit ETDRS averaged 18.7 seconds (SD 11.9 seconds), with a range from 2 to 117 seconds. This was only the time to perform the test and did not include the time to score the results or to change the chart prior to starting each trial (Table 2).

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>With Spectacles</th>
<th>Uncorrected</th>
<th>+1.50 Blur over Spectacles</th>
<th>+3.00 Blur over Spectacles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>N=444</td>
<td>N=111</td>
<td>N=111</td>
<td>N=111</td>
<td>N=111</td>
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<tr>
<td>Average</td>
<td>31.2</td>
<td>24.8</td>
<td>26.8</td>
<td>39.1</td>
<td>16.6</td>
</tr>
<tr>
<td>SD</td>
<td>18.6</td>
<td>9.9</td>
<td>15.9</td>
<td>15.7</td>
<td>9.0</td>
</tr>
<tr>
<td>Low</td>
<td>3</td>
<td>10</td>
<td>3</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>High</td>
<td>180</td>
<td>77</td>
<td>95</td>
<td>118</td>
<td>180</td>
</tr>
</tbody>
</table>

**Discussion**

The four different testing conditions for each chart were chosen to represent both real-world conditions (uncorrected and with spectacles) as well as some research-based conditions (simulated 1.50 D and 3.00 D of uncorrected myopia). We did not anticipate any of our subjects triggering the standard protocol for the conditions when visual acuity was worse than 20/200. When this was encountered, the A-ETDRS program returned a standard value of 20/250 and a letter count of 34. As we reviewed the results, nine subjects in the “+3.00 blur over spectacles” and 24 subjects in the “uncorrected” group had visual acuities worse than 20/200, or logMAR greater than 1.0. In future studies, we will repeat measures in those conditions following the standard protocol, which is to reduce the working distance to one meter and repeat the testing. In that setup, the 20/200-sized letters at four meters are equivalent to 20/800 at one meter. This was not done. Measures where the visual acuity was greater than logMAR 1.0 were removed for analysis. This did not affect any measures in either the “spectacles” or the “+1.50 blur over spectacles” groups.

**Calibration**

In formal research settings, having testing instruments able to be calibrated is a must. Many individual systems are used for periods of years. Though the backlit ETDRS systems have been the gold standard for many years, there is no easy way to calibrate them, short of changing bulbs until the measured luminance levels are within standards. Luminance of the bulbs in the units varies, and the plastic sheets
are prone to yellowing over time, which reduces contrast. The A-ETDRS systems ship with a luminance measuring system, the use of which is integrated into the system. Periodically, as prompted by the software, the measuring system is suspended directly in front of the screen, and the system varies the illumination to reach the exact specified amount of 120 cd/m². Both the bright and dark luminance measures are taken and adjusted to ensure proper calibration, within very tight tolerances. This is a major advantage of the A-ETDRS system over the backlit ETDRS targets.

Randomized letters
Two major advantages accrue to those using A-ETDRS over standard backlit charts. The scoring step is eliminated, from the hard copy made during the testing to however the results are being recorded. The first benefit is that errors are eliminated in the calculation of the score. Others have reported that in their experience, manual recording systems are prone to error. A second benefit is that about 30 seconds are saved, which is the typical time it takes to do the actual scoring.

Time Saving from Automation
The new A-ETDRS is faster to use than standard ETDRS testing when scoring time on the standard ETDRS charts was added to the time needed to perform the test. The A-ETDRS system automatically scores the trial and shows all measures (letter score, Snellen visual acuity, and logMAR) immediately after the testing. All 444 A-ETDRS tests averaged 21.2 seconds (SD 18.6 seconds). Laidlaw et al. found an average time for standard ETDRS measures of 56 seconds with adult populations, and on average their computerized system was 7-10 seconds slower.

Timing for each of the backlit ETDRS trials was recorded in our study, but these did not include the time spent scoring each of the results. We only recorded the raw data for each trial on the matching score sheet for that trial, but we did not take the time to perform the letter count and corresponding conversion to logMAR while the subject was present. We neglected to record the time it took for scoring the data as we did it during downtime between subject sittings, and we did not add in the time to change the backlit ETDRS charts, which would affect this comparison even more. In a future study, the timing of the scoring and conversion to logMAR values as well as changing the charts should be done for each data point to be comparing like entities.

Conclusions
The findings of this study show that the traditional and automated ETDRS charts are functionally equivalent to each other under a variety of testing conditions, mimicking both clinical and research applications. Use of the A-ETDRS system by M&S Technologies is faster and less prone to recording errors or calculation errors, can be calibrated regularly, and is very easy. These findings set the stage for the adoption of the A-ETDRS chart by M&S Technologies in any clinical research study or clinical trial setting that calls for ETDRS testing.

Acknowledgments
Thank you to: Jan Gryczynski, PhD, Founding Partner COG Analytics, Potomac, MD, for his assistance with the statistics in this paper.

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d. https://goo.gl/qaYrTu
e. https://www.stata.com

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Harris PA, Roberts LE, Grant R. Comparison of backlit and novel automated etdrs visual acuity charts. Optom Vis Perf 2018;6(2):87-96.
The Role of Gait Analysis, Egocenter and Yoked Prism in Parkinson’s Disease

Nancy M. Mackowsky, OD, Raleigh, North Carolina

ABSTRACT

Background: Parkinson’s patients commonly experience a visual midline shift that causes postural and gait changes, increasing the risk of falls. If the optometrist can improve the visual midline shift with the use of yoked prism prescriptions, the risk of falls will decline and ultimately decrease the overall potential healthcare cost.

Case Report: A 77-year-old white male diagnosed with Parkinson’s presented for an evaluation. The patient complained of double vision and difficulty judging space perception that was affecting his balance when walking. He was treated with a lens prescription that included a combination of yoked and base-in prisms.

Conclusion: After 1 month of wearing the new prism prescription, he no longer experienced double vision and showed improved balance when walking. This case emphasizes the importance of evaluating visual midline shifts and prescribing yoked prisms in this patient population to improve overall balance and to lower the risk of falls.

Keywords: balance, Parkinson’s disease, visual midline shift, yoked prisms

Background

Parkinson’s disease (PD) is the second most common neurodegenerative disorder, following Alzheimer’s disease. It is a disorder affecting basal ganglia function, leading to the cardinal signs of tremor, rigidity, akinesia (bradykinesia), and postural instability. Parkinson’s disease is caused by a loss of nigrostriatal dopaminergic neurons, which in turn causes the loss of motor function. The classic pill-rolling resting tremor (a tremor that occurs at rest wherein the fingers/wrist move in a repetitive motion similar to a rhythmic voluntary manipulation of small objects or pills in the hand) is one of the best indicators for Parkinson’s, although some other neurological disorders can also present with the same finding.

Many professionals will use the general term Parkinsonism when a patient is found to have stiffness, slowness of movement, and tremors before a definitive diagnosis for Parkinson’s is made. Other types of disorders that fall under Parkinsonism include: progressive supranuclear palsy, multiple system atrophy, vascular Parkinson’s, and drug-induced Parkinsonism.

A Parkinson’s patient will seek neuro-optometric eye care due to poor visual spatial orientation that affects balance and posture, thus increasing the patient’s risk of falls.

This article presents:
1) A review of Parkinson’s characteristics, including diagnosis, testing, prevalence, visual consequences, and postural changes
2) A review of visual midline and posture/gait analysis
3) A systematic method to help determine a yoked prism prescription to decrease risk of falls
4) A case review

PD Characteristics

Diagnosis

Diagnosing Parkinson’s is not easy and can take considerable time. There is not one specific test available that confirms the diagnosis. When a patient consults with a Parkinson’s examiner...
(a neurologist who is trained specifically to treat movement disorders), one critical component of the work-up is the detailed neurological history. The examiner will ask about common early symptoms, including decreased sense of smell, anxiety, depression, disturbed sleep, tiredness, constipation, and loss of memory. The examiner will also want to know if the patient has common motor symptoms, including slowness of movement (bradykinesia), small handwriting tendencies, and a resting tremor (Parkinson's tremors are less noticeable with movement). These symptoms will often worsen with illness or stress.

During the evaluation, the patient will be asked to draw/write, walk, and speak. A Parkinson's patient will print very small and show a gradual fade. When asked to walk, the PD patient will exhibit a reduced arm swing, stride length, and speed. Speech will be soft and lack volume.

A brain scan may be suggested to help rule out other types of Parkinsonism, but there is no scan available at this time that can confirm a definitive diagnosis of Parkinson's. The brain scans of Parkinson's patients usually show no abnormalities. A newer type of brain imaging scan, known as a dopamine transporter scan or DAT-SPECT, can help specialists determine whether there is a loss of dopamine-containing brain cells. Unfortunately, an abnormal DAT-SPECT can also be found with other rarer neurological disease processes and so is not a definitive test for diagnosing Parkinson's.

Prevalence of Parkinson’s Disease

Currently, the exact prevalence of Parkinson's in the United States is uncertain. Many estimates are based upon rates extrapolated from older studies conducted in smaller regions of the United States and are taken to represent the entire United States population.

In 2010, one official estimate determined an extrapolated prevalence rate of 430,000 for the ≥40 y.o. population using the results from a study conducted in a sparsely populated rural county of Mississippi in 1978. Another official estimate found an extrapolated prevalence rate of nearly 920,000° for the ≥40 y.o. population based on findings from a more recent study conducted in Nebraska in 2000.

Because we still do not know how many people have Parkinson's, the Parkinson's Disease Foundation has formed the Parkinson's Prevalence Project to conduct a review of numerous current databases to address this problem. This knowledge will be significant in order to help the medical community determine how to distribute funds for diagnostic testing, pharmaceutical treatment, and rehabilitation strategies wisely in order to serve these patients.

Visual Consequences of Parkinson’s Disease

Parkinson’s disease causes many visual problems, most likely secondary to deficits in the magno-, parvo-, and koniocellular pathways, as reported by Startucci. Armstrong published a review of commonly found visual problems in Parkinson's patients that included poor low-contrast visual acuity, poor color discrimination, abnormal blink reflex, abnormal pupil reactivity with anisocoria, hypometric saccades, smooth pursuit abnormalities (movement interrupted by small saccades), and increased latencies of the visual evoked potential p100.

In addition, Parkinson's patients commonly exhibit problems with visuo-spatial working memory, leading to a shift of egocenter. This shift of one's egocenter will directly affect posture, spatial orientation, and balance. This impairment is most likely secondary to the degenerative process that takes place in the basal ganglia, the dorsal visual stream, and the frontal-prefrontal cortex. If the egocentric shift is severe, risk of fall increases, and subsequent injury becomes more likely.

Postural Changes in Parkinson’s Disease

It is common to see postural changes at some stage with the Parkinson's patient. The
cause changes with posture and balance, thus affecting gait. Yoked prisms have been shown to help remediate these shifts, improving balance and thereby reducing the risk of fall.\textsuperscript{21}

When the eye care provider evaluates a Parkinson's patient with gait abnormalities, there needs to be a systematic approach used for the evaluation of a visual midline shift. This evaluation needs to provide clinical measures that can help to determine whether a yoked prism correction is warranted, and if so, what strength/orientation is needed for the patient.

**Visual Midline Analysis**

There are numerous methods used to evaluate a patient's visual midline. Many practitioners use the Wolf Wand technique, where the patient follows a moving target from the periphery toward the midline and is asked to let the tester know when the target is centered in front of the nose. The tester then determines whether the target is “off-center” and notes the direction/amount of the displacement.\textsuperscript{22} A technique that provides written documentation is the Spatial Location Board, available from Bernell\textsuperscript{a} (Figure 1). This device consists of a grid pattern on both sides of a 3’ x 2’ board. The board can be easily pivoted to either a vertical or horizontal plane. Three magnetic “peg” targets are arranged on one side of the board in a semi-linear fashion set 50cm from one end of the board. The patient stands at the end of the board, with his/her nose directly placed against the handle. The patient is asked to take a dry-erase marker with the dominant hand and mark the opposite side of the board, mirroring the position of each target. An average of the amount of deviation from each target’s center on the vertical y-axis is calculated. The same steps are repeated with the board positioned horizontally, with the magnetic targets now located on the top of the board. The patient...
is given a different colored marker and again stands with his/her nose against the board. The patient is asked to mark from below where each target’s position is perceived. The amount of deviation on the horizontal x-axis is then averaged. The two values are used to estimate the amount of lateral-anteroposterior midline shift.

Static Posture Analysis
In order to understand postural control, it is best first to define posture. Posture is the ability to align the body biomechanically and to orient it to the environment. In order to achieve postural stability or balance, one must be able to control the center of mass in relationship to the base of support. The nervous system produces force to ensure that the center of mass stays within the boundaries of the base of support. The center of the distribution of the total force applied to the supporting surface is known as the center of pressure. It is this interaction between center of mass and center of pressure that determines one’s postural control. It is the responsibility of the optometrist to determine how vision influences this postural control.

The most convenient and least expensive method for documenting one’s posture in static stance is with photos and scales. A photograph is taken from 4 different viewpoints (front, back, left, and right lateral). The patient is asked to stand with equal weight on both feet. It helps to have a grid-type background behind the patient (door-size grids are available from posturezone.com) to aid with the visualization of weight shift in the anteroposterior and mediolateral directions (Figure 2).

With smart phone technology and apps, one can easily organize the photographs on one sheet of paper and print for easier review/chart documentation. Clinically useful information can be obtained by systematic observational analysis, noting variation of weight displacement laterally or anteroposteriorly, which may be suggestive of a visual midline shift. The amount of postural shift is compared to the visual midline shift to determine whether both analyses suggest the same perceptual shift.

Gait Analysis
When the static posture and visual midline assessments suggest a shift, the eye care provider next needs to consider whether the midline shift is present during walking. In order to look at one’s gait, familiarity with the mechanics and the terminology used for observations of pathological gait is needed to understand the functional implications. A well-accepted gait model is the Perry Model. Dr. Jacquelyn Perry and colleagues from Ranch Alas Amigos, California videotaped hundreds of patients’ gait patterns from 1980 to 2000. They used the video tapes to analyze and to collate data in order to create common definitions/defined methods for observational gait analysis. They defined 8 phases of the gait cycle using a systematic approach that compares one limb to the other. When there is disease or trauma, a
disruption will occur to the timing, coordination, speed, and versatility of the gait. Differences are seen in the way each foot strikes the ground and the length of the stride; the positioning of the knees will improve if the visual midline is centered. In addition to the observational gait analysis method, there are also many different devices/instruments used to gather information about gait mechanics.

Observational gait analysis is not typically done in an optometry office, and many private practices do not have the necessary space or the funds to invest in complex, comprehensive equipment. However, there are some screening techniques that can be used to help guide our assessment of the Parkinson's patient's gait.

One easy and inexpensive stride analysis technique is the timed up and go test (TUG). All that is needed is a standard stopwatch. The TUG method evaluates gait speed and is a relatively objective test used to guide decision making regarding the patient's risk of fall. The patient wears his regular footwear and can use a walking aid if needed. For the testing area, an identifiable line is marked on the floor 10 feet away. This can easily be done in the exam lane by placing a piece of colored electrical tape 10 feet from the exam chair. The patient begins by sitting back in the exam chair, and he is asked to identify the line 10 feet away on the floor. The instructions to the patient are as follows:

“When I say ‘Go,’ I want you to stand up from the chair, walk to the line on the floor at your normal pace, turn, walk back to the chair at your normal pace, and then sit down again.”

On the word “Go,” the timer is started. The timer is stopped after the patient sits back down. The time to complete the task is recorded. Differences are recorded as to the way each foot strikes the ground, how the weight is shifted to each side, the length of the stride, and the positioning of the knees. A patient who takes ≥12 seconds to complete the TUG is considered to be at high risk for falling. If the patient has an observable visual midline shift, it is our responsibility to prescribe the best prism prescription that will improve spatial perception. The patient will then have a better visual system to support the motor system. A referral for treatment is then made to a physical therapist trained in gait assessment.

Determining Yoked Prism Correction

Research has shown the effectiveness of yoked prisms on improving spatial orientation. Padula et al. have shown that center of mass can be altered when yoked prisms improve visual midline centration. If yoked prisms can center the visual midline, we can ultimately center and stabilize the center of mass for Parkinson's patients, which will lead to improved weight distribution when walking and decreased risk of fall.

Padula uses a graph analysis technique, where the weight shift is assigned a value between 1 and 12, with 12 being the greatest amount of weight shift in any one direction (the center of gravity limit within or beyond the base of support). I have found that one square on both the Spatial Location Board and Postural Zone door grid correlates to a 2pd visual midline shift. The values obtained from the Spatial Location Board and static postural photos are averaged to determine the starting strength and direction of the prism correction. Figures 3a-c and 4a-c represent examples of visual midline shifts along the x and y axes that can be seen during the Spatial Location Board analysis.

If the patient demonstrates a leftward midline shift, base-right prism is used. If the patient demonstrates a rightward midline shift, base-left prism is used. Base-up is used for a posterior midline shift and base-down for an anterior midline shift. Sometimes a patient can have a paradoxical response to the suggested prism, but usually the above applies. When there is a combination of a lateral and either an anterior or posterior shift, the prism amount
and base direction/axis can be calculated using basic geometry and trigonometry formulas conceptualizing space along the x and y axes. This is a very basic method to help the optometrist determine a starting point for prism treatment.

Figure 5 illustrates an example of the Spatial Location Board with a 2pd right/1.5pd posterior shift. For the right shift, base-left prism is needed; for the posterior shift, base-up prism is needed. In order to determine the prism amount, an x-y graph (Figure 6) is used to visualize the yoked prism lenses needed for 2pd left and 1.5pd up yoked prisms.

A right triangle is formed by connecting the points for 1.5 up and 2 left. The red line on the diagram ("P") is the value needed. Using the Pythagorean Rule, "P", the longest side of the right triangle, is equal to the square root of the sums of the squares of the two shorter sides. The "P" value for 1.5 up and 2 left is:

- Step 1: \( P = \sqrt{(2^2 + 1.5^2)} \)
- Step 2: \( P = \sqrt{4 + 2.25} \)
- Step 3: \( P = \sqrt{6.25} \)
- Step 4: \( P = 2.5 \)

2.5pd is the amount of prism that results from 1.5 up and 2 left. The axis is determined by using the rule of trigonometry that the
tangent of an angle is the opposite side divided by the adjacent side, or the angle between the horizontal meridian and the line marked P (Figure 7). The opposite side is the vertical portion of the prism, 1.5, and the adjacent side is the horizontal part of the prism, 2.

To calculate the angle for 1.5 up and 2 in, follow these steps:

- Step 1: Angle = tan⁻¹ of opposite/adjacent = 1.5/2 = 0.75
- Step 2: Angle = tan⁻¹ of 0.75 = 37° (corrected to 1 decimal place)

The same amount of prism and angle would be used for the left eye. When the prism direction is other than a base-left/up combination, one will need to add or subtract the angle value from the horizontal or vertical axis to obtain the correct axis value.

Once a numerical value for the yoked prism correction has been estimated, the yoked prisms are trial framed, and the patient is asked to perform the TUG test. Observations are recorded noting stride length, speed, and equality of weight distribution. A sensorimotor evaluation is also done to evaluate binocularity. The Spatial Location Board and static photos are repeated. Adjustments are made to the initial prism amount/base based upon the changes observed.

Case Report

A 77-year-old male with Parkinson’s presented to the clinic with problems judging space perception and reduced acuities in both eyes. He reported that he could not read due to constant, horizontal diplopia when viewing print held at near. He was accompanied by his wife and daughter, who both reported that he would frequently veer to the right when walking and bump into people/objects on that side. He used a single-point cane to help maintain his balance. His family was concerned about his risk of falling and requested an evaluation at my clinic. His systemic history included non-insulin type 2 diabetes, hypertension, and Parkinson’s disease. Ocular history included dry AMD, pseudophakia OD, and cataract OS. When walking from the waiting room to the exam room, he leaned and veered to the right side of the hall. Static posture photos showed a 4pd left shift (Figure 2); the Spatial Location Board demonstrated a 1pd left shift. The average of these two values approximated a 2.5pd left shift. Entering visual acuities were 20/40-3 OD and 20/30-3 OS wearing the following progressive bifocal correction: +0.75-1.00×085/+2.50 OD,
+3.25-1.25x090/+2.50 OS. Pupils, extraocular muscle motility, confrontation fields, and Amsler grid testing results were normal OU. Near point of convergence was receded to 37cm break/1m regain. Sensory fusion with Worth 4 Dot testing showed fusion out to 8 feet then crossed diplopia further out. Unilateral cover testing showed an 8pd intermittent, alternating exotropia at distance and a 14pd intermittent, alternating exotropia at near. Retinoscopy showed no changes with his refractive error OU. Pursuit and saccadic tracking were age appropriate. Anterior segment evaluation showed a centered intraocular implant OD, NS 2+ OS. His dilated fundus exam revealed large macular drusen OU. He was found to show an improved sensory fusion response at distance when 2pd base left OD, 2pd base right OS compensatory prisms were worn. Repeat cover testing showed 4pd exophoria at distance, and he could now hold fusion to read without diplopia.

The patient performed the TUG test first wearing his habitual correction. The test took 30 seconds to complete, and his steps were small with a shuffling gait. He leaned and veered to his right. The TUG test was repeated wearing 2pd base left OD, 2pd base right OS compensatory prisms over his spectacle correction to determine whether improved binocularity allowed for better visual midline centration, which would improve his gait and speed. His time did improve to 20 seconds, but he still leaned and veered to the right; step size and gait were unchanged. He continued to show a 4pd left shift observationally, and the Spatial Location Board was unchanged (1pd left shift). The next step was to determine whether the use of yoked prisms would improve his visual midline, binocularity, and gait. The amount used was 2.5pd base-right yoked prisms (the average of the midline shift determined from the space posture board and static photos). The space posture board showed centration. Cover testing, however, showed the return of the intermittent, alternating exotropia. During the TUG test, the patient showed less leaning and veering to the right, but his time worsened to 25 seconds (most likely due to the loss of binocularity). In order to improve both his binocularity and visual midline, a combination of the compensatory and yoked prisms was trialed. The initial amount was determined by taking the average of the two types of prism for each eye: [2pd base left + 2.5pd base right]/2 OD; [2pd base right + 2.5pd base right]/2 OS. The prism amount was determined to be 0.25pd base-right prism OD, 2.25pd base-right OS. When this prism combination was trial framed, cover testing continued to show a mild intermittent, alternating exotropia. In order to aid eye teaming, base-left prism was added back in 1-pd increments OD until sensory fusion was achieved (base-right prism was increased OS first, but the patient noticed a decline with his binocular visual acuity that was intolerable). Two prism diopters base-left prism OD was the amount needed. This, however, eliminated the yoked component from the prescription. The base-right prism was increased to 4.75pd OS to restore the yoked property taken away from OD (2.50pd base right). The patient showed good sensory fusion and achieved 20/25 binocular acuity, and his TUG test was completed in 12 secs. He now leaned and veered slightly to the left. Based on this observation, the base-right prism OS was reduced by 1-pd increments until visual midline centration and sensory fusion were achieved. The patient was able to maintain sensory fusion and 20/25 binocular acuity, and he showed centration on the Spatial Location Board with 2pd base-left prism OD, 3pd base-right prism OS. The TUG speed was 11.45 sec. He now walked a straight path. There was also less shuffling noted with a larger stride length.

Based on the findings and observations, a prism correction in a bifocal format of 2pd base left OD and 3pd base right OS was prescribed for full-time wear. He was referred back to his physical therapist to work on improving his dynamic gait with the prism wear.
Discussion

When evaluating a Parkinson’s patient, the eye care provider must remember that the visuo-spatial orientation may be compromised, causing a visual midline shift and poor binocularity, making it difficult to judge spatial localization accurately. Many times, the patient, spouse, or caretaker will not mention the spatial awareness problems since they will not equate those difficulties to a visual dysfunction. Unfortunately, these visual midline shifts with Parkinson’s patients will go undiagnosed and lead to fall potentials.

In this example, the patient was prescribed a prism correction to aid eye teaming and visual midline. After one month, he no longer experienced double vision and showed improved balance when walking. The initial calculated amount of yoked prism was 2.5pd base right OU. However, this patient had an intermittent exotropia that also needed a compensatory prism correction of 2pd base left OD, 2pd base right OS. Many times, correcting the binocular issue will improve the midline shift, and vice versa. However, in this case, both the binocularity and visual midline did not improve until a combination of compensatory and yoked prism was used. Averaging the two prism values gave a total of 0.25pd base right OD, 2.25pd base right OS. This amount did not work since the patient needed additional base-left prism OD to maintain his binocularity. When additional base-left prism OD was incorporated into the correction, it reduced the yoked component to aid the visual midline. This patient showed best visual midline centration and gait ability when 3pd base-right prism was used OS. Many times, the calculated yoked prism correction will need to be adjusted to take into account binocular dysfunctions. This case study provides a step-by-step process to help the practitioner determine an initial prism correction for a patient with a visual midline shift. An evaluation of the patient’s binocularity with the yoked prism correction must be done, and adjustments must be made to improve both eye teaming and visual midline issues. With our PD patients, if we can improve visual midline shifts, we will reduce the risk of potential falls and ultimately decrease the overall healthcare cost.

References


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The Complexity of Co-existing Functional Vision Loss and Organic Diagnoses

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ABSTRACT

Background: Non-organic vision loss presents with a loss of visual function that oftentimes manifests as either a loss of acuity and/or visual field without identifiable organic pathology. In many cases, non-organic vision loss can be challenging to diagnose due to an association with psychiatric disorders, inconsistent clinical findings, lack of a gold standard for diagnosing, and fear of missing an organic and treatable cause of vision loss. This can be even further complicated when concurrent organic disease exists, especially as organic pathology can manifest over time.

Case Report: A 51-year-old African American male presented to the eye clinic for an eye exam. He reported longstanding, bilateral vision loss that had been present for over 25 years but had progressed over the last few years. He had a prior diagnosis of functional vision loss as well as macular degeneration. A thorough review of past testing was conducted as well as a case history to understand the psychosocial setting. A battery of tests was performed in order to elucidate the cause of the vision loss. Ultimately, this patient was diagnosed with vision loss from concomitant non-organic and organic pathology and was referred for psychiatric/psychological counselling.

Conclusion: The superimposition of both non-organic vision loss and organic disease presents a unique challenge to clinicians, particularly if non-organic vision loss was the initial presenting condition. It is crucial for the practicing clinician to be able to correlate clinical signs and to reconcile them with the degree of vision loss. Non-organic vision loss should be suspected in cases where these inconsistencies exist. This will minimize patient distress, inappropriate referrals, and unnecessary healthcare expenditures. This case highlights the importance of remaining vigilant for future ocular pathology even after an established functional vision loss diagnosis has been made.

Keywords: central serous chorioretinopathy, functional vision loss, non-organic vision loss

Introduction

Non-organic vision loss (NOVL), also known as functional vision loss, is a poorly understood condition that occurs in the absence of identifiable organic pathology. It presents in the form of a visual disturbance, either as a loss of visual acuity and/or a loss of visual field. Although descriptions and categories may vary depending on the literature source, NOVL can be divided into 3 groups: psychogenic,
malingering, and factitious.1 Psychogenic NOVL occurs in a patient who experiences vision loss but is unable to control their symptoms.1 NOVL from malingering refers to patients feigning symptoms for secondary gain.1 In factitious NOVL, the patient intentionally produces symptoms in order to assume the sick role.1 Diagnosis of functional vision loss has several different characteristics, with the common theme being the absence of organic disease on clinical examination and the presence of inconsistent exam findings. To further complicate the diagnosis of NOVL, organic vision loss can be present concurrently. This is known as functional overlay. The occurrence of functional overlay ranges from 6% to 53%, depending on the source.1,3 In addition to organic disease, NOVL has been found to be associated with psychiatric disorders or psychosocial events in approximately 30% and 36% of cases, respectively.4 Again, these percentages vary significantly across the literature.

Diagnosis bias towards a pre-existing condition may mask the detection of organic disease overlay in NOVL. It is easy to fall back on medical parsimony and to assign new or worsening symptoms to an already established diagnosis. Furthermore, inheriting new patients with an incoming NOVL diagnosis can prove even more challenging to manage when prior history and exam records are not accessible. This case study uncovers organic macular disease at the initial exam in a patient with a previously documented diagnosis of NOVL. Without consistent eye exams and ancillary testing throughout the years, it is difficult to determine the onset of this pathology. With the detection of new organic pathology, questions were raised concerning the validity of the prior NOVL diagnosis. This triggered a meticulous review of past records and set off a flurry of diagnostic testing to aid with differentials. A diagnosis was required to initiate further treatment and counseling, if warranted.

This case had three distinct but interrelated elements. The first was the early diagnosis of functional vision loss and how it was first established. The second was the new diagnosis of organic pathology nearly 25 years after the patient’s initial loss of vision and the difficulties inherent in identifying obscure pathology. The final aspect was the important message to remain vigilant in cases when a longstanding diagnosis is present.

**Case Report**

A 51-year-old African American male, MJ, presented on 06/21/2016 to the West Haven Veteran Affairs (VA) Optometry Eye Clinic for a comprehensive eye exam. He reported longstanding bilateral vision loss that had been present for over 25 years, but he felt that it had progressed within the past few years.

MJ’s medical history was remarkable for obstructive sleep apnea, post-traumatic stress disorder, depression, tinnitus, and plantar fasciitis. His medications at the time of the exam were naproxen 375 milligrams (mg) twice a day, sertraline 100mg once a day, and tamsulosin 0.40mg once a day.

MJ reported that while deployed during Operation Desert Storm in Iraq, he fell off a vehicle and experienced a head trauma. He reported rapid vision loss in the 1990s following his return stateside. After returning, he was seen by a multitude of eye specialists, including retinal specialists and neuro-ophthalmologists. He did not recall ever being given a diagnosis or specific cause for the loss of vision. The most recent eye records from 2014 were from an outside provider, who indicated macular degeneration as the source of the vision loss.

**History**

A chart review revealed that MJ had best-corrected vision of 20/20 OD and OS from 1984 through 1987 during army physicals. Significant vision loss was first reported in 1991, with distance best-corrected visual acuity
found to be normal. Computed tomography (CT) and magnetic resonance imaging (MRI) of the brain were also completed and were found to be normal.

There were no available records between 1991 and 2013. In addition, MJ was unsure of whether he was seen by an eyecare provider during that time. Starting in 2014, he re-initiated eye care with a few different private providers who had varied diagnoses. The last diagnosis made prior to transferring care to the West Haven VA Medical Center was macular degeneration OU.

**Exam Findings**

The patient received a comprehensive eye examination upon entering the West Haven VA Medical Center. MJ’s BCVA was measured with a Feinbloom chart to be 10/80- with an eccentric view at 6 o’clock OD and 10/60- with an eccentric view at 11 o’clock OS. The refractive error was compound myopic astigmatism: OD: -4.50-1.00x180 and OS: -3.00-2.25x155. Primary gaze acuity was recorded as 10/140 OD and OS.

Both entrance testing and anterior segment findings were found to be unremarkable OU. Fundus evaluation revealed mild RPE mottling of the maculae OU. The periphery was unremarkable OU. An optical coherence tomography (OCT) was deemed necessary as the patient’s symptom of progressive vision loss OU did not equate with the clinical findings of mild macular retinal pigment epithelium (RPE) mottling OU. Surprisingly, the macular OCT showed a sub-retinal cystic space OD and a hyper-reflective lesion OS, with surrounding subretinal fluid (SRF; Figure 1). After an abnormal OCT finding, the patient was referred for further evaluation with the retinal specialist.

Upon further study of the posterior pole, the retinal specialist discounted the idea of macular degeneration based on demographics and clinical appearance. Fundus autofluorescence (FAF) imaging showed no abnormal hypo- or hyper-fluorescent lesions (Figure 2). Fluorescein
findings and the fact that the clinical signs did not agree with the degree of vision loss, he also diagnosed MJ with functional vision loss.

Discussion

As previously mentioned, functional vision loss, or NOVL, is a visual disturbance manifesting as decreased acuity and/or visual field loss with no apparent organic disease in the structures of the visual system spanning from the cornea to the occipital cortex. It is divided into 3 subgroups: psychogenic, malingering, and factitious disorders. From an examination standpoint, the
delineation is not crucial. Regardless of etiology, a complaint of vision loss should always elicit a complete ocular evaluation. The first step is to rule out refractive error and anterior or posterior segment abnormalities. Next, ancillary testing such as OCT, ERG, VEP, FA, and/or FAF should be ordered to aid in diagnosis. Only then should a functional vision loss diagnosis be considered. Neuro-imaging is recommended in particular cases where a reproducible visual field defect is discovered and/or other neurological deficits are present. In addition to ruling out abnormalities, a common aspect is an inconsistency in exam findings, especially if the vision loss is worse than exam findings would predict. Management of NOVL is typically just reassurance, with some sources suggesting placebo visual exercises.

A psychiatric referral may be appropriate if the patient is not already being followed and especially when other impairments of psychological behavior are present.

MJ was first seen by an eye care provider in August of 1991. Myriad testing was done at that initial exam to address the unexplained vision loss. After an extensive work-up, the provider had functional vision loss high on the differential. There were several critical exam findings that made that diagnosis more likely. The first finding was the near-normal stereopsis result, where MJ scored 8/9 on the Titmus circles stereotest. That score corresponds to 50 secs of arc. According to the study conducted by Levy, to achieve a stereoacuity of 50 secs of arc, a visual acuity of about 20/30 is required, better than MJ’s BCVA of 20/50 OD/OS at that time. A second exam finding that could possibly suggest a functional vision loss component occurred during the refraction. Initially, MJ saw 20/200 OD/OS at distance; however, was able to read the 20/40 line at near. This represents an inconsistency as the angle of resolution should be the same at both distance and near.

Finally, as seen in Figure 6, a tangent screen visual field test was performed at both one and two meters. In a patient with either intact vision or organic disease, visual field should expand with increasing distance in a characteristic cone shape. In a patient with NOVL, the field will not expand and will remain the same at both one and two meters, producing a tube shape.

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| Table 1. Testing Completed During Initial Examination, 1990 |
|------------------------|------------------------|
| **Testing**            | **Results**            |
| Refraction             | BCVA OD: 20/200; 20/50 with coaxing |
|                        | BCVA OS: 20/200; 20/50 with coaxing |
| Stereo                 | 8/9 on Titmus circles  |
| Red Saturation         | Normal                 |
| PIP (Ishihara)         | 2/14 OD/OS             |
| Farnsworth D-15        | Normal OD/OS           |
| Amsler Grid            | Normal OD/OS           |
| OKN                    | Normal OU              |
| Anterior Segment       | Normal OU              |
| C/Ds                   | OD: 0.5R               |
|                        | OS: 0.5R               |
| Tangent Screen         | Tubular field (Figure 6) |
| HVF 30-2               | Small central scotoma  |
| HVF 10-2               | Small central scotoma that fluctuated on repeat fields |
| HVF 30-60              | Normal OU              |
| Fluorescein Angiography| Normal OU; (-)leakage, hyper-/hypofluorescence |
| VEP                    | Normal OU (Borderline latencies) |
| CT/MRI                 | Normal                 |
| CBC                    | Normal                 |
| ESR                    | Normal, 19             |
| Serum protein electrophoresis | Normal          |
| FTA-ABS                | Negative               |
| ANA                    | Negative               |
| 24 hr urine collection | Hg, Pb, As normal      |
| Folate, RBC, B12       | Normal                 |

**Figure 6.** Tangent screen of the right eye (OD) and left eye (OS) measured in 1991. The blue lines represent measures taken using a 3mm target at 1 meter. The red lines represent measures taken using a 6mm target at 2 meters. Both eyes display a tubular visual field.
this tubular field OD and OS. Although these findings were suggestive of NOVL, a complete work-up was executed to rule out any possible organic causes.

All testing and results from 1991 are depicted in Table 1. An extensive work-up was completed, including a dilated fundus exam, automated perimetry, brain imaging, blood work, electrodiagnostics, and urine analysis.

As mentioned earlier, following the diagnosis of NOVL, records for MJ's visits were not found until 2014, when an outside provider made a diagnosis of macular degeneration. Following a comprehensive exam by the retinal specialist at the West Haven VA, macular degeneration was placed much lower on the list of differential diagnoses. Age-related macular degeneration (AMD) is a disease that affects central vision. Typical demographics are Caucasian, male, and typically over 50 years old. Individuals aged 43-54 have an 8% chance of developing AMD, whereas in those aged over 75, the risk jumps to 30%. In addition, diagnosis of macular degeneration is based on clinical appearance, with differentiating characteristics such as drusen, pigment migration, and geographic atrophy. Fundus evaluation revealed only mild RPE mottling, but no other characteristic findings for AMD. Furthermore, macular OCT (Figure 1) showed no characteristic drusenoid pigment epithelial detachments (PED). The patient's younger age and race made the diagnosis even less likely.

During the course of the examination with the retinal specialist, several other potential differential diagnoses were discussed: Leber's hereditary optic neuropathy, macular pattern dystrophy, Stargardt's, achromatopsia/cone dystrophy, and chronic central serous chorioretinopathy. A brief discussion of each disease entity and the pertinent exam findings follows.

Leber's hereditary optic neuropathy (LHON) is a mitochondrial genetic disease with preponderance for young adult males. Optic atrophy is a universal trait of LHON, accompanied by reduced vision not exceeding 20/200. A fluorescein angiography, while not essential for proper diagnosis, confirms the non-vascular origin of the atrophy when there is no leakage from the optic nerve. Pattern ERG can be used to confirm optic nerve dysfunction. Family history may be positive for visual dysfunction on the maternal side. CT and MRI scans are also usually unremarkable.

Following the initial retinal evaluation, MJ was seen by a neuro-ophthalmologist to rule out LHON in addition to any other possible optic neuropathies. The lack of nerve head pallor and normal RNFL OCT excluded LHON. The neuro-ophthalmologist further stated that there was likely no other optic neuropathy and relegated the decreased vision to the outer retinal degeneration noted on the macular OCT in combination with NOVL.

Autosomal dominant macular pattern dystrophies comprise five similar types: adult-onset foveomacular vitelliform dystrophy, butterfly-shaped pigment dystrophy, reticular dystrophy, multifocal pattern dystrophy, and fundus pulverulentus. These diseases, originating from a mutation in the peripherin/RDS gene, are characterized by pigment disruption and migration primarily affecting the RPE. Disease onset is typical in the 4th and 5th decades of life and may lead to progressive vision loss. Hannan et al. show that macular OCT typically reveals RPE disruption, with expanding hyper-reflectivity extending from the RPE towards the outer nuclear layer. Additionally, they indicate that the FA shows variable hyper- and hypo-fluorescence. As indicated by Boon et al., FAF shows distinctive hyper- and hypo-fluorescent patterns, which allows for better differentiation of the 5 sub-types. Although MJ's macular OCT (Figure 1) somewhat resembled the lesions seen in adult-onset foveomacular vitelliform dystrophy OD, macular pattern dystrophy was discounted after viewing the results of both the autofluorescence and fluorescein angiography.
angiography; both imaging sets were devoid of any significant or typical hyper- or hypo-
fluorescent lesions.

Stargardt’s and fundus flavimaculatus are autosomal recessive macular dystrophies caused by a mutation on the ABCA4 gene. Differentiation of the two dystrophies is ill-defined; some believe that the dystrophies are part of a continuum of the same disease. Visual loss from either can vary but is usually no worse than 20/200. Macular OCT will show disruption of both the RPE and photoreceptor integrity line (PIL) in delineated areas. The fundus hallmark of the disease is yellowish-white flecks mainly located in the posterior pole. The flecks can be differentiated from drusen as they are generally pisciform (fish-like) in shape, as opposed to the commonly round shape of drusen. FAF is not highly diagnostic, as it will show areas of hyper- and hypo-fluorescence consistent with other macular dystrophies. An FA provides diagnostic gravitas, as it will show the defining “dark choroid,” a clinical finding where background fluorescence of the choroid is blocked by the lipofuscin buildup within the RPE. In addition, flecks generally do not hyperfluoresce during FA, in contrast to drusen. Visual fields tend to have central deficits that spread more peripherally with further progression of the disease. Stargardt’s, like the autosomal dominant macular dystrophies, was removed from consideration in this case: the patient’s fundus exhibited no signs of the classic pisciform flecks, fluorescein angiography was clear of any hyper- or hypo-fluorescence, and the defining “dark choroid” was not present in MJ’s FA.

Cone dystrophies are conditions that generally affect the cones within the macula. Achromatopsia, also known as rod monochromatism, is a genetic condition where no functioning cones exist within the retina. This is considered a stationary cone dystrophy as it is present in infancy and does not tend to progress. As is expected, these patients have no color vision, and BCVA is generally around 20/200. Other characteristics include pendular nystagmus and photophobia. Progressive cone dystrophy, in contrast to the aforementioned stationary counterpart, typically presents in childhood or early adult life. Patients generally start with cone dysfunction; however, rods may begin to be affected in later stages of the condition (at times described as cone-rod dystrophies). A prominent early symptom is photophobia. With progression, vision can deteriorate to 20/200, and color vision can progress from a deficiency to total loss. Bull’s eye maculopathy may be observed but can be as seemingly insignificant as mild RPE disruption. Fundus autofluorescence may show hyper-fluorescence early in the disease and will show hypo-fluorescence due to atrophy late in the disease. As it pertains to MJ’s condition, achromatopsia was removed from consideration as he had a normal Farnsworth D-15 at 26 years of age. That finding also made the progressive cone dystrophies less likely as well. Autofluorescence provided further evidence, as no atrophy was present in MJ’s condition. Although MJ did report longstanding photophobia, the finding was insufficient for diagnosis.

Central serous chorioretinopathy (CSCR) is a disorder caused by a dysfunctional RPE that is abnormally permeable to fluid. This permeability leads to fluid retention in both the sub-retinal and sub-RPE potential spaces. The demographics of this condition typically include middle-aged males averaging between 45-51 years old. Several associated risk factors have been identified, including use of glucocorticoids, pregnancy in the third trimester, type A personality, and psychotropic medication or psychological stress. Psychological stress induces release of cortisol, an endogenous steroid hormone, which is part of the corticosteroid family. CSCR can present in an acute or chronic form. Chronicity has a varied time interval, ranging from 3 to 6 months of persistent fluid presence. Acute forms may be recurrent but tend to resolve
spontaneously with minimal damage. Chronic CSCR has the potential for further damage as the sub-retinal fluid is not absorbed in an efficient manner, leading to photoreceptor loss. Additionally, individuals with chronic CSCR are at risk for choroidal neovascularization. Fundus evaluation will usually identify a neurosensory detachment via elevation. Chronic cases can be further identified by RPE atrophy and RPE pigment clumping. Macular OCT will show the typical neurosensory detachment located in the posterior pole. It is not uncommon to have associated PEDs within the neurosensory detachment. A thickened choroid can be found with enhanced depth imaging (EDI) OCT. An FA can display the hallmark “smokestack” pattern but more often there is a single pinpoint leak that spreads with time. Color vision deficits, mostly blue deficits, have been reported in patients with CSCR. MJ’s fundus evaluation revealed very mild hypo- and hyper-pigmentation in the macula of both eyes. Macular OCT showed a small, central neurosensory detachment in the right eye and a central neurosensory detachment in the left eye with an associated hyper-reflective lesion. Hyper-reflective lesions have been reported in the past and are due to subretinal fibrosis from a possible now-quiescent retinal neovascularization. FAF was not significant. The FA showed very mild hyperfluorescence in the OS only.

MJ’s presentation was atypical for several reasons. First, the lesions were located symmetrically in the central macula, where generally they can show up anywhere in the posterior pole. Additionally, the area of the central lesions was very small, whereas CSCR lesions are generally larger. Despite these characteristics, chronic CSCR may be responsible for MJ’s current clinical appearance. Unfortunately, possible treatments such as laser photocoagulation depend on the FA identifying leaks in acute CSCR. There was no identifiable leak on MJ’s FA, making laser an unviable option. Unfortunately for MJ, there were two conditions contributing to his vision loss: the longstanding functional vision loss in addition to the atypical chronic CSCR. Functional vision loss remained important despite the recognition of an organic pathology. Since optic neuropathy was ruled out, it stood to reason that beyond the outer retinal degeneration at the fovea of both eyes, healthy retina remained. As mentioned, at its widest, the outer retinal lesions spanned 1300 um OD and 700 um OS. One degree of visual field corresponds to approximately 288 um, which in turn calculates to 4.51 degrees OD and 2.43 degrees OS in our patient. MJ was seen in the low vision clinic and underwent extensive eccentric viewing training at every clock hour. Despite this training, MJ was unable to improve beyond 20/160 OD and 20/120 OS. According to the study by Wertheim, peripheral visual acuity at 5 degrees beyond fixation, well beyond the lesions, is expected to be at least 20/66. Even at 10 degrees beyond fixation, expected VA is 20/100. As can be seen, MJ’s decreased BCVA cannot be fully accounted for by the lesions. When comparing the size in degrees of the lesions on OCT, 4.51 degrees OD and 2.43 degrees OS, these numbers were significantly less than the HVF 24-2 in Figure 5. Based on the HVF, the central scotomas in both eyes were at minimum 6 x 6 degrees in size. These findings supported the concurrent existence of both NOVL and central vision loss.

Interestingly, it seems that both NOVL and CSCR have a common correlation to psychological factors. For CSCR, patients report more psychosomatic problems, unfavorable stress coping skills, and increased critical life events. All of these factors increase both physical and emotional stress on the body. In particular, elevated aggression was a risk factor for chronic CSCR. A look into MJ’s medical record showed that he had a history of aggression, agitation, and involvement in verbal altercations. NOVL has also been found to be related to concomitant psychiatric disorders.
(30%) or psychosocial events (36%), although these percentages vary significantly from study to study. Psychosocial events include stressors such as physical trauma and sexual abuse. This etiological link between NOVL and CSCR has been noted before, where the author suggested that care should be taken, as CSCR could mimic NOVL due to a similar presenting history of a psychological event. Perhaps, then, it is not so happenstance that MJ, with his history of post-traumatic stress disorder and aggression, developed CSCR following his longstanding NOVL. The common link is MJ's longstanding history of psychological factors. For patients with longstanding NOVL, it may prove practical to screen for CSCR due to this possible relationship.

Once NOVL has been diagnosed, management should be focused towards stressing a good prognosis to encourage visual recovery. As with MJ, co-existing ocular pathology and patients' concern for it may incite or exacerbate the functional component, so this must also be addressed. Care should be taken to voice concerns in a compassionate and supportive manner, as confrontations are rarely helpful. Reassurance alone seemed more likely to result in recovery than would the addition of nonspecific treatments like eye exercises, glasses, eye drops, or placebo medicines. Additionally, Chen et al. recommended at least one follow-up appointment to give the patient the perception that the problem was undergoing active management. Good prognostic indicators for full recovery are young age and lack of associated psychiatric disease. Because MJ did not have these good prognostic indicators and therefore was at risk for having persistent NOVL, he was ultimately referred for psychiatric/psychological counseling. In general, because adults are more prone to having psychiatric disease, it is suggested that the focus of treatment be on the psychiatric condition itself rather than the visual dysfunction.

This case reiterates the importance of thorough examinations, even in individuals with well-established chronic conditions. In 1991, MJ did not have outer retinal lesions; his Amsler grid was clear, his color vision was normal, and his fundus examination was unremarkable. Fast-forwarding to 2016, definitive organic pathology was present with reduced color vision and a central scotoma on Amsler grid in both eyes. At some point during that 25-year gap, the organic condition developed. It is not clear whether the patient was seen regularly, but would a full work-up have been completed had the patient not already been diagnosed with functional vision loss? This case underscores a critical diagnostic bias that can strongly impact the outcome of an encounter. Premature closure bias occurs when further information is not sought after once a diagnosis is made. MJ was impacted by this bias once he was identified to have NOVL. Once that occurred, further organic pathology was not thoroughly investigated, which ultimately influenced diagnosis, management, and treatment.

**Conclusion**

Although chronic CSCR is not a progressive disease, and MJ will not likely experience further organic loss due to it, it was critically important to identify it. Knowing the diagnosis, particularly when the disease is treatable, is essential in proper patient management. MJ was diagnosed with functional vision loss in 1991, and that label stayed with him until just recently. It is possible that having this diagnosis allowed providers to forego additional testing as the vision loss was already accounted for. That assumption, however, runs significant risk.

In healthcare, providers strive to come to the correct diagnosis as quickly and efficiently as possible so as to direct proper treatment. Soaring healthcare costs make a quick diagnosis cost-effective. Once patients are diagnosed with a particular condition, they are then
taken down that specific disease's treatment protocol. The inherent difficulty in this delivery method is the risk of missing newer conditions as they develop, a notion that is highlighted in this case report. Underlying this topic is the medically oriented Hickam's dictum, which states that patients can have as many diseases as they please. It is easy to fall back to medical parsimony and to assign all symptoms a patient has to an established diagnosis, but that is not always the most prudent. Providers must remain vigilant at all times, particularly in cases where the vision loss is multifactorial.

References


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