# Determining the amplitude of accommodation by advanced proximetry in patients of different age groups

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# Визначення амплітуди акомодації у пацієнтів різних вікових груп методом вдосконаленої проксиметрії

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**Abstract**

***Purpose.*** *To improve the accuracy of determining the amplitude of accommodation (AA) by proximetry through the use of an advanced proximeter and to develop a methodology for personalized management of AA assessment.*

***Methods.*** *We prospectively examined 1420 patients from different age groups at routine optometric visits. We compared measurements of the AA by a conventional method of proximetry and advanced proximetry (using a device that we had developed) in the same patients. Advanced proximetry involves using Scheiner's principle which improved the accuracy of image fixation on the retina.*

***Results.*** *The sensitivity and specificity of advanced proximetry were 99.2% and 95.6%, respectively.*

***Conclusion.*** *Advanced proximetry enables improving the efficacy of AA measurements in optometric patients and can be recommended for routine practice.*

***Keywords:*** *accommodation; diagnostics, refractive errors, amplitude of accommodation, proximetry, optometry, ophthalmology.*

DOI: https://doi.org/10.31288/Ukr.j.ophthalmol.202645665

UDC: 617.753.2-07

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Received 2025-10-16

Accepted 2026-06-24

**Cite this article as:** Kriuchko OV, Shargorodska IV, Shkribliak II. Determining the amplitude of accommodation by advanced proximetry in patients of different age groups. Ukr. j. ophthalmol. 2026;4:56-65.



**Резюме**

***Мета.*** *Підвищити точність дослідження амплітуди акомодації у пацієнтів різних вікових груп шляхом проксиметрії із застосуванням вдосконаленого проксиметра та розробити методику персоналізованого менеджменту оцінки амплітуди акомодації.*

***Методи.*** *Проспективно обстежено 1420 пацієнтів різних вікових груп під час поточних оптометричних візитів. Порівнювали результати вимірювання амплітуди акомодації, обчислені за допомогою загальновідомої проксиметрії та шляхом застосування запропонованого нами приладу та методу вдосконаленої проксиметрії у одних і тих же пацієнтів. Вдосконалена проксиметрія передбачала використання феномену Шейнера, що підвищувало точність фіксації зображення на сітківці ока.*

***Результати.*** *Аналіз отриманих результатів свідчить про переваги визначення амплітуди акомодації методом вдосконаленої проксиметрії у пацієнтів різних вікових груп з чутливістю методу у 99,2%, специфічністю методу вдосконаленої проксиметрії у 95,6%.*

***Висновок.*** *Застосування методу вдосконаленої проксиметрії для визначення амплітуди акомодації у пацієнтів різних вікових груп дозволяє підвищити ефективність дослідження амплітуди акомодації у оптометричних пацієнтів і може бути рекомендовано для впровадження в рутинну оптометричну практику.*

***Ключові слова:*** *акомодація, діагностика, аномалії рефракції, амплітуда акомодації, проксиметрія, оптометрія, офтальмологія.*

### Introduction

Measurement of accommodation is a routine procedure during an optometric examination, with the accommodative function assessed by measuring the amplitude of accommodation (AA), accommodative response (AR), negative relative accommodation (NRA), positive relative accommodation (PRA), and accommodative facility (AF) [1].

AA is an eye's maximum range of focusing power at a particular time. It is expressed in dioptres. It can be measured monocularly as a characteristic of absolute accommodation, and binocularly as a characteristic of relative accommodation [2]. It is noteworthy that, even in the complete absence of active (lenticular) accommodation, the eye has a capacity for clear vision within a certain range, a feature known as depth of focus. The corresponding distance range in which the objects are seen clearly is known as depth of field [3].

The AA is a measure of the closest point at which the eye can focus the image of an object on the retina: it is the range from the fair point to the near point of clear vision in dioptres.

Four methods of measuring AA are encountered in clinical practice and described in the literature. They are push-up, push-down, minus lens, and retinoscopy [2].

One should keep in mind that examiner bias is a source of error in any measurement that is not fully automatic. The practitioner examining the patient will have an expectation of approximately where the measurement end-point should be. That expectation, and inevitable differences in technique between practitioners, may influence how the measurement is taken (e.g., the visual object's speed), which may in turn influence the result. It may affect naive patients more [2].

Additionally, research of accommodative response and fixation disparity [4] has shown that the exact wording of instructions can influence the results of measurement. Significant differences between five different examiners' results for push-up measurement of AA were found and attributed to possible differences between examiners' measurement techniques [5].

Despite advances in optimizing the methodology for determining the amount of accommodation, the results of recent studies indicate that it should be further improved.

To the best of our knowledge, no data has been reported on solving this important scientific and technical problem of modern ophthalmology.

The purpose of this study was twofold: first, to improve the accuracy of measuring the AA in patients of various age groups by comparing the results of measurements of the near point of clear vision (NPCV) by a conventional method of proximetry with those by a method of advanced proximetry using an improved proximeter based on Scheiner's principle, and, second, to develop a methodology for personalized management of AA assessment.

### Material and Methods

We prospectively examined 1420 patients (aged 6 to 60 years and older) at routine optometric visits. They were divided into age groups of 6-8, 9-11, 12-14, 15-17, 18-24, 25-39, and 40-59 years, and 60 years or older. Of the 1420 patients, 457 (32.2%) were males and 963 (67.8 %) were females. Additionally, 702 individuals (49.4%) were spectacle wearers, and 718 (50.6%), contact lens wearers. Patients underwent complete optometric examination including the assessment of visual acuity at a far distance using a visual acuity chart projector and at a near distance using optotype charts, and automated refraction and keratometry. Moreover, AA measurements performed with conventional proximetry were compared to those performed with advanced proximetry. AA was measured with the patient wearing full distance correction. In all patients, the BCVA was sufficient to perform proximetry with the assessment of the optotypes presented. AR was estimated using dynamic monocular estimate method (MEM) retinoscopy. NRA and PRA were measured with positive and negative lenses, respectively, if required. Accommodative facility was tested using a ± 2 diopter (D) lens flipper.

The status of binocular vision and the presence of stereoscopic vision were estimated with polarization and anaglyph tests of the visual acuity chart projector. Associated phoria at distance was estimated with polarization tests of the visual acuity chart projector. Dissociated phoria at distance and near was estimated with dissociation tests (including prism dissociation tests), and cover test and Crimsky test were performed, if required. Accommodative convergence/ accommodation ratio (AC/A), positive and negative vergence amplitudes, near point of convergence and near point of convergence recovery were measured. Axial length (AL) was measured by optic biometry. Tonometry and pachymetry were performed in patients of 18 years or older. The ocular surface and retina were assessed by external examination with slit lamp biomicroscopy and fundoscopy, respectively.

The inclusion criterium was the possibility of performing AA measurements using conventional proximetry and advanced proximetry for further comparative analysis.

Informed consent was obtained either from participants themselves of their guardians.

The method of advanced proximetry includes using the developed advanced proximeter [6].

This optometric proximeter developed consists of a 4-cm plastic cube that has a slit on its top face to fasten the hook of the tape measure. The latter is glued to the lateral face to make the hook slot of the tape measure be at the same level with the front face of the cube. Two plastic handles are fastened with screws to the bottom face of the cube and the beginning of the tape measure. "A rectangular with letters" chart against white background is attached to the front face of the cube.

Figure 1 shows the arrangement of the components of the optometric proximeter. Figure 2 shows the general view of the proximeter.

The methodology of advanced proximetry was as follows. Best corrected optical power lenses were placed in the trial frame and the sensory dominant eye was determined in the patient. In phase 1 of the procedure, the patient was asked to fixate the contours of letters of the "rectangular with letters" optometric chart on the forward face of the cube and to tell whether they were clearly visible. The NPCV was determined if and when the contours of the letter became blurred as the proximeter was brought gradually nearer to the eye, and the patient failed to overcome this blurring during 2-3 s..

In phase 2 of the procedure, a Bagolini striated glass was placed in the trial frame in front of the patient's sensory dominant eye [7] and the patient was asked to look at the vertical line of the "rectangular with letters" chart. Initially, the vertical line appeared as a single line due to accommodation. Once further focusing the image on the retina through accommodative effort became impossible for 2-3 s, the patient stopped the movement of the proximeter along the tape and reported seeing two images of the vertical line instead of one image. In this way, the NPCV was measured.

A conversion table was used for converting the NPCV measurements expressed in centimeters into diopters and comparing the determined AA value with Hofstetter's norms [8].

The minimum, optimum and maximum AA in diopters were estimated using Hofstetter's formulas: minimum AA = 15 – 0.25 x (age in years); optimum AA = 18.5 – 0.3 x (age in years); and maximum AA = 25 – 0.4 x (age in years) [8].

The EZR software (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R statistics (R Foundation for Statistical Computing, Vienna, Austria), and Excel 2023 (Microsoft Corp., Redmond, WA) were used for statistical analysis. Statistical significance was set at $P < 0.05$ for all analyses. Sensitivity and specificity of the prognostic test were calculated using the following formulas [9]:

Sensitivity = [TP/(TP + FN)] x 100% and

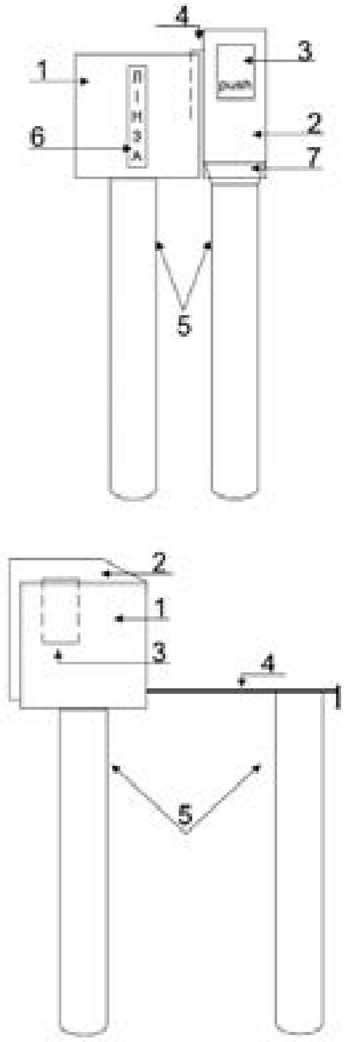


**Fig. 1.** Arrangement of the components of the optometric proximeter. Note: 1, cube; 2, tape-measure case; 3, clamp; 4, tape of the tape measure; 5, handles; 6, optotype; 7, holder (tape's zero point)


**Fig. 2.** Structure of the proximeter: a plastic cube, a tape-measure, and markers used as handles

Specificity = [TN/(TP + FN)] x 100%, respectively, where

TP was a true-positive result (the number of correctly identified positive cases),

FP was a false-positive result (the number of incorrectly identified positive cases),

TN was a true-negative result (the number of correctly identified negative cases), and

FN was a false-negative result (the number of incorrectly identified negative cases).

### Results

Table 1 compares the results of measurements of AA using advanced proximetry and conventional proximetry for the total study sample.

The sensitivity and specificity of advanced proximetry were

[(62+1346)/(62+1346+12)] x 100% = 99.2 % and
[1358/(1358+1408-1346)] x 100= 95.6 %, respectively.

The rate of discrepancies in the results between advanced proximetry and conventional proximetry was 5.2%.

Table 2 compares the results of measurements of AA using advanced proximetry and conventional proximetry for various age groups. AA distribution by age of patients with myopia will be reported in later publications.

Table 3 summarizes the advantages and disadvantages of AA measurements using the Royal Air Force (RAF) Rule and advanced proximetry.

For convenience of optometric practitioners, we provide a reference table (Table 4) for converting the NPCV measurements expressed in centimeters into diopters and comparing the determined AA value with Hofstetter's norms.

**Table 1.** Comparing differences in the results of amplitude of accommodation measurements by advanced proximetry and conventional proximetry for the total sample

| Comparing near point measurements by advanced proximetry (NPCV_1) and conventional proximetry (NPCV_2) | Actual results | |
|---|---|---|
| | Case | Non-case |
| NPCV_1 > NPCV_2 | TP=62 | FP=1408 |
| NPCV_1 = NPCV_2 | 1346 | 74 |
| NPCV_1 < NPCV_2 | FN=12 | TN=1358 |

Note: NPCV_1, result of measurement by advanced proximetry; NPCV_2, result of measurement by conventional proximetry; TP, number of true positive cases (the advanced method is more sensitive than the conventional method); FP, number of false positive cases; TN, number of true negative cases (the advanced method is less sensitive than the conventional method); FN, number of false negative cases

**Table 2.** Comparing differences in the results of amplitude of accommodation measurements by advanced proximetry and conventional proximetry for different age groups

| Age group (years) | Total number of individuals in the group | NPCV_1 > NPCV_2 | | NPCV_1 < NPCV_2 | |
|---|---|---|---|---|---|
| | | number | percentage | number | percentage |
| 6-8 | 50 | 1 | 2.0 | | |
| 9-11 | 129 | 3 | 2.3 | | |
| 12-14 | 157 | 4 | 2.5 | 1 | 0.6 |
| 15-17 | 136 | 9 | 6.6 | | |
| 18-24 | 193 | 9 | 4.7 | 1 | 0.5 |
| 25-39 | 272 | 15 | 5.5 | 2 | 0.7 |
| 40-59 | 438 | 20 | 4.6 | 7 | 1.6 |
| 60+ | 45 | 1 | 2.2 | 1 | 2.2 |
| TOTAL | 1420 | 62 | 4.4 | 12 | 0.8 |

Note: NPCV_1, result of measurement by advanced proximetry; NPCV_2, result of measurement by conventional proximetry

**Table 3.** Advantages of NPCV measurements with advanced proximetry and disadvantages of NPCV measurements with the RAF Rule

| # | Disadvantages of NPCV measurements with the RAF Rule | Advantages of NPCV measurements with advanced proximetry |
|---|---|---|
| 1 | Ambiguity about which part of the sliding component indicates the reading | The fixation object is at the same level as marks of the near-point tape measure |
| 2 | Ambiguity regarding which scale-gradation (or neither) the scale's numbers describe, because each number is equidistant between two graduations and indicates neither | Near-point tape measure markings are millimeters, with millimeter measurements converted to diopters using the conversion table |
| 3 | Uncertainty about the location of the scale's zero point, as RAF rules appear to vary in the distance of any particular scale graduation from the check rest | The zero point of the near-point tape measure is definitely located at the cheek rest |
| 4 | The slider's opaqueness, obscuring interpolation between graduations | The slider is not opaque |
| 5 | The effect on the location of the scale arising from the inter-individual differences in facial anatomy, at any given distance, *d*, of the cheek rest below the corneal vertex | The difference in measurements with the zero point of the near-point tape measure located at the cheek rest is within the measurement error for the method, and is similar for repeat measurement trials in a particular patient |
| 6 | The effect of not specifying the distance *d*, as facial anatomy is not perpendicular to the RAF rule | The cheek rest below the examined eye is similar for all patients, and the contact area for the tape-measure rest is significantly smaller than for the RAF rule, thus making the measurement error smaller |
| 7 | The effect of not specifying the distance *d*, as facial anatomy varies between people | The cheek rest below the examined eye is almost similar for all patients irrespective of the examiner and its slight shift does not influence the range of measurement error for the method |
| 8 | The effect of not specifying the distance *d* on point (14) below | It is recommended to maintain the position of the proximeter 10-15° below the horizontal line, in a way similar to other accommodation measurements, in an attempt to approximate natural accommodation conditions |
| 9 | The variability of luminance contrast of the text. The contrast could be standardized by backlighting the text; | The variability of contrast is insubstantial under conditions of a single office with constant illumination |
| 10 | The limits of the scale. The values of AA higher than the measurement range of the unmodified instrument have often been reported; | The near-point tape measure can measure distances much longer than the length of an adult's hand; however, it is recommended to use auxiliary reduction lenses for measurements at a distance of 15-25 cm in elderly patients |
| 11 | The variable location of fixation within one line of target print, since different letters in the line, which is 27 mm long, are at different distances from either eye, producing differing accommodative demand of up to 0.25D when measuring approximately 6 D of accommodation with the RAF Rule. | Because only one vertical column of letters is used for NPCV measurements, the fixation on one letter makes this error negligible |

| | | |
|---|---|---|
| 12 | The effect of target detail size, through depth of focus | It is impossible to eliminate completely the effect of the depth of focus; in order to reduce the measurement error, it is recommended to note an initial blurring of target contours, slow speed of movement of the proximeter, and failure to fixate within 2-3 seconds when the target is kept static; it is noting the initial blurring of target contours, but not that of the gap of the optotype that neutralizes the dependence on the linear size of the target |
| 13 | The effect of scale interval linearity, through reaction time as previously discussed | Repeated trials for AA measurement with and without a Bagolini striated glass improve the accuracy of the method while taking the given tolerances into account; to enable a smooth device movement at a constant speed, the proximeter may be held and guided by the examiner in the absence of direct hand-to-hand contact with the patient |
| 14 | The variability of the rail declination because the rule may be held above or below the primary position of gaze | It is recommended to maintain the position of the proximeter 10-15° below the horizontal line, in a way similar to other accommodation measurements, in an attempt to approximate natural accommodation conditions |
| 15 | The other source of error inherent in the design of this instrument applies to the monocular measurement. The error is that the rule is placed on the midline between the two eyes, rather than on the visual axis of the eye being measured. | The error mentioned is absent because the design of the device envisages placing the target before the examined eye |

Note: AA, amplitude of accommodation (diopters); NPCV, near point of clear vision; RAF Rule, the Royal Air Force Rule for accommodation measurements

**Table 4.** Near-point of clear vision values and Hofstetter's age-expected norms for amplitude of accommodation

| Age | Minimum | Optimum | Maximum | Age | Minimum | Optimum | Maximum | NPCV | | NPCV | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| років | 15-0,25*р | 18,5-0,3*р | 25-0,4*р | років | 15-0,25*р | 18,5-0,3*р | 25-0,4*р | cm | D | cm | D |
| 5 | 13.75 | 17.00 | 23.00 | 31 | 7,25 | 9,20 | 12,60 | 5 | 20,00 | 31 | 3,23 |
| 6 | 13.50 | 16,70 | 22,60 | 32 | 7.00 | 8.90 | 12,20 | 6 | 16,67 | 32 | 3,13 |
| 7 | 13,25 | 16,40 | 22,20 | 33 | 6,75 | 8,60 | 11,80 | 7 | 14,29 | 33 | 3.03 |
| 8 | 13.00 | 16.10 | 21.80 | 34 | 6.50 | 8,30 | 11,40 | 8 | 12,50 | 34 | 2.94 |
| 9 | 12,75 | 15,80 | 21,40 | 35 | 6,25 | 8.00 | 11.00 | 9 | 11,11 | 35 | 2,86 |
| 10 | 12,50 | 15,50 | 21.00 | 36 | 6,00 | 7.70 | 10,60 | 10 | 10,00 | 36 | 2.78 |
| 11 | 12,25 | 15,20 | 20,60 | 37 | 5,75 | 7,40 | 10,20 | 11 | 9.09 | 37 | 2,70 |
| 12 | 12,00 | 14,90 | 20,20 | 38 | 5,50 | 7,10 | 9,80 | 12 | 8,33 | 38 | 2,63 |
| 13 | 11.75 | 14,60 | 19,80 | 39 | 5,25 | 6,80 | 9,40 | 13 | 7,69 | 39 | 2,56 |
| 14 | 11,50 | 14,30 | 19,40 | 40 | 5,00 | 6,50 | 9,00 | 14 | 7,14 | 40 | 2,50 |
| 15 | 11,25 | 14,00 | 19.00 | 41 | 4,75 | 6,20 | 8,60 | 15 | 6,67 | 41 | 2,44 |
| 16 | 11.00 | 13,70 | 18,60 | 42 | 4,50 | 5,90 | 8,20 | 16 | 6,25 | 42 | 2,38 |
| 17 | 10,75 | 13,40 | 18,20 | 43 | 4,25 | 5,60 | 7,80 | 17 | 5,88 | 43 | 2,33 |
| 18 | 10,50 | 13,10 | 17,80 | 44 | 4,00 | 5,30 | 7,40 | 18 | 5,56 | 44 | 2,27 |
| 19 | 10,25 | 12,80 | 17,40 | 45 | 3,75 | 5,00 | 7,00 | 19 | 5,26 | 45 | 2,22 |
| 20 | 10.00 | 12,50 | 17.00 | 46 | 3,50 | 4,70 | 6,60 | 20 | 5.00 | 46 | 2,17 |
| 21 | 9,75 | 12,20 | 16,60 | 47 | 3,25 | 4,40 | 6,20 | 21 | 4,76 | 47 | 2,13 |
| 22 | 9.50 | 11,90 | 16,20 | 48 | 3,00 | 4,10 | 5,80 | 22 | 4,55 | 48 | 2,08 |
| 23 | 9,25 | 11,60 | 15,80 | 49 | 2,75 | 3,80 | 5,40 | 23 | 4,35 | 49 | 2,04 |
| 24 | 9.00 | 11,30 | 15,40 | 50 | 2,50 | 3.50 | 5.00 | 24 | 4,17 | 50 | 2.00 |
| 25 | 8,75 | 11,00 | 15,00 | 51 | 2,25 | 3,20 | 4,60 | 25 | 4,00 | 51 | 1,96 |
| 26 | 8,50 | 10,70 | 14,60 | 52 | 2,00 | 2,90 | 4,20 | 26 | 3,85 | 52 | 1,92 |
| 27 | 8,25 | 10,40 | 14,20 | 53 | 1,75 | 2,60 | 3,80 | 27 | 3,70 | 53 | 1,89 |
| 28 | 8,00 | 10,10 | 13,80 | 54 | 1,50 | 2,30 | 3,40 | 28 | 3,57 | 54 | 1,85 |
| 29 | 7,75 | 9,80 | 13,40 | 55 | 1,25 | 2,00 | 3,00 | 29 | 3,45 | 55 | 1,82 |
| 30 | 7,50 | 9,50 | 13,00 | 56 | 1,00 | 1,70 | 2,60 | 30 | 3,33 | 56 | 1,79 |

Note: NPCV, near point of clear vision

### Discussion

Most commonly used methods of measuring AA are push-up, push-down, minus lens, and retinoscopy.

In the push-up method the examiner instructs the patient to report when a test-object becomes blurred as it is brought gradually nearer to the eye. Devices which are a ruler with a sliding test-object are often used for this measurement. The RAF rule is an example of such a device [2].

The push-down method can also use the RAF Rule and similar devices. The object is moved away from the patient, from being too near for the patient to resolve, until it can be seen. This method particularly lacks standardization of nomenclature and technique. For example, different authors specify differing end-points [10]. Naming the method and its endpoint criterion presents some confusion. When the "just recognizable" criterion was first described [1] the push-down approach was described as the "modified push-up method" which has been used [11, 12] in research where it has been termed the "modified push-down method" [13] which resembled the "modified pull-away method" [14] in another report [15]. However, all of these reports used auxiliary fixed-power diverging trial lenses to extend the range of measurement.

In the negative lens method [16], negative spherical lens power is added to the distance refractive correction until the patient cannot maintain the initial acuity at a pre-set viewing distance well beyond the expected near point. The AA is given by the maximum power added while the patient can maintain focus, corrected for the vergence of the viewing distance. This method should only be used for monocular measurement and only under monocular conditions. These limitations arise because accommodation and convergence work together although the link between their operations is not rigid [17].

AA can also be measured with a retinoscope. Although retinoscopy relies on the clinician's interpretation of the retinoscopy reflex, it requires no judgment by the patient. It can be used for measurement of AA by stimulating accommodation maximally while the practitioner determines the end point. This method requires practitioner skill, judgment and experience [18]. That may explain why it use has been reported less often than other methods.

The RAF Rule is a common instrument for measuring AA. However, in the opinion of Burns and colleagues [2], each of the following fifteen sources of error in the RAF rule has the potential to cause clinically significant error:

1) ambiguity about which part of the sliding component indicates the reading;

2) ambiguity regarding which scale-gradation (or neither) the scale's numbers describe, because each number is equidistant between two graduations and indicates neither;

3) uncertainty about the location of the scale's zero point, as RAF rules appear to vary in the distance of any particular scale graduation from the cheek rest;

4) the slider's opaqueness, obscuring interpolation between graduations;

5) the effect on the location of the scale arising from the inter-individual differences in facial anatomy, at any given distance, d, of the cheek rest below the corneal vertex;

6) the effect of not specifying d, mentioned in point (5) above, as facial anatomy is not perpendicular to the RAF rule;

7) the effect of not specifying d, as facial anatomy varies between people;

8) the effect of not specifying the distance d on point (14) below;

9) the variability of luminance contrast of the text. The contrast could be standardized by backlighting the text;

10) the limits of the scale. The values of AA higher than the measurement range of the unmodified instrument have often been reported [19];

11) the variable location of fixation within one line of target print, since different letters in the line, which is 27 mm long, are at different distances from either eye, producing differing accommodative demand of up to 0.25D when measuring approximately 6 D of accommodation with the RAF Rule. Higher errors occur at shorter target distances;

12) the effect of target detail size, through depth of focus;

13) the effect of scale interval linearity, through reaction time as previously discussed;

14) the variability of the rail declination because the rule may be held above or below the primary position of gaze;

15) the other source of error inherent in the design of this instrument applies to the monocular measurement. The error is that the rule is placed on the midline between the two eyes, rather than on the visual axis of the eye being measured. This would inflate results by an amount that can be trigonometrically estimated as about 5% at the highest levels of AA and approximately proportionally less at the lower levels, so it is not as large as some errors listed above. Correction for this source of error has been precise, approximate or missing [20]. In the above list of sources of error arising from apparent weakness in the design and production of the RAF Rule, published information was not found for items 1–13 [2].

*Anomalous distance cues*

Awareness of a visual object's distance influences accommodation. In comparing methods of measuring AA, the test object is further away in the minus lens method and measurement conditions are monocular, reducing awareness of proximity. Other methods give higher results, to differing extents [21].

With particularly careful methodology it was found that accommodation measured with either the push-up or push-down methods was higher when the participant grasped and guided the target than when the target was held and guided by the examiner [22]. No reason for this finding has been demonstrated but it could have been due to various psychological factors including increased awareness of proximity when the participant connected with, and controlled, the target. Accommodation rules such as the

RAF rule may therefore give higher measurements because of reasons including their physical contact with the patient.

The method of advanced proximetry proposed is different from the conventional proximetry in that it uses a Bagolini striated glass instead of a device that is no longer in production [23]. Given the subjective nature of patient's answers regarding the moment of near point fixation, possible short-term blurred vision due poor tear exchange during conventional proximetry, possible inadequate pediatric patient's attention to performing the test procedure, and other disadvantages of the push-up method, the examiner has to use several trials to assess the NPCV..

The results of this study, however, demonstrated that the method of advanced proximetry proposed reduced the need for repeat trials if the difference between the results of the two phases of the procedure was within a specified range: if the NPCV was larger than 20 cm, the allowable difference (AD) was 1 cm (the NPCV error smaller than 0.25 D); if the NPCV was larger than 15 cm and less than or equal to 20 cm, the AD was 0.5 cm (the NPCV error smaller than 0.5 D); and if the NPCV was smaller than 20 cm, the AD was 0.2 cm (the NPCV error smaller than 0.5 D). The difference had no substantial clinical value in the last case because the AA in the presence of such values characterizes the normal accommodative function [1].

Additionally, it is noteworthy that, obtaining nearness, the goal for the patient using the push-up method, probably offers little motivation to produce higher results, although this may depend on the instructions given. Maximum accommodative effort would be more likely to meet the challenge of discovering detail encountered with the "just recognizable" end point, the minus lens method, and retinoscopy with a suitable visual object such as a Snellen chart reduced to about 5% of its usual size [2].

The sources of error differ considerably in their nature and in the magnitude of their effect. Some are relatively systematic while others are of unpredictable size or direction or both, some affect lower readings more than higher readings and vice versa, some affect only certain methods of measurement, some affect different methods differently, some are due to human factors of the patient or of the practitioner, some are due to factors of the equipment, or of the method, used for measurement. Their overall effect greatly reduces the validity of clinical results with current methods [2].

The measurement errors caused by these many sources of error can all be reduced (and a few of them can be eradicated) by better attention to measurement technique and by the standardization of equipment and methods. However, such improvements to existing methods would generally increase the complexity, duration and difficulty of the measurement.

The results of the study [2] indicate that the individual practitioner may take certain steps to reduce AA measurement errors in current clinical practice. For example, visual object detail should be close to the limit of resolution at the near point, and the method used should be recorded with the measurement; when measuring with devices using a ruler with a sliding visual object, such as the RAF Rule, movement of the slider should be slow, perhaps approximately one diopter per second; during measurement the patient should receive positive feedback for effort; the rule should be held in the primary position of gaze; in push-down, the end-point criterion of sharp focus should be adopted; measurement should be to a clear, precise reference point such as the corneal vertex; any correction for refractive error should be referenced to the same point; the practitioner should check the individual rule's accuracy by measuring the near-point distance with a separate rule; the practitioner should consider taking a first measurement using the push-up method and then moving the slider away from the patient to obtain a push-down measurement. The recorded AA should be the average of these two values [2, 22]. It should be, however, noted that all the methods listed are rather unreliable and difficult to repeat, which lowers their reliability.

The results of the current study indicate that the conventional method of proximetry has measurement errors and does not provide the required test-retest reproducibility of measurements. Therefore, it is still important to improve the reliability of accommodative function measurements under conditions of routine optometric practice. In order to achieve this goal, the following stages of personalized management should be used: explaining the procedure of AA measurement to the patient; emphasizing the need to be attentive; responding timely to the initial blurring of the contours of optotypes presented; and increasing the number of pairwise repeated trials for AA measurement with and without a Bagolini striated glass.

Our study demonstrated high sensitivity and specificity of advanced proximetry (99.2% and 95.6%, respectively) in patients of various age groups. It is noteworthy that the innovation is easy to use, cost effective and will save time. The method can be used in optometric examination and further studies on the predictors of development and progression of refractive errors.

### Conclusion

An adequate methodology of advanced proximetry has been devised which uses an optical proximeter developed. Compared with the conventional proximetry, the advanced proximetry showed improved measurement accuracy based on the criteria that determine the sources of measurement error in the RAF rule. The methodology of advanced proximetry proposed and the optical proximeter developed can be used in optometric examination for the detection and differentiation

### Author Contributions

KOV: Investigation, Database Development, Data Analysis and Interpretation, Writing – original draft; SIV: Conceptualization, Methodology, Writing – review & editing; SII: Data Analysis and Interpretation, Writing – original draft.. All authors have read and approved the final version of the manuscript.

### Disclaimers

The opinions presented in this article are those of the authors and do not necessarily represent those of their institutions.

### Funding

This paper is a part of the 2023-2026 research project "Theoretical and Practical Aspects of Advances in Clinical and Experimental Methods for the Diagnosis, Treatment and Prevention of Eye Diseases and Injuries and their Associated Sequelae" of Department of Ophthalmology and Optometry of Post-Graduate Education, Institute for Post-Graduate Education, Bogomolets National Medical University, (State registration number № 0123U104207).

The authors declare that no funds, grant or other support was received during the preparation of this manuscript.

### Conflict of Interest

The authors declare that they have no actual or potential conflict of interest that could inappropriately influence, or be perceived to influence, the subject matter or material discussed in this manuscript.

### Ethical Statement

This study involved human subjects, was approved by the local bioethics committee, and followed ethical standards as outlined in the Declaration of Helsinki of the World Medical Association and the European Convention on Human Rights and Biomedicine, and relevant laws of Ukraine. Informed consent was obtained from all subjects or their representatives..

### Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

### Abbreviations

AA, amplitude of accommodation; AC/A, amplitude of accommodation / accommodation ratio; AF, accommodative facility; AL, axial length; AR, accommodative response; D, diopter; NPCV, near point of clear vision; NRA, negative relative accommodation; PRA, positive relative accommodation

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