

Target-Dependent Variability in Near Point of Convergence Measurements: A Repeated-Measures Study



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ABSTRACT

Purpose: To determine the test difference between the Near Point of Convergence (NPC) break and recovery distance depending upon accommodative fixation target and non-accommodative fixation target and the degree of difference that could be ascribed to the measurement method in healthy young adults that have normal binocular vision.

Study Design: A Repeated-Measures Study.

Place and Duration of Study: Teerthanker Mahaveer University, India from January 2025 to December 2025.

Methods: The study involved 130 subjects (20-26 years of age) with normal vision. RAF ruler and pencil scale push up (accommodative target) and NPC with red-filter torchlight (non-accommodative target) methods were used for NPC break and recovery. Measurements were taken under ordinary conditions by one examiner. Descriptive statistics, ANOVA and Bonferroni adjusted post-hoc analysis were used.

Results: The three methods were found to be statistically significant in the NPC break and recovery distances ($p < 0.001$). The accommodation targets were much closer to NPC than the non-accommodative. The RAF ruler provided the least distance of break and recovery and was followed by the pencil push-up method and then finally, the NPC with red-filter torch-light method provided the most receded values. The size of the effect was significant that indicated that the level of influence of target type on NPC outcomes was high.

Conclusion: Accommodative and non-accommodative NPC are exhaustive of each other and NPC is a clinic-dependent strategy. NPC assessment techniques should also be used and reported consistently to achieve proper clinical interpretation and comparability of the results in research.

Keywords: Binocular Vision, Accommodative Convergence, Fusional Vergence, Convergence Measurement Near Point of Convergence.

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INTRODUCTION

The closest distance which the eyes can maintain single diaphragm focus in a single pair of field glasses is known as the nearest point of convergence (NPC),

and thus it is a fundamental parameter when it comes to the measurement of the binocular visual function.^{1,2,3} Since NPC is the process of interaction of the vergence-accommodation, it is often checked in cases of convergence insufficiency, anomalies in the interaction of accommodative-vergence, visual discomfort during all near-tasks, and oculomotor imbalance after concussion.⁴⁻⁶

A fixation stimulus is gradually placed on the midline towards the patient until a convergence break is observed and then it is removed to measure the point of recovery which is clinically assessed through NPC. It is a relatively simple process, but the values of NPCs obtained depend on the nature of fixation target

used. NPC is generally assessed at least on the accommodative stimulus (NPC with RAF ruler and pencil push-up test) or non-accommodative stimulus (NPC with red filter test), each one of different components of the vergence system.^{7,8}

Previous studies have shown that nearer NPC break and recovery values are obtained when stimuli are accommodative as compared to those which are non-accommodative.^{9,10} This is because of the extra blur convergence effort that is fomented by the presence of accommodative blur cues in testing. Non-accommodative targets in contrast reduce the demand of accommodation and are believed to represent principally fusional convergence capacity and thus lead to inconsistent comparison and clinical misinterpretation of NPC values measured with different types of targets.⁹⁻¹¹

Although several studies have evaluated differences among NPC measurement methods, many were limited by small sample sizes or focused solely on methodological comparisons without quantifying inter-method differences using effect size measures.^{12,13} In addition, normative data for non-accommodative NPC measurement techniques, including the red filter NPC method, remain sparse, particularly in young adults with normal vision.^{11,12,13}

Thus, the present study aimed to compare NPC break and recovery distances obtained by using two accommodative techniques (RAF rule and pencil push-up test) and one non-accommodative technique (red filter NPC test) in the same group of young adults with normal visual function using a repeated-measures design.¹⁴ By evaluating method-dependent differences and quantifying their effect sizes, the study seeks to clarify the influence of target characteristics on NPC outcomes and to support the need for method-specific interpretation in both clinical practice and research settings.

METHODS

This study employed a repeated-measures design to compare differences in measures of near point of convergence (NPC) with three popular types of targets. They were young adults (not older than 25 years) who have normal visual acuity and whose visual perception showed a normal visual condition without binocular vision abnormalities, neurological conditions, or ocular abnormalities. The study was approved by institutional ethics committee of T.M.U.

College of Paramedical Sciences, Teerthanker Mahaveer University, Moradabad, India (**Ref: PM/ETHICAL/2024/016**). All the procedures followed Declaration of Helsinki, and a written informed consent was obtained from each participant prior to their recruitment.

A priori estimation of the sample size was performed to make sure that the statistical power used was sufficient to determine the differences in NPC values between methods. Based on effect sizes reported in prior studies comparing NPC measurement techniques⁸ a sample size exceeding the minimum required for repeated-measures analyses was targeted. This method was adequate to provide enough power to identify intra-subject differences at a traditional alpha value of 0.05.

The NPC examination was performed in a sequential manner by maintaining three unique targets of fixation, the RAF near point scale (accommodative); the pencil-push up method (accommodative); and the NPC with red filter (non-accommodative).

One examiner carried out the measures in a standardized clinical setting to reduce variability. The subjects were comfortably seated with the refractive correction on and sustaining fixation of the binoculars on each target as it was moved along the midline at a steady pace.

For each method, the clinician moved the fixation target gradually toward the subject along the midline until the subject reported diplopia or the clinician observed an outward deviation of one eye. The distance between the target and the lateral canthus at the point where convergence failed was recorded as the break point. The target was then moved away from the subject until binocular single vision was regained, and this distance was documented as the recovery point.

The testing sessions were conducted under controlled environmental conditions. The lighting of the room was kept at a moderate and consistent level, and distractions were minimized. To minimize variability, the rate at which the target was moved was standardized across the subjects and the methods. Measurements were made in a single session to eliminate the effects of diurnal variation on convergence.

All targets were measured using calibrated rulers and scales in millimeters, and NPC values were

Table 1: Baseline demographics and visual parameters of participants (n = 130).

Demographic and ocular Parameter	Category / Range	n (%)	Mean ± SD
Age (years)	20–26	130 (100%)	22.72 ± 1.86
Gender	Male	81 (62.3)	–
	Female	49 (37.7)	–
UCVA (OU)	6/6	124 (95.4)	–
BCVA (OU)	6/6	130 (100)	–
Objective refraction (D)	–0.50 to +0.50	–	0.00 ± 0.32
Subjective refraction (D)	–0.50 to +0.75	–	0.03 ± 0.28
Stereopsis	≤60 arc sec	130 (100)	–
Cover test (distance)	Orthophoria	130 (100)	–
Cover test (near)	Orthophoria	130 (100)	–

Abbreviations: UCVA, Uncorrected Visual Acuity; BCVA, Best-Corrected Visual Acuity; OU, Oculus Uterque (both eyes); D, Diopters; SD, Standard Deviation; n, number of participants.

recorded. Mean NPC break and recovery distances for each participant were calculated and stored in a secure electronic database for subsequent statistical analysis. Comparisons among the three target methods were performed to identify similarities and differences in NPC break and recovery distances. For normally distributed data, comparisons were made using repeated-measures analysis of variance (RM-ANOVA). Post hoc analyses were done to identify pairwise differences between methods. In addition, effect sizes were calculated to quantify the magnitude of differences attributable to the measurement techniques.

RESULTS

One hundred and thirty individuals in between the ages of 20-26 years with normal eyesight were recruited (Mean age: 22.72 ± 1.86 years). There were 81 males (62.3%) and 49 females (37.7%). Best corrected visual acuity was 6/6 in both eyes. Objective and subjective values were near to emmetropia (objective: 0.00 ± 0.32 D; subjective: 0.03 ± 0.28 D). Patients had normal stereopsis (60 arc seconds), orthophoria at distance and near on cover test and normal Maddox rod responses. Table 1 shows detailed demographic and baseline ocular characteristics.

Table 2 present the mean NPC break and re-fusion distance using the three methods of the test. The shortest break distance was seen with RAF rule (9.74 ± 0.81 mm), and the longest break distance was seen with red filter (11.78 ± 1.08 mm). The enhancements in both break and recovery distance with methods are graphically represented in Figure 1. The small range of differences and the given confidence intervals demonstrate the accurate estimation of group means,

which may make a strong basis to proceed with the additional inferential examination.

Table 2: Descriptive analysis of NPC break and recovery distances across methods.

Method	Break (mm)	Recovery (mm)	Min	Max
	Mean ± SD	Mean ± SD		
RAF ruler	9.74 ± 0.81	10.42 ± 0.81	6.67	11.33
Pencil push-up	10.61 ± 0.96	10.97 ± 0.96	8.67	13.33
NPC with Red filter	11.78 ± 1.08	12.24 ± 1.03	9.33	14.67

Abbreviations: NPC, Near Point of Convergence; RAF, Royal Air Force ruler; SD, Standard Deviation; Min, Minimum; Max, Maximum; mm, millimeters.

Shapiro-Wilk test showed that some of the readings of RAF rule and pencil push up were not normally distributed ($p < 0.05$). However, the distribution plots revealed that there was approximate symmetry of data. Since the sample size (n = 130) was large, it was decided to use parametric analysis. As a confirmatory analysis, non-parametric analysis was done to enhance the strength of the findings.

RM-ANOVA demonstrated a highly significant effect of target method on NPC break distance ($F(2,128)=216.44$, $p<0.001$), with a large effect size (partial $\eta^2=0.627$), indicating a strong influence of the assessment technique on convergence break measurements. Post-hoc Bonferroni analysis showed significant differences between all methods ($p<0.001$). The RAF ruler produced significantly lower NPC break values compared with the pencil push-up method and the red filter with torch-light method. In addition, the pencil push-up method showed significantly lower break values than the red filter technique. These inter-method differences are illustrated in Table 3 and Figure 1.

Table 3: Bonferroni post-hoc comparisons for NPC break.

Comparison	Mean difference (mm)	SE	p-value
RAF – Pencil	-0.867	0.102	<0.001
RAF – Red lens	-2.038	0.112	<0.001
Pencil – Red lens	-1.172	0.077	<0.001

Abbreviations: RAF, Royal Air Force ruler; Pencil, Pencil push-up method; Red lens, NPC with Red-filter torch-light method; SE, Standard Error; mm, millimeters.

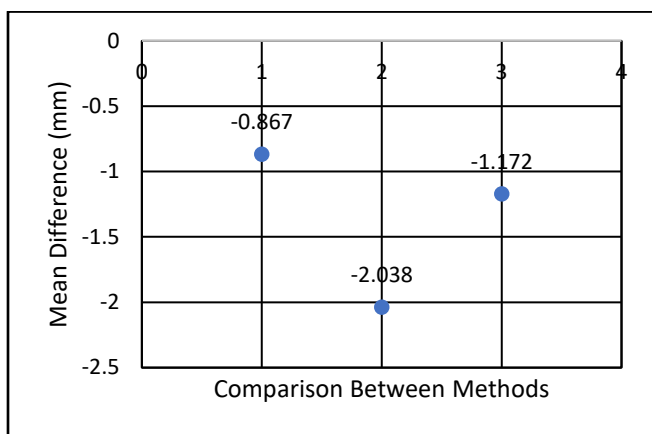


Figure 1: Pairwise differences in NPC break distances (Bonferroni comparisons).

Comparison of NPC recovery distances also demonstrated a significant effect of the testing method ($F(2,128)=185.81, p<0.001$), with a large effect size (partial $\eta^2=0.590$). There were statistically significant differences between all method pairs ($p<0.001$). The RAF ruler consistently produced the nearest recovery distances compared with the pencil push-up and red lens with torch-light methods. This pattern was observed for NPC break distances, indicating method-dependent variation in both convergence break and recovery measurements.

The Friedman test supported the parametric analysis, demonstrating significant differences among the three techniques for both NPC break ($\chi^2=161.72, df=2, p<0.001$) and recovery measurements ($\chi^2=157.03, df=2, p<0.001$). Mean ranks increased progressively from the RAF ruler, which showed the lowest ranks, to the pencil push-up method, and were highest for the red filter with torch-light technique. Figure 2 illustrates the distribution of NPC break and recovery values. The concordance between parametric and non-parametric analyses strengthens the validity of the findings and confirms that target variation has a statistically and clinically significant effect on NPC measurements.

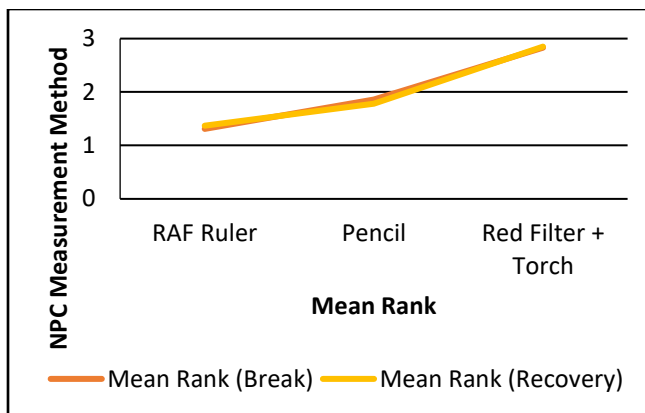


Figure 2: Distribution of Mean ranks for NPC break and recovery values.

DISCUSSION

The current study showed significant and statistically significant variations between convergence break and recovery distance in accommodative versus non-accommodative target conditions, and the findings of the current study agree with previous findings that NPC performance largely depends on the optical characteristics of the employed fixation stimulus.¹ Accommodative targets are more likely to elicit closer NPC values than non-accommodative targets, probably because accommodative convergence contributes to the overall convergence effort when blur cues are present.

Rovira-Gay C et al, described a novel method, the Nonius polarized target method, which offered several advantages over conventional techniques for NPC measurement. It provided a more sensitive assessment of convergence ability, minimized inter-test variability across clinical settings, and improved the reliability of NPC evaluation in both clinical practice and research.¹⁵

Clinical studies have consistently shown that NPC values vary according to the measurement method used. Scheiman M et al, reported that NPC norms differ with target type, with conventional techniques typically producing normative break values of approximately 5–7 cm.⁸ It is well established that accommodative targets, such as letters on a rule, yield more proximal NPC break and recovery distances compared with simple light targets. Likewise, normative studies across different populations have demonstrated variability in NPC measurements, partly attributable to methodological differences in target selection.^{16,17} A large cross-sectional study among

students reported a mean NPC of 7.25 cm using accommodative targets, further supporting the influence of target type on clinical NPC measurements.¹⁷

Differences between methods may also reflect underlying physiological processes engaged during testing. Accommodative targets involve accommodative convergence, proximal convergence, and fusional vergence, potentially resulting in more proximal break points. Conversely, non-accommodative targets minimize blur cues, emphasize fusional components, and yield more receded NPC measurements. This explanation is consistent with experimental findings demonstrating method-dependent NPC outcomes.¹⁵

The current findings have clinical implications. Practitioners must recognize that NPC values obtained with different target types cannot be used interchangeably. Applying normative thresholds established for one method to data collected via another, for instance during convergence insufficiency screening risks inaccurate diagnostic classification.^{9,18,19} Standardizing NPC measurement protocols or reporting method-specific normative reference values may reduce inconsistencies in both clinical and research settings.²⁰

The repeated-measures design employed in this study across three target types strengthens the evidence for method-dependent variability in NPC outcomes. Earlier studies often compared only two methods or included smaller samples, limiting generalizability.^{7,14} The present analysis extends previous work by evaluating multiple methods within the same participants and quantifying the magnitude of inter-method differences.

The study has several limitations. First, the sample consisted of young adults with normal binocular vision; therefore, the findings may not be directly generalizable to patients with convergence anomalies or to older populations. Second, despite the use of standardized testing procedures, subtle examiner- and participant-related variability cannot be completely excluded. Future studies should investigate NPC differences across a wider age range and include symptomatic cohorts to enhance clinical relevance.

Recognizing target-specific effects on NPC can improve clinical decision-making and enhance comparability across studies.

CONCLUSION

NPC is necessarily method sensitive as opposed to a physiological absolute and that the target characteristics bring about an effect on convergence performance. The values of NPC measured using various targets cannot be directly interchanged. It is therefore essential that clinicians contextualize NPC findings within the specific assessment technique used, and that cross-method comparisons be approached with caution and appropriate methodological transparency. Standardized reporting of NPC target type could be beneficial in improving the accuracy of diagnosis and improving comparability across both clinical evaluations and research.

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Conflict of Interest: Authors declared no conflict of interest.

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Shamit Pal; Optometrist: *Concepts, Design, Literature Search, Data Acquisition, Data Analysis, Manuscript Preparation.*

Priye Suman Rastogi; Professor: *Design, Data Analysis, Statistical Analysis, Manuscript Editing, Manuscript Review.*

