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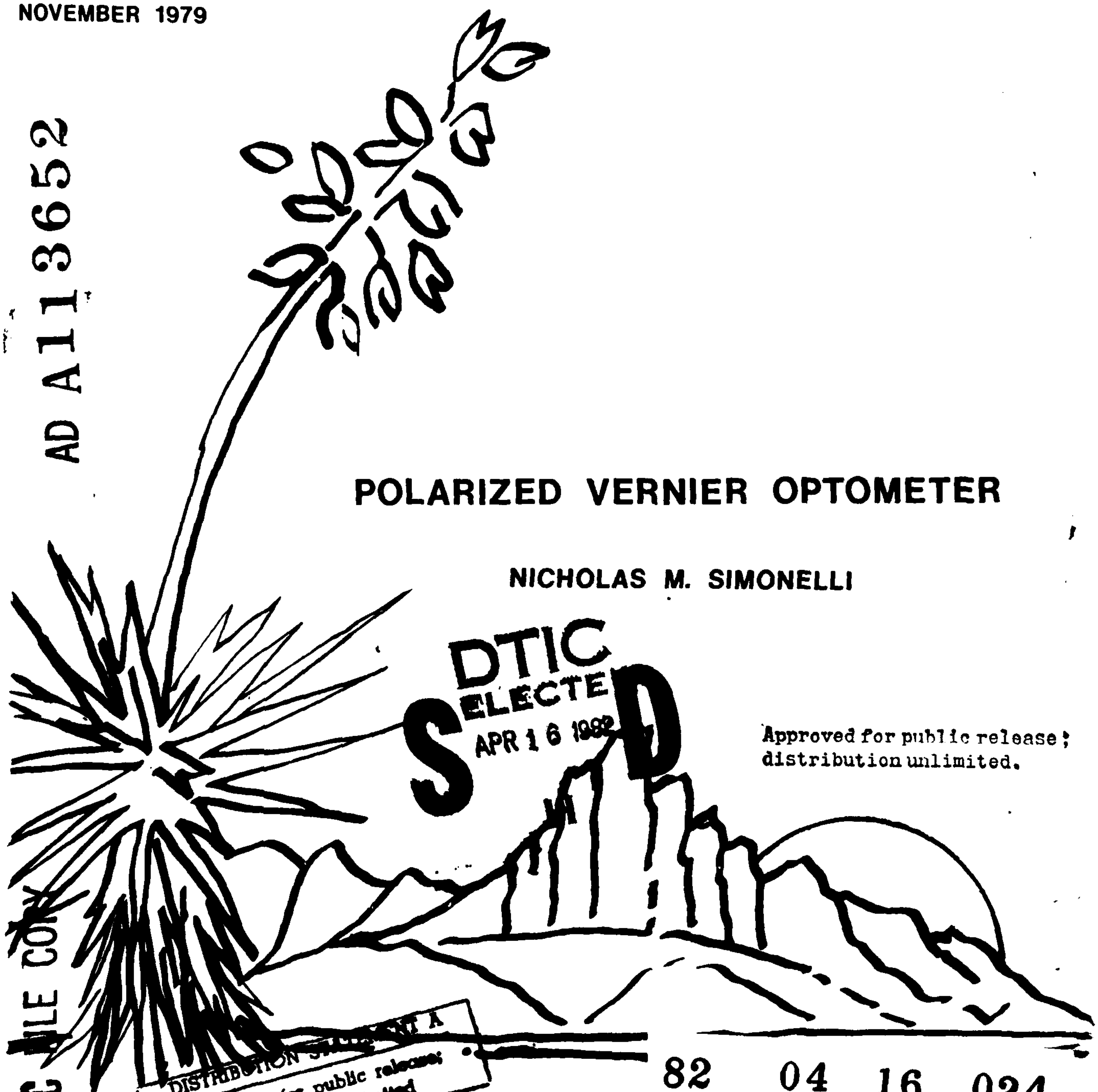

POLARIZED VERNIER OPTOMETER

NICHOLAS M. SIMONELLI

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AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
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An optometer is described that makes use of polarized light. It is similar in construction and use to the better-known laser optometer but is less expensive, avoids some problems inherent in using lasers, and is responded to very well by subjects in behavioral research. Uses of the device are discussed, and the laser and polarized optometers are contrasted. It is concluded that the polarized vernier optometer is an economical and effective alternative to the laser optometer in behavioral research settings.

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POLARIZED VERNIER OPTOMETER

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ABSTRACT

An optometer is described that makes use of polarized light. It is similar in construction and use to the better-known laser optometer but is less expensive, avoids some problems inherent in using lasers, and is responded to very well by subjects in behavioral research. Uses of the device are discussed, and the laser and polarized optometers are contrasted. It is concluded that the polarized vernier optometer is an economical and effective alternative to the laser optometer in behavioral research settings.

CONTEXT

Research has increased in recent years on both the effects of accommodation on psychophysical and perceptual phenomena and on the "dark focus," or "intermediate resting position" of accommodation. This is in large part due to greater availability of measuring devices. The infrared optometer and eye tracker (Crane and Steele, 1978) have proved to be useful devices for the continuous, objective measurement of refractive state but are complex and very expensive. The laser optometer (Hennessy & Leibowitz, 1972) is a simpler device which yields discreet measures of refractive state and is being employed in a number of laboratories. It is relatively easy to construct, straightforward to use, and is much lower in cost.

Recently, however, another optometer has been developed that is also very simple to construct and is less expensive than even the laser optometer. It uses polarized light and is suitable for use in many research situations.

PRINCIPLE

Moses (1971) briefly described an optometer principle that takes advantage of the properties of polarized light. Figure 1 is an illustration of this principle. Using two pairs of perpendicularly oriented polarizing filters, the retinal image of a viewed object -- in this case, a horizontal bar -- will split when the retina is not conjugate with the plane of that bar. Likewise, the image will be whole when the retina <u>is</u> conjugate with the bar. This is an application of the Scheiner principle, (see Duke-Elder, 1970, p. 155) whereby one image (here, one half of the bar) is directed through the upper half of the pupil, and another image (the other bar half) is directed through the lower half.

This direction of bar halves through different portions of the pupil is accomplished by creating bar-segment images whose light rays are of different polarities (indicated in the figure by the direction of the parallel lines in the filters). The left half of the target bar, for instance, is vertically polarized. Such rays will pass through the upper portion of the next pair of filters (with some absorption loss), as the polarities of the light and filter are identical. These vertical rays, however, cannot pass through the horizontal filter below.

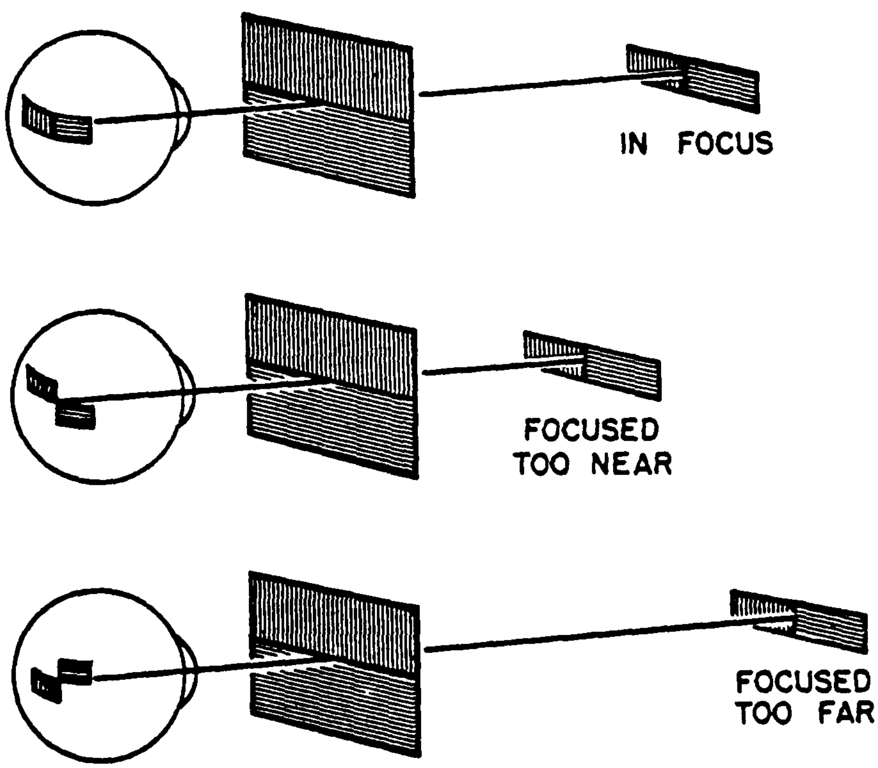

Figure 1. Illustration of the polarizing phenomenon (adapted from Moses, 1971).

Consequently, when this second pair of filters is aligned to "split" the pupil in half, the vertically polarized rays from the left portion of the target bar enter only the upper half of the pupil. Similarly, the image of the right half of the bar enters only the lower half of the pupil. When the eye is focused on the bar, both halves will "meet" at the retina and reform the whole bar. Moreover, one half will shift relative to the other when the eye is focused in front of or behind the stimulus bar. The amount and direction of the shift are related to the amount and direction of the focal error.

Thus, if a viewer reports alignment of the two bars, his accommodative state is correct for the distance from the eye to the stimulus bar. His report of the direction of misalignment indicates the direction of the focal error. The use of such a split bar, or vernier, yields the device's name -- polarized vernier optometer. Although the vernier effect is relatively straightforward and easy to obtain, no reports have been found of research involving the use of a refracting device using this phenomenon. Given the simplicity and low cost, the application of this principle has been explored further. A device using a polarized vernier has been built to investigate ocular phenomena such as the dark focus (the focal state of the eye in complete darkness).

COMPONENTS OF THE OPTOMETER

Figure 2 illustrates the principal components of the optometer. The polarizing aperture and the box producing the polarized vernier create the split bars used in the measurement of refractive state. Adding a shutter to the system allows the brief exposures needed to employ the "bracketing technique" commonly used in laser refraction. That is, refractive state is measured using repeated short stimulus exposures -- each adjusted according to the observer's response to the previous stimulus -- until the correct response is found. This technique enables measurement of the dark focus and, with appropriate combining glass, superposing of the vernier onto another scene or experimental stimulus. With the shutter open, the vernier can be viewed continuously for measurements such as the far point (the farthest point to which the eye can focus).

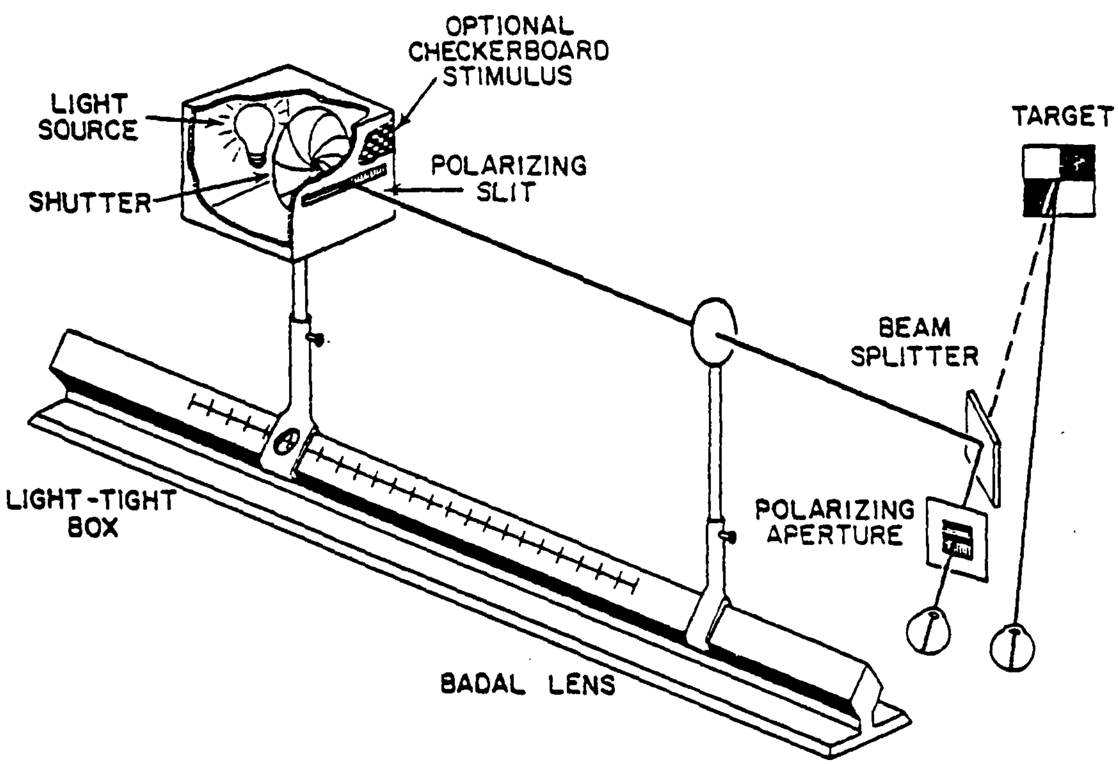

Figure 2. Schematic of the polarized vernier optometer.

The use of a box enclosure as shown in Figure 2 is optional for room-lighted situations. However, for measuring the dark focus, light scattering can be avoided by enclosing the light source which, as illustrated, is a 40-watt incandescent bulb. A shutter provides the only means for light to escape the box. The light then passes through the polarizing slit. The observer's eye is placed at the posterior focal plane of a convex lens and the bar is moved relative to the anterior focal plane, varying its dioptric power. (This arrangement is known as a Badal optometer.) The current optometer used by the author contains an +8.0 diopter (D) lens, requiring only 12.5 cm of movement to place the bar at from 0 to just under 8 D. The use of a convex lens also allows positioning the vernier at negative dioptric values. The box has been mounted onto a rack and pinion track (not shown), allowing smooth, easy positioning of the light box.

The observer should not be wearing contact lenses if this can be arranged. With each blink, the lens may float over the surface of the cornea and can cause distortions as the lens floats back into position. The observer may see shifts in the bars as the lens moves.

USES

Measurement of the dark focus is accomplished using a procedure identical to that employed with the laser optometer. After a brief exposure of the vernier, the observer reports the relative positions of the two bars and the experimenter adjusts the position of the box forward or backward as necessary. When the observer reports the bars aligned (by responding "even") the experimenter has located the point conjugate with the observer's retina. Of course, this "point" is actually a range over which the "even" response will be given. The size of this range is partially a function of the pupil width. The wider the pupil the smaller the range.

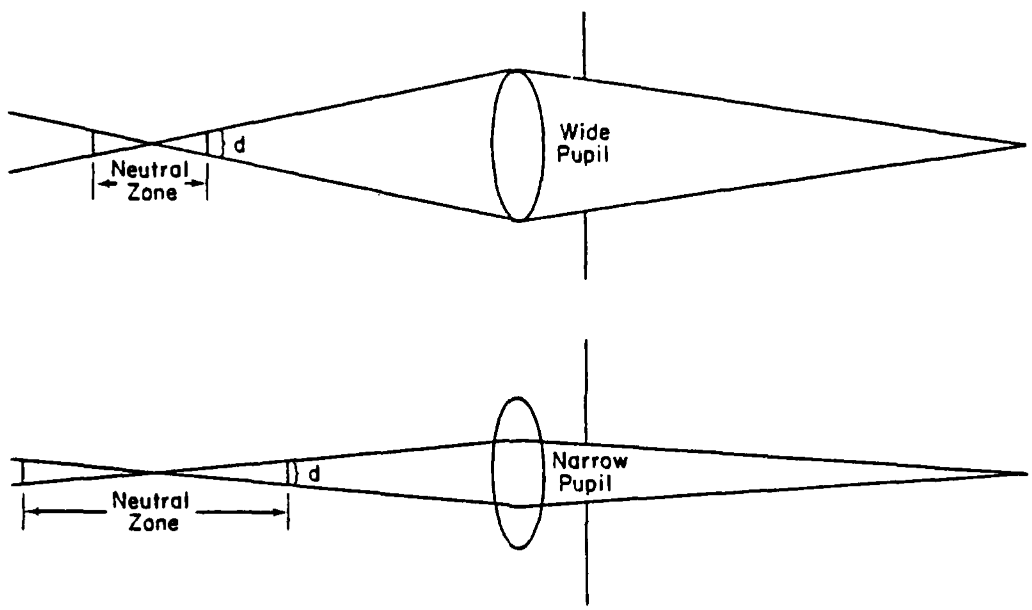

Figure 3. Relationship between pupil width and neutral zone.

This can be seen in Figure 3 where the distance "d" is the minimum displacement between the two bars necessary to see them as not aligned. With a narrow pupil a greater amount of accommodative change can occur before d is reached. A wide pupil admits more of the peripheral rays which are furthest apart on the retina.

Vernier acuity is quite sensitive, and, if tne polarizing aperture is properly positioned, most observers will notice a shift in tne bars when the vernier is at the edge of the neutral zone and is moved by 0.1 D. Smaller pupils yield a wider neutral zone, but even this is usually only 0.2-0.6 D. It is convenient to choose one bar, the left, for instance, and have the observer always report its position relative to the other bar ("higher," "lower," or "even"). As the bars near alignment, they come into sharper focus. Conversely, as the bars move apart, they are increasingly out of focus, but the discrimination is unimpaired as the separation between the bars is greater.

An astigmatism in the vertical meridian of the eye will manifest itself as bars seen to be of different widths. That is, if the upper half of the cornea refracts at a different power than the lower half, both bars will not be in focus on the retina at the same time. When one bar is in focus, the other will be blurred and therefore slightly wider. In such a case, the measurement obtained is not exact for the entire corneal surface, but only part of it. (Of course, <u>any</u> single axial measurement of refractive error for an astigmatic eye, no matter the method, is only approximate.)

The device can also be used to measure the near and far points of the eye. Theoretically, an observer can focus on the vernier, seeing it aligned, and follow it as it is moved away from his eye out to his far point, at which time the vernier will break (the halves will not be aligned). The observer will be unable to accommodate further outward to align the bars. A similar procedure could be followed for the near point, following the vernier inward until it can no longer be held together.

In practice, however, it has been found that microfluctuations of accommodative state, which are easily reflected in the sensitive vernier, give rise to false break points with untrained participants. For example, when following the vernier out to the far point, a sudden, small accommodative shift inward causes a shift in the bars identical to that observed when the far point is reached. Several such false far points may be observed during one measurement.

Moreover, most people usually do not focus accurately on a near target, but rather a bit further out (see Sheard, 1922, p. 93), therefore the vernier may not appear aligned when the observer is looking at it and has it "in focus." A satisfactory procedure has been to place a well lit checkerboard pattern in the plane of the vernier (as seen in Figure 2) and approach the far point from beyond ("out to in") rather than from within. The observer will report initial misalignment (as it is too far out for his eye to focus on) and as the vernier and checkerboard slowly approach the far point, they will be increasingly clear. At the far point, the checkerboard is in focus and the vernier aligned.

In measuring the near point, a similar procedure is not satisfactory. A observer's "near point" is largely a function of the amount of convergence (with associated discomfort) that he is willing to exert. Moving a near-point card toward the observer's face, as is done by an optometrist, gives an approximation of a observer's near point. However, the level of tolerable discomfort varies among and within observers, varying the near point measured. Thus, with young observers, a monocular view of the vernier, requiring no convergence for fusion of two images, usually yields a near point several diopters further out than a binocular near point (which is itself subject to individual differences in blur interpretation).

The accommodative responses to other targets can be measured by the brief exposure technique. Viewing both the vernier and a target simultaneously is accomplished with a beam splitter as seen in Figure 2. This procedure is used to measure accommodative response to virtually any target and is identical to that used with the laser optometer. A variable power supply to the light allows vernier brightness to be adjusted appropriately for the target. An exposure time for the vernier of 250 ms has been found to be quite satisfactory for most observers. The exposure time must be less than the reaction time for visual accommodation (300-400 ms) so that the lens has no opportunity to accommodate to the vernier rather than the target.

COMPARISON WITH LASER REFRACTION

The simplicity of the polarized vernier optometer results in several differences with the laser optometer which may make tne vernier optometer preferable. The laser speckles are not a stimulus to accommodation (one of the virtues of the device) but "Newton rings" produced by some of the lenses used are. If exposure time is too long, a observer's accommodation may be drawn toward the rings, interfering with his response. Eliminating the rings requires a spatial filter which is not always available in the less expensive laser assemolies.

It has also been accepted that there are occasional observers who just cannot readily interpret the speckles. For unpursued reasons, these few people are unable to give meaningful, confident reports of the speckle movement and are rejected from research using laser refraction. No observer in the author's experience, however, has reported that he could not interpret the vernier stimulus.

A structural advantage of the polarizing technique is that the plane of the vernier can be brought right up to the lens, allowing production of a dioptric power very near the power of the lens. That is, little range is lost. The typical laser arrangement incorporates a moving mirror that limits the maximum accommodation that can be measured to well short of the power of the lens used, although newer designs have avoided this problem. The reduced measurement range is due in part to the fact that the "plane of stationarity" in laser refraction is actually behind (not on) the drum surface (Charman, 1974), and in part to the mirror's forward position. Thus, for a given lens, which determines the proximity of the device to the observer, a larger range of accommodation can be measured with the vernier arrangement. Additionally, the maintenance of a light bulb is cheaper than that of a laser.

Eye position is a critical factor that can be a problem for both optometers. With both devices, one wants the observer's eye at the focal point of the lens. However, slight changes of head position vertically do not noticeably impair the observer's view of the speckles. With the polarizing optometer, on the other hand, the polarizing aperture must split the pupil and vertical head movements are more detrimental. In general, the same type of head restraint used in laser refraction is adequate, but in particular the use of a headrest and chinrest combination has proved very effective. Proper use of the headrest keeps head movements minimal for most observers, although there are those who have significant difficulty in this respect. A possible improvement would be incorporating the polarizing aperture into an eye patch or similar eye covering. With this arrangement, any head movements should not disturb the positioning of the polarizing aperture with respect to the pupil.

In an experimental comparison of the two optometers (Simonelli, 1979) measurements of the dark focus obtained with each device were in very close agreement. (A nonreliable difference of 0.16 D was found.) Additionally, successive measurements taken with the vernier showed greater agreement than those taken with the laser. That is, there was more intraobserver variability from one measurement to the next in the laser measurements than in the vernier. Subjects were also asked to evaluate the ease with thich they could make responses to the stimuli. They rated the vernier as easier to respond to and indicated more confidence in their vernier responses.

In summary, the polarized vernier optometer is an economical and effective alternative to the laser optometer in behavioral research settings. The device may allow investigators to measure refractive state in psychophysical research who would otherwise not have access to a refracting device.

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REFERENCES

Charman, W. On the true position of the plane of stationarity in laser refraction. American Journal of Optometry and Physiological Optics, 1974, 51, 832-837.

Crane, H. D. & Steele, C. M. Accurate three-dimensionsl eye tracker. Applied Optics, 1978, 17, 691-705.

Duke-Elder, S. System of Ophthalmology. Vol. 5. St. Louis: C. V. Mosby, Co., 1970.

Hennessy, R. T. & Leibowitz, H. W. Laser optometer incorporating the Badal principle. Behavioral Research Methods and Instrumentation, 1972, 4(5), 237-239.

Moses, R. A. Vernier optometer. Journal of the Optical Society of America, 1971, 61, 1593.

Sheard, C. The comparative value of various methods and practives in skiametry. American Journal of Physiological Optics, 1922, 3, 177-208.

Simonelli, N. M. The dark focus of visual accommodation: Its existence, measurement, and effects. Unpublished doctoral dissertation. University of Illinois at Urbana-Champaign, 1979.