Validez de las técnicas para evaluar la foria de cerca

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Validity of Techniques to Evaluate Near Phoria[1]

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Abstract

Background: While a number of previous studies have investigated the repeatability of techniques designed to measure heterophoria, there have been few studies of their validity. Accordingly, the present study examined the ability of 3 standard techniques; Von Graefe (VG), Maddox Rod (MR) and Modified Thorington (MT) tests to quantify a known change in heterophoria. *Methods*: The study was performed on 30 young subjects using each of the 3 procedures listed above. Near (40 cm) heterophoria was quantified both without and with an additional base-out prism. Five possible values were available, namely 2, 4, 6, 8 and 9Δ. After a period of 24 hours, the heterophoria measurement was repeated using the same technique with one of these prisms added to the refractive correction. *Results*: The mean heterophoria value measured before the introduction of prism using the VG procedure was significantly more exophoric than the findings obtained using the other 2 techniques (p = 0.035). No significant difference was observed between the measured and predicted change in heterophoria following the introduction of the prism for the VG and MT procedures, but a significant difference was found with the MR technique (p<0.001). *Conclusions*: The ability to measure a known change in oculomotor deviation was significantly poorer with the MR technique, when compared with the VG and MT procedures. Given that the mean pre-prism measurement was significantly more exophoric when using the VG procedure, we recommend that MT be adopted as the technique of choice for the subjective measurement of oculomotor deviations in the clinical setting.

Keywords: Heterophoria, Maddox Rod, Modified Thorington, validity, vergence, Von Graefe.

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Resumen

Antecedentes: si bien varios estudios han investigado la repetibilidad de técnicas para medir las heteroforias, ha habido pocas pruebas de su validez. El presente estudio examinó la capacidad de tres técnicas: Von Graefe (VG), bastón de Maddox Rod (MR) y Thorington modificado (MT), para cuantificar un cambio conocido en la heteroforia. *Métodos*: se estudiaron 30 sujetos jóvenes utilizando los 3 procedimientos. Se cuantificó la heteroforia cercana (40 cm) sin un prisma de base afuera adicional y con este. Hubo cinco valores posibles disponibles: 2, 4, 6, 8 y 9Δ. Después de 24 h, la medición se repitió utilizando la misma técnica, con uno de estos prismas agregados a la corrección refractiva. El cambio medido en la desviación se comparó con la diferencia esperada, es decir, la magnitud del prisma. *Resultados*: el valor medio de heteroforia antes de la introducción de un prisma usando VG fue significativamente más exofórico que los resultados obtenidos usando las otras 2 técnicas (p = 0,035). No se observaron diferencias significativas entre el cambio medido y el predicho en la heteroforia después de la introducción del prisma para VG y MT, pero se encontró una diferencia significativa con MR (p < 0,001). *Conclusiones*: la capacidad de medir un cambio conocido en la desviación fue significativamente más pobre con MR, en comparación con VG y MT. Dado que la media de la medición previa al prisma agregado fue significativamente más exofórica cuando se utilizó VG, recomendamos que se adopte MT como la técnica de elección para la medición de heteroforia.

Palabras clave: bastón de Maddox, heteroforia, Thorington modificado, validez, vergencia, Von Graefe.

INTRODUCCIÓN

Disparity (or fusional) vergence eye movements are critical for maintaining binocular vision in the presence of a heterophoria. This clinical parameter indicates the eye position under dissociated conditions, i.e., when the stimuli to the 2 eyes are non-fusible (1). Under associated (or fusible) conditions, a disparity vergence response is required to "compensate" for the heterophoria, thereby placing the images of each eye onto corresponding retinal points (i.e., retinal locations having the same visual direction) (2,3).

While the prevalence of heterophoria is close to 100% of the population, especially when viewing near targets (2), comparatively few individuals (approximately 9%) experience symptoms as the result of this oculomotor deviation (4). The presence of symptoms depends on a number of factors including the degree of compensation, the visual demands of the stimulus and the general well-being of the viewer (5).

Clinically, there are a number of standard techniques for measuring heterophoria, which vary either in the way dissociation is achieved or how the deviation is quantified. Significant differences in repeatability have been observed between different methods of measurement, with the Modified Thorington (MT) technique being the most repeatable procedure, while the Von Graefe (VG) method showed the poorest repeatability (6-8).

While having high repeatability is clearly important when multiple measurements of heterophoria are recorded on an individual patient over time, assessing the validity of a technique, i.e., determining whether the results are an accurate reflection of the state of the eye may be more difficult. A technique might provide repeatable, but incorrect findings. Accordingly, in the present investigation, a novel method of assessing the validity of clinical heterophoria measurements is presented, namely the ability to detect a known change in vergence stimulus. Heterophoria was measured both before and after the introduction of a base-out prism, and the measured change compared with the known difference. The Maddox Rod (MR), VG and MT techniques were used to measure horizontal heterophoria at a viewing distance of 40 cm.

METHODS

The study was performed on 30 subjects (12 male, 18 female) having a mean age of 22.2 years (SD = ±1.22 years; range 20-25 years). The protocol was approved by the General Director of Research at the Universidad Autonoma de Aguascalientes, and the study conducted in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained from each subject following a full explanation of the nature and risks of the procedures. Inclusion criteria were best corrected visual acuity in each eye of 20/25 or better at both distance (6m) and near (40cm), stereopsis of at least 30 seconds of arc, near and distance heterophoria between 10Δ esophoria and 15Δ exophoria; spherical refractive correction between +2.00 and -4.00D and astigmatism of no more than 2.00D. Any individual with strabismus, amblyopia, nystagmus or a history of refractive surgery was excluded from the study.

Near (40 cm) heterophoria was quantified using the MR, MT and VG techniques both without and with an additional base-out prism. In both cases, measurements were taken through the subject's habitual refractive correction, positioned in a Topcon VT-10 phoropter (Topcon Medical Systems, Oakland, NJ). Five possible prism values were available, namely $2, 4, 6, 8$ and 9Δ base-out. The value of the prism was obscured with tape

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so that it was not visible to the examiner. The experimenter picked out a prism at random from an open storage container (while looking away from the box). The unknown prism was then attached to the phoropter using Velcro tape, as shown in Figure 1. All measurements were recorded by the principal author (JBE), an optometrist with over 25 years of experience in binocular vision testing.

Each session began with the right eye being occluded for 10 minutes. This period was selected to allow any vergence adaptation induced by visual activities conducted before the start of the experimental session to dissipate (6,9,10). The near heterophoria was then measured (without any supplementary prism) using either the VG, MR or MT techniques. After a period of at least 24 hours, this heterophoria measurement was repeated using the same technique with an unknown prism in place. This sequence was repeated for the other two procedures, with a period of at least 24 hours between the experimental sessions. The order of performing the three tests was counterbalanced across subjects. One measurement of heterophoria was recorded for each experimental condition.

Figure 1. Example of a base-out prism of unknown power attached to the phoropter using Velcro

Source: image made by Jaime Bernal Escalante

Von Graefe (VG) Procedure

6Δ base-up and 12Δ base-in prisms were introduced before the right and left eyes, respectively, using the rotary prisms mounted on the Topcon VT-10 phoropter described previously. Subjects viewed a 7 by 7 block of letters, whose size was equivalent to 20/20, at a viewing distance of 40cm. They were instructed to fixate the lower (non-moving) image, and the magnitude of horizontal prism altered until the two images appeared

to be "one directly beneath the other". Heterophoria was recorded as the horizontal prism that brought the diplopic images into precise vertical alignment (6).

Maddox Rod (MR)

A red Maddox rod, axis horizontal, was introduced before the right eye, while subjects observed a penlight at a viewing distance of 40cm. They were instructed to fixate the penlight, and while doing so to indicate the relative position of the red Maddox streak with respect to the white light. Horizontal prism was introduced before the left eye, using the rotary prism mounted on the phoropter, until the patient reported that the red streak passed through the image of the penlight (6).

Modified Thorington (MT)

Subjects viewed a Muscle Imbalance Measure (MIM) card (Bernell Corp, South Bend, Indiana), which uses the MT technique to assess the near heterophoria. The MIM test card consists of a horizontal row of numbers, each of which is 4mm apart (i.e., equivalent to 1Δ at a viewing distance of 40cms). The card contains a small central hole, through which a penlight was shone, while a red Maddox Rod, axis horizontal, was placed in front of the subject's right eye. The subject reported which number the vertical red streak appeared to pass through, and this finding represented the horizontal heterophoria in prism diopters (6).

RESULTS

The mean heterophoria values (± 1SEM) measured before the introduction of supplementary prism for the VG, MR and MT techniques were -6.10Δ (0.93), -3.20Δ (1.04) and -2.82Δ (0.91), respectively. The minus sign indicates exophoria. One factor analysis of variance indicated that these differences were significant ($F = 3.48$, $df = 2, 89$; $p = 0.035$). Paired t-tests showed that the mean finding obtained using the VG procedure was significantly different from the values obtained with the MR and MT tests ($p < 0.001$), while there was no significant difference between the mean results for the MR and MT techniques ($p = 0.18$).

The mean change in heterophoria following the introduction of prism is shown in Table 1. When calculating the difference between the measured change in heterophoria and the expected shift, the mean difference (±

1SEM) for the VG, MR and MT techniques was -0.33Δ (0.31), -4.35Δ (0.54) and 0.45Δ (0.35), respectively. One factor analysis of variance demonstrated that these differences were significant (F = 3.10, df = 2, 89; p < 0.0001). Paired t-tests indicated that the mean value obtained using the MR procedure was significantly different from the values obtained with the VG and MT tests (p <0.001), while there was no significant difference between the mean differences for the VG and MT techniques (p = 0.11).

Table 1. Mean amount of prism introduced and the mean change in heterophoria measured following introduction of the prism for the three measurement techniques.

| Technique	Prism power (Δ)	Measured change (Δ)
VG	5.73 (0.45)*	5.40 (0.50)
MR	6.10 (0.45)	1.75 (0.28)
MT	6.03 (0.46)	6.48 (0.58)

* Figures in parentheses indicate ±1 SEM
Source: own work

Linear regression analysis showed significant positive correlations between the measured change and the magnitude of the interposed prism for both the VG (r^2 = 0.64; p<0.00001) and MT (r^2 = 0.65; p<0.00001) techniques, but not for the MR procedure (r^2 = 0.01; p =0.78). These associations are illustrated in Figure 2. Furthermore, the 95% limits of agreement between the measured change and the anticipated difference (i.e., the prism magnitude) for the VG, MR and MT techniques (calculated as 1.96* the standard deviation of the differences) were 3.31Δ, 5.83Δ and 3.73Δ, respectively.

Figure 2. Association between the measured change in heterophoria and the magnitude of the interposed prism for the VG, MR and MR techniques
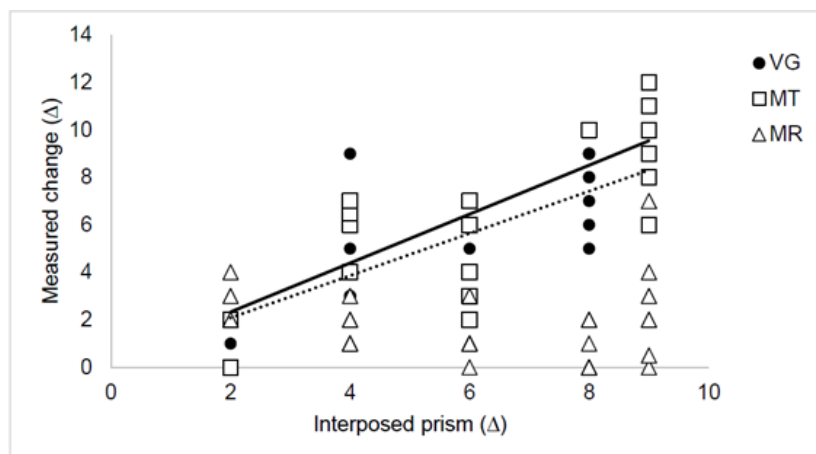
Significant positive correlations were observed for the VG (dashed line) and MT (solid line) procedures. The equations for these two linear regression lines were $y = 0.89x + 0.03$ ($r^2 = 0.64$; $p < 0.0001$) and $y = 1.03x + 0.27$ ($r^2 = 0.65$; $p < 0.0001$), respectively. No significant correlation was found with the MR method ($r^2 = 0.003$; $p + 0.78$).

Source: Image made by Mark Rosenfield

DISCUSSION

The values of heterophoria obtained without supplementary prism using the VG technique were significantly more exophoric (the mean difference was approximately 3.1Δ), when compared with the MR and MT procedures. This result is consistent with a number of previous investigations (7,11,12). Casillas and Rosenfield (12) suggested that the greater exo deviation observed with the VG test came from the fact that the procedure typically begins with the patient viewing through a 12Δ base-in prism. Even with non-fusible stimuli, subjects may make a disparity divergence response in an attempt to reduce the horizontal separation between the diplopic images. Indeed, the observation of vergence adaptation in strabismic patients confirms that a disparity vergence response may still occur even when non-fusible stimuli are present (13,14). Since neither the MR nor the MT tests begin with a prism before the eye, then this adaptive bias will not be present for these two procedures.

In addition, the results demonstrate that the ability of the MR procedure to quantify a known change in heterophoria was significantly poorer than the other two procedures. This was confirmed by the absence of a significant correlation between the measured change in oculomotor deviation and the additional prism (a significant positive correlation was recorded for both the MT and VG techniques). Further, Cebrian et al. (7) observed that the MR technique had poor inter- and intra-examiner repeatability, which may at least

partially account for the difference between the expected and measured difference in response following the introduction of the additional prism. These authors noted the reduced control of accommodation due to the lack of detail in the fixation target (a light), as well as the rivalry arising from the different retinal images being seen in each eye.

Each experimental session began with a 10-minute period of monocular occlusion in order to minimize the effects of vergence adaptation resulting from prior visual activities. Rosenfield et al. demonstrated that this duration was adequate to allow the dissipation of the majority of slow disparity vergence (9,10). Given that in the present investigation, the additional prisms were only present for a few seconds prior to dissociation, then it seems unlikely that they would produce any further significant vergence adaptation.

This paper proposes an alternative technique for estimating the validity of a clinical procedure, namely its ability to quantify a predictable change in response. Most assessments of clinical techniques compare the **measured value with a "gold standard".** For example, several studies have compared subjective measurements of heterophoria with the objective cover test finding (7,13). However, the gold standard test will also have inherent variability, and may itself not provide a veridical measurement of the function being assessed. While it is valuable for the clinician to know how the results of one test compare with the findings of another procedure, even perfect agreement may not indicate validity, i.e., that the test is actually measuring the function being examined.

In summary, the findings from the present study indicate that heterophoria measurements obtained using the VG technique were significantly more exophoric than the results obtained using the MR and MT procedures. Additionally, the ability to measure a known change in oculomotor deviation was significantly poorer with the MR, when compared with the VG and MT tests. Furthermore, several investigations have demonstrated that the MT technique has the highest level of repeatability of the 3 procedures tested here (6-8). Accordingly, we recommend that the MT procedure be adopted as the technique of choice for the subjective measurement of oculomotor deviations in the clinical setting.

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