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Reproducibility of nearwork-induced transient myopia measurements using the WAM-5500 autorefractor in its dynamic mode

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Abstract

Purpose To evaluate the reproducibility of nearwork-induced transient myopia (NITM) measurements obtained objectively using an open-field autorefractor (WAM-5500) in its dynamic mode.

Methods NITM was assessed in 22, visually-normal, teen-aged and young-adult subjects using an infrared autorefractor (WAM-5500) in the dynamic mode. Measurements were obtained from the right eye in two test sessions separated by either 30 minutes or 2 days. Initial NITM and its decay were assessed monocularly by the same experimenter immediately after binocularly viewing and performing a detailed near task (5D) for 5 minutes incorporating a cognitive demand, with habitual distance refractive correction in place. Data were averaged over 10-second bins for 3 minutes (180 seconds; 18 bins) for the decay analysis. The NITM post- minus pre-task difference and its limits of agreement (LOA), as well as intraclass correlation coefficient (ICC), were calculated to evaluate reproducibility over the two test sessions for the initial NITM magnitude and its decay.

Results The group mean (±SE) initial NITM and its decay duration were 0.33±0.09 D and 0.28±0.08 D, and 118.6±14.3 seconds and 132.3±12.2 seconds respectively, for each test session, which were not significantly different ($p>0.05$). The difference (range), LOA, and ICC (95% confidence interval [CI]) were 0.06D (−0.15, 0.64), −0.29 to 0.40D, and 0.90D (0.77, 0.96) for the initial NITM; they were −13.6 (−150.0, 140.0) seconds, –174.5 to 147.3 seconds, and 0.14 (0.00, 0.52) for decay duration, respectively, for each test session. The ICC range for the first 50 secs of the NITM response/decay was 0.90 to 0.96.

Conclusions The initial NITM was highly repeatable. The initial decay phase was moderately repeatable, with the later decay phase being more variable, yet still yielding acceptable reproducibility in many cases. Both of these key parameters, namely initial NITM and its early decay, can be assessed reliably and with good reproducibility. This is important in future longitudinal studies of NITM, and its possible relation to refractive development.

Keywords Near-work induced transient myopia · Myopia progression · Reproducibility · Accommodation

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Introduction

Previous investigations have reported extensively on the possible relation between nearwork and myopic progression [1–6]. Recently, there has been considerable interest in the potential short-term effects of nearwork-induced changes on refractive error, known as nearwork-induced transient myopia (NITM) [7–9]. NITM refers to the small and transient myopic shift in the far point of the eye after a period of sustained nearwork, with it reflecting an accommodative aftereffect.

Two important parameters, namely the initial NITM and its decay duration, have been used to describe the accommodative response that is assessed following the completion of a sustained nearwork task. The *initial NITM* is defined as the difference in accommodative response in diopters at far immediately before and after a sustained near task. The *decay duration* represents the amount of time for return of the transient NITM accommodative response back to the pre-task baseline level. Based on previous investigations (see Ciuffreda and Vasudevan [10] for a review), the initial NITM usually ranges from 0.12 to 0.60 D, with a mean of approximately 0.30 D (Ciuffreda [11]). The decay duration ranges from 30 seconds to 1 hour, or even more, depending on many factors such as the task duration and accommodative demand, with typical values of 20–60 seconds.

Refractive condition is one major factor that influences the initial NITM and its decay duration. The consensus is that myopes exhibit an increase in initial NITM in addition to slowed decay duration, as compared to emmetropes and hyperopes (e.g., Vasudevan and Ciuffreda [12] , Wolffsohn et al. [13, 14].). Furthermore, one recent investigation has also reported on the additivity of NITM (Vasudevan and Ciuffreda [12]), which was observed predominantly in myopes as compared to the fellow emmetropic cohort tested. One of the reasons for this refractive susceptibility was speculated to relate to abnormally-reduced sympathetic function in these myopic individuals (Vasudevan et al. [15]).

Although several investigations have been performed to study the characteristics of NITM (see Ciuffreda and Vasudevan [12] for a review), one aspect of NITM that has not been assessed is its reproducibility, that is, its repeatability. This information is critical for future longitudinal studies involving NITM, for example, its possible role in the progression of childhood myopia and other situations involving intense nearwork, such as the college environment in young adults [9, 10].

Thus, the purpose of the present study was to evaluate objectively the reproducibility of the initial NITM, and its decay, using the open-field WAM-5500 autorefractor in its dynamic mode in visually-normal, teen-aged children and young adults.

Methods

Subjects

Twenty-two, visually asymptomatic, children/adolescent and young-adult volunteers served as subjects. This sample size was determined based on power-analysis calculation. Measurements were obtained on the right eye in two test sessions separated by either 30 minutes or 2 days by a well-trained experimenter and co-author (ZL). All subjects had best-corrected distance visual acuity of 0.0 (LogMAR) or better monocularly and binocularly, with no evidence of ocular, systemic, or neurological disease. The mean (± SD) age of the 22 subjects (seven males and 15 females) was 15.9±4.5 (range 7 to 23) years. There were three emmetropes and 19 myopes. Subjects classified as having emmetropia had a spherical equivalent refraction ranging from 0.00 to +0.375D, with a mean of +0.125D. Subjects classified as having myopia had a spherical equivalent refraction ranging from −5.375 to −0.75D, with a mean of −2.44D. The mean (± SD) astigmatism was −0.57±0.32D. Five (three emmetropes and two myopes) of the 22 subjects were unaided, and the remainder wore either spectacles or ophthalmic trial lenses throughout the experiment. Nine of the subjects completed the two NITM measurements in the same day with a rest interval of 30 minutes.

To obtain the cycloplegic refractive error of each subject, three drops of cyclopentolate (1 %) were administered. When the effect of the drug reached its peak at 60 minutes, objective refraction was performed with an open-field autorefractor [WAM-5500]. The refractive category of each subject (emmetropia: −0.25D to +0.75D; myopia: < −0.25D) (Ciuffreda and Lee [16]) was classified according to the cycloplegic refraction obtained after all other testing was completed. Informed consent was obtained from each subject after the nature and possible consequences of the study were explained. The study was conducted in accordance with the ethical tenets of the Declaration of Helsinki, and it was approved by Beijing Tongren Hospital Ethical Committee.

Instrumentation

All measurements of refractive state during the experiment were obtained objectively using an open-field, infrared autorefractor (WAM-5500; Grand Seiko Co., Ltd.), which has been demonstrated to be effective for vision research (Win-Hall et al. [17], Sheppard and Davies [18]) in its dynamic mode. To function in the dynamic mode, the WCS-1 software provided by the manufacturer was installed on the computer. To initiate measurements, the instrument was aligned with the pupil of the right eye, the joystick button was depressed and released once, and then the instrument commenced recording dynamic measurements at approximately 5 Hz (i.e., five samples per second). During the dynamic measurements, the observer ensured that the instrument remained carefully aligned with the subjects' right eye by observing the alignment target imaged within the pupillary center in the LCD monitor for the entire duration of the testing. To cease measurements, the joystick button was pressed and released again. The instrument writes the data to a Microsoft Excel file that records the time of measurement, eye measured (left or right), spherical equivalent refraction, and pupil diameter highlights approximately every 200 msec.

Procedure

Pretask All subjects were seated in total darkness for 3 minutes, to allow for the dissipation of potential transient accommodative aftereffects (Krumholz et al. [19]). Then the accommodative response was assessed in the right eye, while the subject binocularly-viewed 20/30 Snellen letters at 6 m with full-distance refractive correction in place. Ten seconds of measurements (approximately 50 samples total) were obtained in the dynamic mode. The mean spherical equivalent, which represented the mean pretask baseline distance refractive state, was calculated. During assessment periods, subjects either were unaided (n=5), wore their spectacles or ophthalmic trial lenses (n=17) as their distance refractive correction in place (log MAR VA 0.0 or better). In the subjects where trial lenses were used, the measurements were at times taken with very slight lens tilt (<10 degrees) (i.e., pantascopic tilt) introduced to prevent undesired reflections into the system without inducing changes in the accommodative measurements.

Task Subjects were seated in the autorefractor under moderate fluorescent room illumination (60 lux). They were encouraged to identify as many differences as possible in the high contrast (>60 %) pictures of a test card (3×3 cm) held at a distance of 20 cm (5D) during the 5-minute near test period (Fig. 1). The test card contained 12 pairs of black-and-white pictures on a greyish-white background. Each pair of pictures included eight subtle differences, which had to be identified. Subjects were instructed to keep the targets in focus at all times. Furthermore, the number of differences they had found was queried every minute to assure their concentration and attention to the high focusing demand. The distance of the reading material was assessed every minute to ensure its constancy.

Posttask Immediately after the 5-minute period of sustained near viewing, the test cards were removed quickly (less than 2 seconds), and the subject was asked to focus as rapidly as possible on the distance Snellen target once again. The distance refractive state was assessed in the dynamic mode for a period of 3 minutes (approximately 900 samples total). Subjects were queried about target clarity periodically to ensure that they were focusing accurately.

Data analysis

First, any measurement obtained during a blink was deleted and recorded as a gap by the system, and hence was not included in the data analysis. Second, any unusually high values (e.g., −6.07 D) were considered noise and deleted, with this being a rare event (<3 % of the time). The immediate posttask minus pretask difference in distance refractive state represented the initial NITM dioptric magnitude. The NITM values were then averaged over each consecutive 10-second bin interval (18 total bins) for 180 seconds. Decay duration was defined as the time taken for the NITM magnitude to dissipate to the pretask distance baseline level and sustain for at least 10 seconds. Both NITM and its decay duration were calculated in each subject, and then these values were averaged across subjects to obtain the group mean initial NITM and decay duration.

Statistical analyses were performed using SPSS version 13.0. The intrasession difference and its limits of agreement (LOA), as well as the intraclass correlation coefficient (ICC), were calculated. An ICC of <0.40 indicates poor reproducibility, between 0.40 and 0.75 indicates fair to good reproducibility, and >0.75 indicates excellent reproducibility. *T*-tests and two-way repeated measures ANOVA were also performed.

Results

Initial NITM and its decay duration were the primary variables that were compared between the two sessions. Paired t-tests were performed to compare the group mean initial NITM for sessions 1 and 2, and no significant difference was found (t=1.50, p=0.14). Similarly, paired t-tests were performed to compare the group mean decay duration for sessions 1 and 2, and again no significant difference was found (t=0.77, p=0.44). The mean (± SE) initial NITM and its decay duration were 0.33±0.09 D and 0.28±0.08 D, and 118.6±14.3 seconds and 132.3±12.2 seconds respectively, for each test session for each parameter. A two-way, repeated-measures ANOVA for the factors of time and session was performed. It revealed a significant effect for time ($F_{(17,35)}$= −2.95; p=0.003), but not for session ($F_{(1,35)}$=2.47; p=0.14).

Figure 2 presents the overall group mean response decay patterns for the two test sessions. The intrasession difference, LOA, and ICC, of the 18 NITM mean data points for each 10-second time interval, i.e., the initial NITM and its decay, are presented in Table 1. The ICCs for NITM ranged from 0.41 to 0.96, with 11 (11/18, 61.1 %) of them (including the initial NITM) being greater than 0.75. The first five

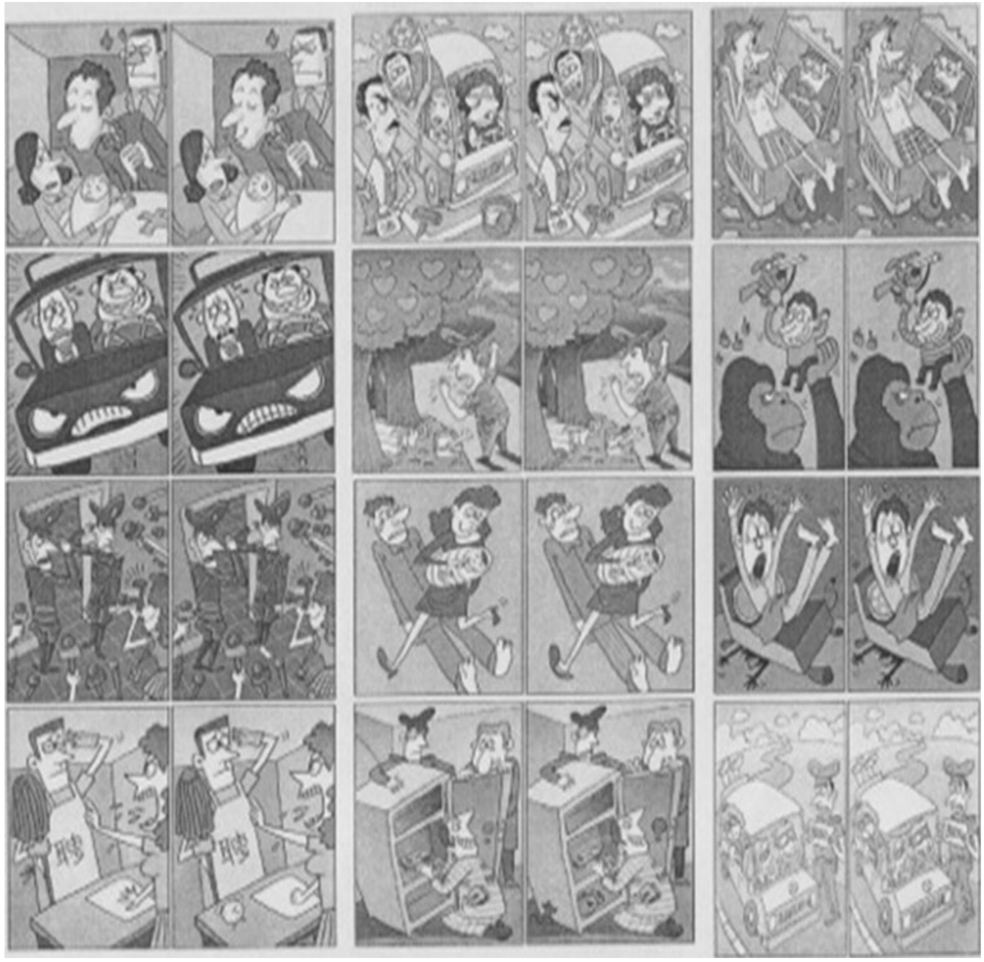

Fig. 1 Targets used for near task

ICCs (i.e., first 50 seconds) of the group mean initial NITM and its decay were 0.90 or more. Moreover, 77.3 % (17/22) of the differences in initial NITM was within 0.1D, with only 13.6 % (3/22) having a difference in initial NITM being greater than 0.3D. Furthermore, for each of the 18 time intervals depicting the initial NITM and its decay, the first and second session distributions exhibited considerable overlap well within their spherical equivalent statistically-derived intervals (Table 1).

Figure 3 depicts the plots of two representative individual subjects with regard to inter-session reproducibility of the mean initial NITM and related decay. Both exhibited relatively small variability, with similar response profiles, between the two sessions. This was confirmed statistically when comparing the mean NITM and its decay values averaged over time for session one and for session two for each subject (subject 1: t=1.233, p=0.23; subject 2: t=0.68, p=0.50). Although 17 out of the 18 mean data points in

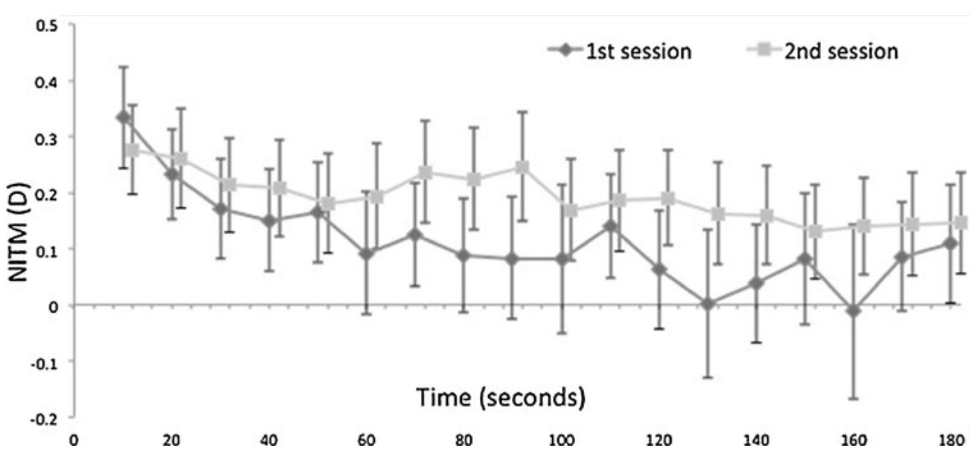

Fig. 2 Overall group response patterns for the two 180-second test sessions divided into 10-second bins. The mean ± SE (standard error) is plotted. The 2nd session is displaced by 2 seconds at each time interval for the sake of clarity

Table 1 Intraobserver reproducibility of the NITM measurement

	Mean ± SE		Difference (range)	LOA	ICC (95 % CI)
	1st session	2nd session			
NITM_1(D)	0.33±0.09	0.28±0.08	0.06 (−0.15, 0.64)	−0.28, 0.39	0.90 (0.77, 0.96)
NITM_2(D)	0.23±0.08	0.26±0.09	−0.03 (−0.37, 0.34)	−0.32, 0.26	0.93 (0.84, 0.97)
NITM_3(D)	0.17±0.09	0.21±0.08	−0.04 (−0.42, 0.23)	−0.33, 0.25	0.93 (0.85, 0.97)
NITM_4(D)	0.15±0.09	0.21±0.09	−0.04 (−0.27, 0.14)	−0.26, 0.17	0.96 (0.91, 0.98)
NITM_5(D)	0.16±0.09	0.18±0.09	0.00 (−0.23, 0.46)	−0.28, 0.28	0.94 (0.87, 0.98)
NITM_6(D)	0.09±0.11	0.19±0.09	−0.10 (−1.96, 0.36)	−0.98, 0.77	0.57 (0.21, 0.79)
NITM_7(D)	0.13±0.09	0.24±0.09	−0.11 (−0.53, 0.19)	−0.48, 0.25	0.88 (0.74, 0.95)
NITM_8(D)	0.09±0.10	0.22±0.09	−0.14 (−1.55, 0.18)	−0.84, 0.57	0.65 (0.33, 0.84)
NITM_9(D)	0.08±0.11	0.25±0.10	−0.17 (−1.90, 0.21)	−1.03, 0.70	0.56 (0.19, 0.80)
NITM_10(D)	0.08±0.13	0.17±0.09	−0.08 (−2.46, 0.93)	−1.25, 1.08	0.41 (−0.10, 0.71)
NITM_11(D)	0.14±0.09	0.19±0.09	−0.05 (−0.66, 0.56)	−0.55, 0.46	0.82 (0.63, 0.92)
NITM_12(D)	0.06±0.10	0.19±0.08	−0.13 (−1.23, 0.18)	−0.72, 0.46	0.75 (0.48, 0.89)
NITM_13(D)	0.00±0.13	0.16±0.09	−0.16 (−2.12, 0.17)	−1.08, 0.76	0.58 (0.22, 0.81)
NITM_14(D)	0.04±0.10	0.16±0.09	−0.12 (−1.22, 0.27)	−0.70, 0.46	0.76 (0.51,0.90)
NITM_15(D)	0.08±0.12	0.13±0.08	−0.05 (−1.39, 0.30)	−0.74, 0.64	0.73 (0.47,0.88)
NITM_16(D)	−0.01±0.16	0.14±0.09	−0.15 (−2.65, 0.36)	−1.32, 1.02	0.48 (0.10, 0.75)
NITM_17(D)	0.09±0.10	0.14±0.09	−0.06 (−0.69, 0.34)	−0.50, 0.39	0.87 (0.71, 0.95)
NITM_18(D)	0.11±0.11	0.14±0.09	−0.04 (−0.43, 0.25)	−0.44, 0.36	0.92 (0.81, 0.97)
Decay duration (sec)	118.6±14.3	132.3±12.2	−13.6 (−150.0, 140.0)	−174.5, 147.3	0.14 (0.00, 0.52)

SE: standard error; LOA: limit of agreement; ICC: intraclass correlation coefficient

NITM_1 to NITM_18: 18 NITM time bin intervals; NITM1 refers to the initial NITM

session 2 were numerically greater than those in session 1, they were not significantly different based on the group mean parametric analysis described earlier.

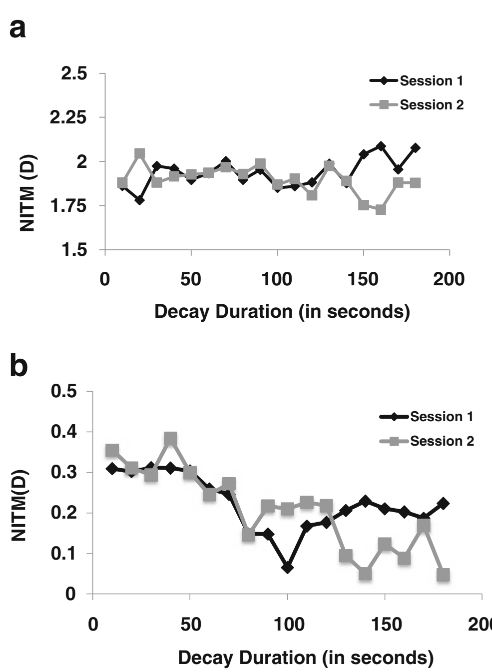

Fig. 3 **a** Repeatability of the initial NITM and its decay in one subject performed on two separate sessions. The mean is plotted. **b** Repeatability of the initial NITM and its decay in one subject performed on two separate sessions. The mean is plotted

The decay duration was defined as 180 seconds if the NITM did not decay to the pre-task distance baseline level during 3-minute post-task assessment. Using this criterion, nine of the subjects did not decay to the baseline in the first session, while 11 of the subjects did not decay completely in the second session; five of them did not decay completely in either test session. The difference (range), LOA, and ICC of the group mean decay duration were −13.6 (−150.0, 140.0) seconds, −174.5 to147.3 seconds, and 0.14 (0.00, 0.52) respectively, over the entire 180-second test interval.

Based on the above information/data and further analysis, the following values would represent a range of statistically similar NITM values for this sample of subjects to assess intersession reproducibility. For the initial NITM, the average value across the two sessions was approximately 0.30D; similarly, its mean variability (SEM) was approximately 0.08D. Thus, the upper limit (mean + 2 SEM) for a significant difference would be 0.46D, while its lower limit (mean − 2 SEM) would be 0.14D.

Individual subject values for initial NITM and decay are shown in Fig. 4a,b. With regard to the initial NITM, nearly all subjects (90 %) exhibited high intersession reproducibility, that is a difference in value of less than 25 % intersession reproducibility. With regard to NITM decay, approximately 50 % of the subjects exhibited high intersession reproducibility using the same criterion. Similarly, for the overall NITM averages across the 18 time periods (180 seconds), the mean was approximately 0.15D and its mean variability (SEM) was approximately

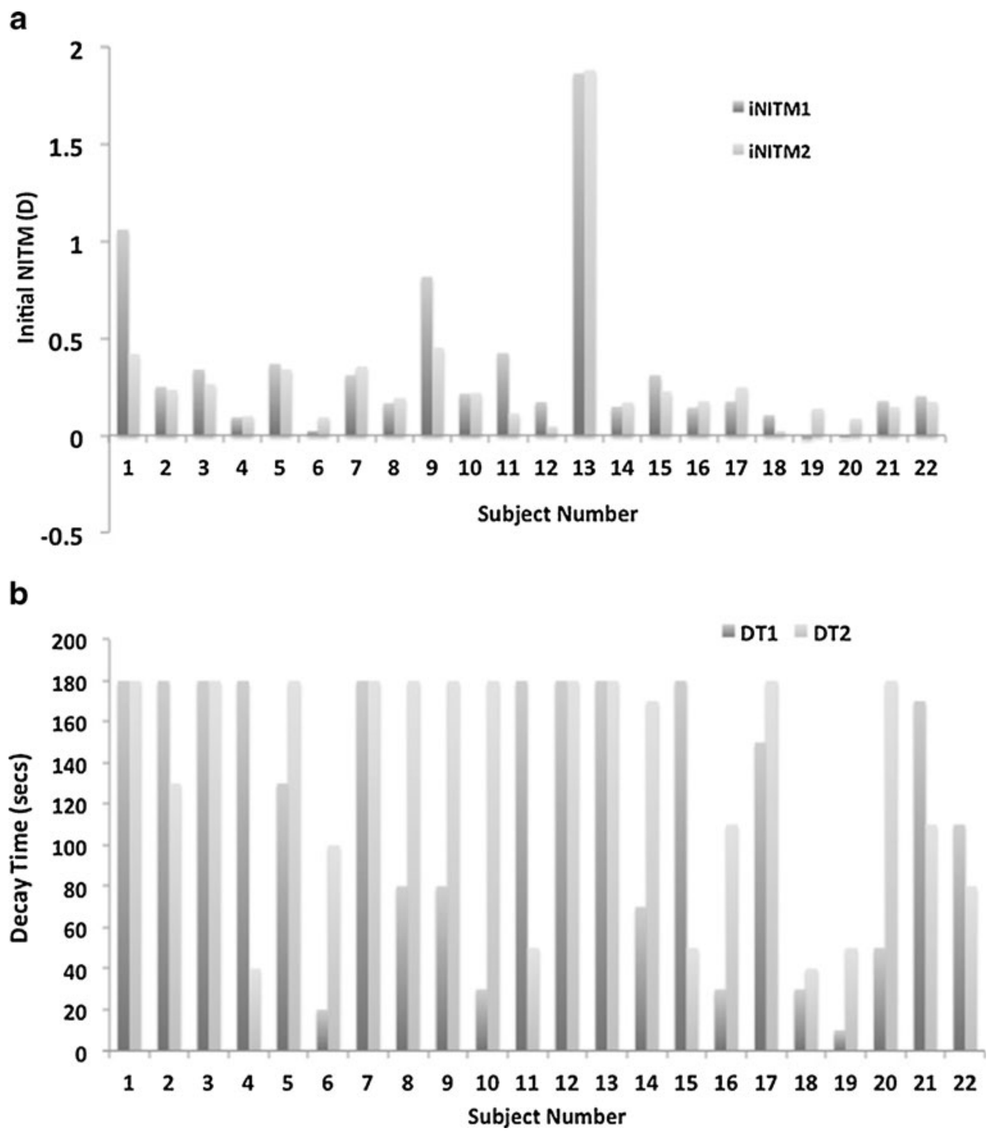

Fig. 4 **a** Plot of initial NITM for two sessions performed for all the subjects. **b** Plot of decay time for two sessions performed for all the subjects

0.10D. Thus, the upper limit for a significant difference would be 0.35D, and the lower limit would be −0.05D.

Discussion

This is the first study to assess the reproducibility of initial NITM and its decay in a detailed and quantitative manner in a group of visually-normal, young subjects. The two test sessions were performed at approximately the same time of the day, since diurnal variation of NITM remains unknown. For the majority of subjects, NITM dissipated fully following the 5-minute period of near viewing (Ong and Ciuffreda [20]). Moreover, using conventional parametric statistical analyses (e.g., *t*-tests), no significant differences were found with respect to the mean initial NITM and its mean overall decay duration between the two test sessions. The group mean (±SE) initial NITM (approximately 0.30D) and decay duration (approximately 120 seconds) were similar to previous studies assessed, especially in myopes, with an objective autorefractor in its rapid static mode approximately sampled every 2 seconds [7, 8, 16]. In addition, the mean difference in NITM for all 22 subjects was calculated to be 0.09D, which is considerably higher than the overall noise of the equipment/human observer combination (0.04D) as determined in an absolute presbyopic subject fixating at distance in the high-speed dynamic mode. Lastly, it is much larger than the system's resolution (0.01D), as specified by the manufacturer.

There are little data on NITM reproducibility, although this is critical for relating NITM to nearwork and refractive development [9, 16, 20, 21]. Ciuffreda and Lee [16] assessed two young-adult myopes (one early-onset and one late-onset myope) with respect to reproducibility of their overall NITM trends. They found good reproducibility based on non-quantitative gross visual analysis of the response profiles. In the present study, the majority of the ICCs (61.1 %) of the initial NITM values were greater than 0.75, which indicated excellent reproducibility. Furthermore, response over approximately the first post-task minute, which included the maximal magnitude and initial rapid decay of NITM, were also highly reproducible (ICCs of 0.9 or more).

The decay patterns for the two test sessions varied to a considerable degree after the first post-task minute period, with lower ICC values ranging from 0.41 to 0.88. This more variable late decay may relate to variation in the sympathetic component of the accommodative response [22], which was also recently found in a subgroup of young-adult myopes by Vasudevan et al. [15]. They reported sympathetic dysfunction in a considerable percentage of the myopes (~30 %), thereby increasing the time it takes for NITM to decay back to the baseline, as well as increasing its decay response variability. This would be mainly reflected in the latter two-thirds of the decay profile, as found in the present study. The initial NITM is a parasympathetically-driven far-response, with is subsequently intruded upon by the more slow-acting (10–40 secs initiation), sympathetically-mediated response function that results in a decrease of the NITM back to the pre-task baseline. In the event of sympathetic dysfunction, however, the NITM would not decay back to the baseline very rapidly, and would do so with more variability, as observed in approximately 50 % of the subjects tested in the present study. This has been explained mechanistically in detail elsewhere (Vasudevan et al. [12]). Hence, the use of ICC to assess the reproducibility of the latter decay phase might not be an optimal metric for the above-mentioned reasons. Finally, the good reproducibility of sustained 180-second NITM decay in approximately 50 % of the subjects might suggest that these subjects, who manifest repeatable non-decay, and thus presumably chronic retinal defocus, would have a greater tendency to develop myopia in accordance with a proposed retinal-defocus theory of myopia development [9]. A longitudinal study investigating the accommodative dynamics in NITM decay could be necessary to address this issue.

In summary, the initial NITM was highly repeatable. However, the initial decay phase was moderately repeatable, with the later decay phase being more variable, yet still yielding acceptable reproducibility in many cases. This result suggests that both of these key parameters, namely initial NITM and its early decay, can be assessed reliably and with good reproducibility in future longitudinal studies of NITM, and its possible relation to near work and refractive development, with the WAM-5500 device using the present protocol.

Conflict of interest The authors have no commercial interests in the instrument used in this study, or in the company that manufactures the instrument.

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