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# Impact of Computer Experience on the Viability and Repeatability of the Moorfields Motion Displacement Test in a Developing and Underserved African Setting

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## Abstract

**Background:** The current study was designed to explore the effect of computer experience on the viability and test-retest repeatability of the Moorfields Motion Displacement Test (MMDT), a novel computer-driven glaucoma screening device, in an African community setting.

**Methods:** 164 healthy subjects were recruited from a semi-rural Mozambican environment, and stratified according to computer experience (computer naïve: n=85, computer familiar: n=79). A suprathreshold screening test algorithm was employed, and the global probability of true damage (GPTD), testing time (TT) and false positive (FP) response rate were recorded. The visual field test was conducted twice on the same eye, and results compared to determine intra-sessional repeatability.

**Results:** No inter-group differences in GPTD or TT ($p$>0.05) were observed between computer subgroups, although FP response rate was significantly higher among computer naïve subjects ($p$=0.00 for both tests). No inter-sessional differences were observed for GPTD, TT and FP ($p$>0.05 for all) for either subgroup. A statistically significant positive correlation was found between repeat GPTD, TT and FP measures for all subgroups ($P$<0.05 for all). Bland Altman analysis revealed good repeatability for both subgroups.

**Conclusion:** This is the first study to evaluate the effect of computer experience on the test-retest repeatability of the MMDT device in an African setting, which is important given the glaucoma screening challenges and the disparities in access to information technology that are unique to developing countries. The results support its general repeatability for those community members likely to be encountered in developing countries, without prior experience of computers.

**Keywords:** Moorfields motion displacement test; Glaucoma; Africa; Computer experience; Repeatability

## Introduction

Most recent estimates indicate that there are 285 million people who are visually impaired worldwide [1]. About 90% of the world's visually impaired live in developing countries, and up to 80% of visual impairment is avoidable [1]. As the second leading cause of global blindness [1,2], the World Health Organisation (WHO) and VISION 2020 programmes for the prevention of avoidable blindness have specifically identified glaucoma as a priority condition [3,4].

The global trend towards increasing life expectancy is accompanied by a synchronous increase in the prevalence of age-related morbidities, including irreversible ophthalmic disease, that have a deleterious effect on health-related quality of life, and include glaucoma [5-7]. Globally, the number of people with glaucoma and glaucoma related blindness is set to increase substantially to 80 million and 11.2 million respectively by 2020 [8]. In Australia it has been predicted that the number of persons suffering glaucoma will double by the year 2030 [9], while other predictions indicate a likely 30% increase in the global prevalence of glaucoma by 2020, with an associated 33% rise in cases of bilateral, glaucoma-related blindness [5].

Within African and Asian derived groups, the relationship between glaucoma prevalence and age is a linear one, with Africans having the highest prevalence (four to five times higher) of open angle glaucoma [6,7]. In addition, disease onset is typically earlier [10], progresses more rapidly, and leads to more severe vision loss than is observed in other racial groups [10-12]. In Ghana, the prevalence of glaucoma among those aged over 30 has been estimated as 7.7% (8.5% among those aged over 40) [10]. In Tanzania, the prevalence of primary open angle glaucoma was 3.1% among those over the age of 40 [13], while in South Africa, the reported prevalence was 5.3% [14].

In most resource-poor countries the number and distribution of trained ophthalmologists and eye health personnel is not adequate to meet the service delivery needs [3]. Almost invariably, there are no primary care screening strategies in place, few trained community health professionals (e.g. optometrists), and ineffective or non-existent

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public awareness strategies for ocular disease [3]. Furthermore, the lack of equipment and other resources requires the centralisation of those services that are available, which renders eye health interventions inaccessible to the majority [15]. The combined effects of such contextual barriers to equitable eye health services include a failure to detect and treat glaucomatous disease for the vast majority of cases (likely very close to 100%, compared to the estimated 50% undiagnosed rate in developed countries), and high prevalence of unilateral and bilateral blindness at the time of presentation and disease detection [16,17].

The Moorfields Motion Displacement Test (MMDT) is a novel computer-based glaucoma screening device, designed for community screening in developing countries. The test employs vertical white line stimuli (124 cd/m$^2$) at 31 test locations, each designed spatially to correspond to Humphrey 24-2 programme test locations. The locations are scaled by estimates of retinal ganglion cell density and selected using the Garway-Heath anatomical map [18,19]. Stimuli are presented continuously throughout the test, against a grey background (10 cd/m$^2$), giving a Weber contrast ratio of 11.4.

The MMDT is a hyperacuity stimulus [20], presented at constant high contrast and has been shown to be more resistant to cataract than standard automated perimetry [21]. Uncorrected refractive error, including presbyopia, represents the most significant cause of visual impairment globally, largely as a consequence of the paucity of refractive services in developing countries [2,22]. Traditional perimetric techniques are known to be affected by uncorrected refractive error [23,24]. The MMDT, however, has been designed, through the specific sizing of the four central stimuli, to be resistant to the effects of defocus, which would suggest that it can be used reliably in the presence of uncorrected refractive error, in the range of +4.5 DS to -6.0 dioptres.

The current MMDT offers an affordable and portable community glaucoma case-finding technology that could be implemented by suitably trained community healthcare workers, and thereby addresses some of the health inequality issues described herein. As a computer-driven technology, the current study was designed to investigate the effect of computer experience on MMDT applicability and repeatability within a semi-rural African setting.

## Materials and Methods

### Subjects

Subjects were recruited from different communities in the Nampula region of Northern Mozambique. One hundred and sixty four subjects (male=87; female=77), aged 18 to 56 (mean age 31 ± 11 years), were recruited to partake in the study. Informed consent was obtained from all participants, and the study was conducted in accordance with the Tenets of the Declaration of Helsinki. Participants were recruited at Lúrio University (staff and students), the Nampula central hospital (staff and clinic attendees), three local primary schools (school teachers) and the surrounding rural communities of Mutaunha and Muatala. Inclusion criteria for the study were minimum age of 18 years, unaided visual acuity of logMAR 0.3 (6/12) or better, normal ocular health, no history of ocular disease or treatment. Visual acuity was assessed using a Bailey-Lovie logMAR test chart at a four-metre test distance. Normal ocular health was determined by ophthalmoscopic examination and self-report.

Subjects were stratified into one of two subject groups: a computer-familiar group (n=79), comprised of individuals engaged in regular study-related, recreational and/or occupational computer use, and a computer-naive group (n=85), comprised of individuals with no prior exposure to, or experience of, computer use.

### The Moorfields motion displacement test

The MMDT enhanced suprathreshold screening algorithm (ESTA) 99.5 program (software version 1.7.0) was used for this study. The ESTA 99.5 program presents displacements at the 99.5 centile, according to normative values derived in the UK from a population familiar with modern technology. ESTA applies a spatial filter and multisampling techniques [25-28], and calculates an index of the Global Probability of True Damage (GPTD). The PTD for the 31 individual test locations (PTD value range 1 to 100) are summed and expressed as a quotient of 100, where higher GPTD values represent a greater probability of damage (GPTD value range=0.31 to 31). Test reliability is determined by computation of the false positive (FP) response rate, with FPs categorised as responses made during the first 180 milliseconds following a stimulus presentation (MMDT Pandora response algorithm version 1). The pass-fail and reliability criteria, recommended by the developers from retrospective analyses of prior data, are a GPTD ≥3, and FP response rate ≤15%. In addition, a difference of ≥3 on the GPTD between repeat tests was adopted as a cause for exclusion on the basis of poor reliability.

One eye was selected for each subject, typically the eye with better visual acuity, or through random selection in cases of equal acuity and where both eyes met the study inclusion criteria. In all cases, subjects were tested without the use of spectacles, as these are generally inaccessible in developing African countries. The test distance of 30 centimetres was maintained by a dedicated collapsible chin and forehead rest and laptop mount. Stimuli were presented on a laptop (Lenovo T520i) screen. The device and test task was verbally explained in their native language (Portuguese), and each participant undertook a maximum of three MMDT preliminary sessions (12 stimulus presentations) to demonstrate understanding of the task. Subjects were required to fixate a central white spot for the duration of the test, and to click the computer mouse each time a line stimulus was seen to move. Subject fixation was monitored visually by the examiner throughout the test, with verbal reinforcement to maintain central fixation used as required. The test was repeated, after a five minute interval, on completion of the baseline test, in order to assess intra-sessional test repeatability. Test time (TT), FP response rate and the ESTA GPTD index values were recorded from the graphical output provided by the device software.

The test was administered indoors, under naturally dim illumination conditions (as would be typical in community settings in developing countries, often without electricity or adequate means to fully control illumination). Room illumination was not specifically measured, but every effort was made to source test rooms with approximately similar illumination conditions across test locations, without any direct glare source on the test screen. The laptop was fully charged prior to each test session, and operated in battery mode with power saving options turned off to maintain standard luminance settings (the device incorporates a warning display which activates should motion displacement speed reduce in low battery conditions).

The statistical software package SPSS (version 18) was used for the analyses (SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was used to test for normality. Independent samples Mann-Whitney U-tests were used to test for differences between computer subgroups. Wilcoxon Signed Rank tests were used to test for differences in performance between repeat measures. Spearman's Rank correlation

coefficients were calculated to investigate the relationship between repeat measurements. Bland–Altman analysis and plots, as well as the limits of agreement, were used to quantify the agreement between repeat measures [29]. Test-retest repeatability was expressed as a coefficient of repeatability, calculated as the standard deviation of the mean difference between measurements and multiplied by 1.96. A five percent significance level was used throughout the analysis.

## Results

All 164 participants gave a positive indication of their understanding of the task, and successfully completed the task demonstration. Of the 164, however, 18 subjects were deemed not to have performed the actual tests reliably, on the basis of the MMDT ESTA FP rate >15% (n=16: computer-familiar=2; computer-naïve=14), or GPTD difference >3 between repeat measures (n=2, both computer-naive). The remaining 146 subjects were included in the device/screening false positive rate analysis. Two further computer-naïve subjects were excluded from subsequent inter-group and repeatability analysis on the basis of GPTD values >3 (the normative GPTD screening cut-off point provided by the MMDT developers, such subjects exceed the fail criterion threshold) on both tests, leaving a total of 144 subjects eligible for analysis [computer-familiar, n=77 (male=49, female=28); computer-naïve, n=67 (male=38, female=29)].

### Screening device false positive rate

Of the 146 participants deemed to be in good ocular health by self report and ophthalmoscopic examination, five subjects (2 computer-familiar; 3 computer-naïve) demonstrated initial GPTD values in excess of the normative cut-off GPTD value of 3.0 at the baseline test, yielding a baseline screening presumed false positive rate of 3.4% (the percentage of subjects who failed the test at the chosen GPTD criterion level, but were deemed, by ophthalmoscopy, not to suffer glaucoma). On repeat testing, only two of those subjects (both computer-naïve) exhibited GPTD values above 3.0, thereby failing both baseline and repeat tests, yielding an overall presumed screening false positive rate for the device of 1.2% when those exhibiting poor reliability (FP response rates in excess of 15%) were excluded, and repeat testing was included in the screening protocol for those failing the baseline test. The concordance between missed points on the baseline and repeat tests for these two subjects, however, was poor, indicating that the defects

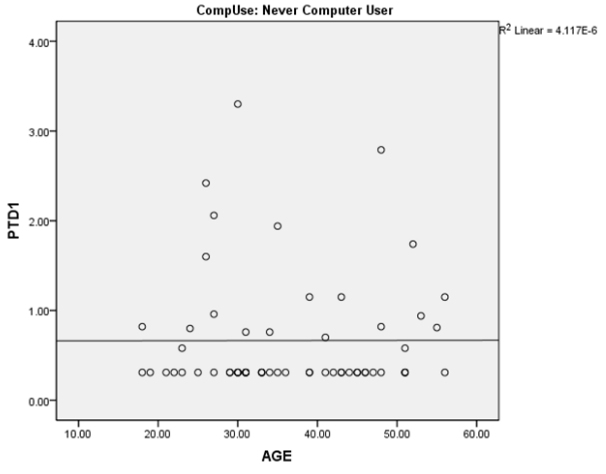


**Figure 1:** Scatterplot demonstrating the absence of any age effect on the baseline GPTD measure among computer naïve observers.

| Test Parameter | Computer-Familiar | Computer-Naïve | Mann-Whitney U-test |
|---|---|---|---|
| | Median (range) | Median (range) | *p* value |
| **GPTD baseline** | 0.31 (0.31-3.93) | 0.31 (0.31-3.30) | 0.47 |
| **GPTD repeat** | 0.31 (0.31-3.11) | 0.31 (0.31-2.80) | 0.97 |
| **FP baseline (%)** | 0.00 (0-9) | 0.00 (0-12) | 0.01 |
| **FP repeat (%)** | 0.00 (0-5) | 0.00 (0-11) | 0.00 |
| **TT baseline (secs)** | 105 (89-218) | 107(87-269) | 0.33 |
| **TT repeat (secs)** | 103 (90-195) | 103 (90-221) | 0.47 |

GPTD: Global Probability of True Defect; FP: False Positive; TT: Test Time; SD: Standard Deviation.

**Table 1:** Test performance measures stratified according to computer experience, including Mann-Whitney U test comparison of performance between groups.

| | Computer-Familiar | | Computer-Naïve | |
|---|---|---|---|---|
| | Wilcoxon signed rank test (*p* value) | Spearman rank correlation (R) | Wilcoxon signed rank test (*p* value) | Spearman rank correlation (R) |
| **GPTD** | 0.14 | 0.55 (*p*=0.00) | 0.11 | 0.32 (*p*=0.01) |
| **False positive response rate** | 0.05 | 0.23 (*p*=0.04) | 0.95 | 0.24 (*p*=0.04) |
| **Test time** | 0.08 | 0.73 (*p*=0.00) | 0.25 | 0.59 (*p*=0.00) |

GPTD: Global Probability of True Defect.

**Table 2:** Comparison of baseline and repeat performance measures stratified according to computer experience.

cannot be assumed to indicate the presence of glaucoma (it should be noted, however, that participants were not subjected to a rigorous glaucoma assessment as standard tonometry and perimetry or other devices were unavailable, so the possibility of glaucoma cannot be fully discounted, hence the term "presumed false positive" is used).

### Inter group analysis

Kolmogorov-Smirnov testing revealed a skewed, non-normal, distribution for each of the test variables, and as a consequence, non-parametric statistical tests were employed throughout the analysis. There was no statistically significant difference in sex distribution between groups ($p$=0.12). There was, however, a statistically significant age difference between groups ($p$=0.01), with computer-familiar subjects tending to be younger (median age=28, range=18 to 54), compared to the computer-naïve group (median age=34, range=18 to 56). There was no effect of age, however, on test performance, which displayed a weak and non-significant correlation (Spearman Rank test) with baseline and repeat GPTD (R=0.04 and 0.06; $p$=0.77 and 0.64 respectively – see Figure 1), TT (R=0.14 and 0.19; $p$=0.27 and 0.15 respectively) and FP response rate (R=0.10 and 0.19; $p$=0.45 and 0.14 respectively).

Furthermore, analysis of computer-naïve subjects, stratified into two age groups, those age 35 and under (n=35; likely non-presbyopic) and those age 36 and over (n=32; likely early to moderate presbyopia), revealed no significant difference in baseline and repeat GPTD ($p$=0.99 and 0.78 respectively), TT ($p$=0.72 and 0.11 respectively) and FP measures ($p$=0.99 and 0.28 respectively) between groups (Mann-Whitney U-test). Distribution inequalities in the computer familiar group (35 and under, n=67; 36 and over, n=10) rendered similar age stratified comparison meaningless for that group (Figure 1).

The GPTD, TT and FP values for baseline and repeat tests, stratified according to prior computer use, are presented in Table 1. Independent samples Mann-Whitney U-tests revealed no significant differences in GPTD, for baseline or repeat measures, between those familiar with and those naïve to computer use. Similarly, no significant differences were observed for TT measures between groups. There were, however,

statistically significant differences in FP rates between groups on both baseline and repeat measures ($p<0.01$ for both), with computer-naïve subjects demonstrating significantly higher FP response rates compared to those familiar with computers (Table 1). The significant majority of subjects, however, achieved a zero FP response rate in both the computer familiar (89% of subjects) and computer naïve (70% of subjects) groups.

## Repeatability analysis

The Wilcoxon Signed Rank test revealed no statistically significant differences between baseline and repeat GPTD, FP and TT measures across both computer-familiar and computer-naïve groups (Table 2). Moderate and statistically significant Spearman rank correlations were observed for repeat GPTD and TT measures for both groups (Figure

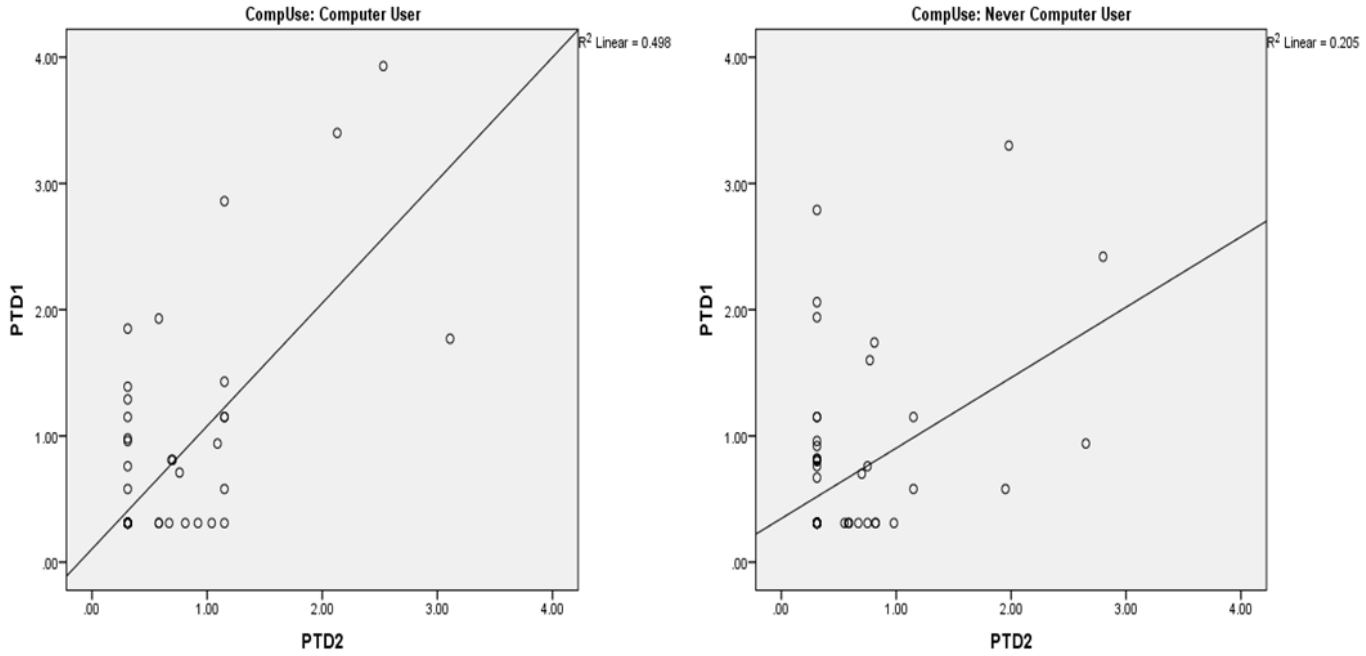


**Figure 2:** Scatterplot demonstrating significant correlation between baseline and repeat GPTD measures among computer-familiar and computer-naïve subjects.

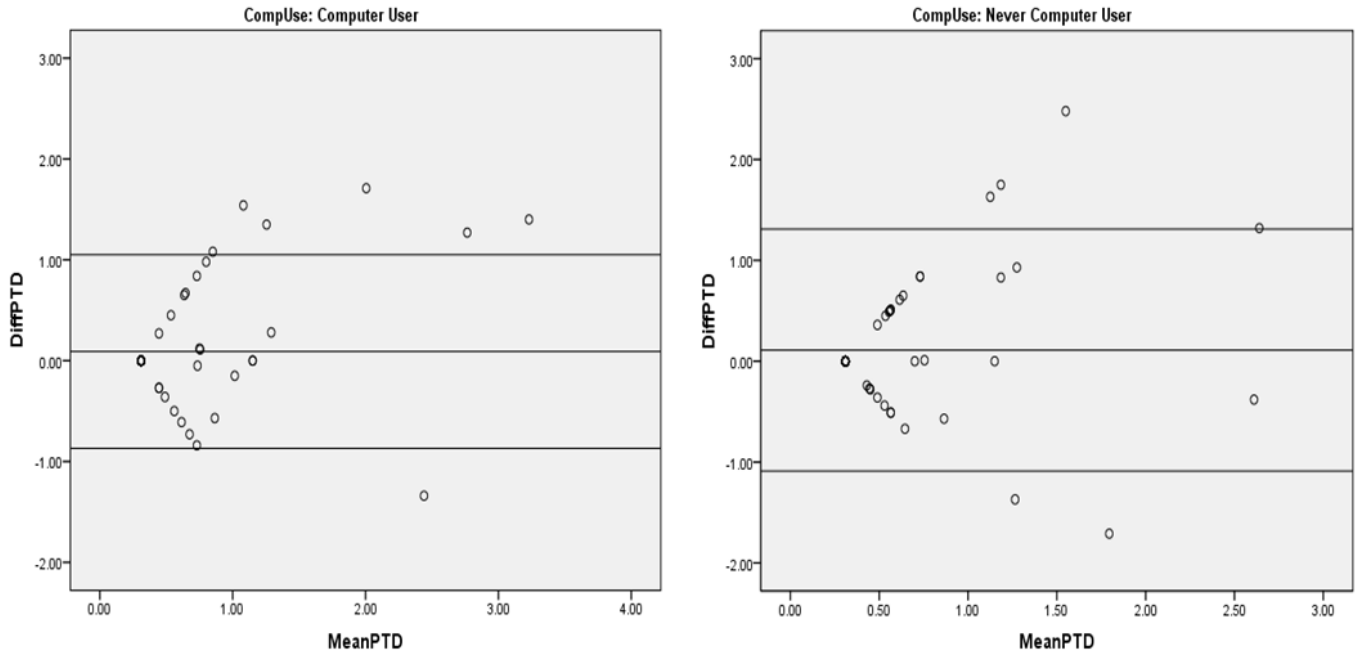


**Figure 3:** Bland Altman plots and limits of agreement for repeat measures among computer-familiar and computer-naïve subjects.

2 and Table 2), while FP rates were more weakly, but still significantly, correlated for both groups (Table 2).

Bland-Altman analysis and plots were used to assess intra-measurement agreement between repeat GPTD values. The difference in mean GPTD and limits of agreement between baseline and repeat measures for computer-familiar and computer-naïve groups, are presented in Figure 3.

The coefficient of repeatability for computer-familiar subjects was 0.96, marginally better than that determined for computer-naïve subjects at 1.20. Close to two-thirds of computer-familiar (49/77=64%) and computer-naïve (39/67=58%) subjects achieved perfect inter-test concordance, producing identical GPTD values between the baseline and repeat tests. Additionally, repeat GPTD values were within ±1 for 91% and 93% of computer-familiar and computer-naïve subjects respectively, thus indicating generally excellent repeatability across both subject groups, and for the significant majority of individuals, irrespective of computer experience.

## Discussion

The MMDT incorporates a number of design features that potentially enhance its applicability for use in community glaucoma screening programmes in developing countries. The suprathreshold screening algorithm is designed to be efficient, and quick to perform. The average test time across all subjects in the current study was 113 (±27) seconds for the baseline test, and 110 (±23) seconds for the repeat test, and did not differ significantly between computer familiar and computer naïve participants. This is of obvious merit for potential glaucoma screening protocols, likely to involve vast numbers of community attendees given the general inaccessibility of eye-care services.

Although refractive error, including presbyopia, was not the primary focus of the current study, and was not specifically quantified for individual participants, the findings herein do provide further evidence that the MMDT is resistant to the effects of optical defocus. The 144 participants, who successfully completed the test, provided reliable and repeatable results without the aid of optical correction. Although the study entry criteria (minimum visual acuity of logMAR 0.3) eliminated the possibility of including those with significant uncorrected refractive error, the study did include a substantial number of individuals with early to moderate presbyopia (n=42). The observation that test repeatability was equivalent among younger and older participants in the computer naïve group, and that GPTD, TT and FP outcomes showed no relationship with age (the primary factor in presbyopia) is important. The 30 cm test distance employed for the duration of the study did not disadvantage those with presbyopic defocus. Glaucoma and presbyopia remain mutually associated with ageing, and therefore likely to co-exist in the target population for glaucoma screening. Typically, there is little or no access to spectacles for those with presbyopia and other forms of uncorrected refractive error [22], and the resistance of the MMDT to optical defocus is, therefore, of obvious merit in the developing world context. Although the findings of the current study are broadly applicable, future studies should, perhaps, prioritise and seek to extend the experimental analyses to a specifically targeted glaucoma screening population, aged 30 and over (given the earlier onset and shorter life expectancy among the target population in Africa [10].

This is the first study to be conducted using the MMDT in a developing country in Africa. Mozambique, as a country, is ranked 184$^{th}$ out of 187 countries on the Human Development Index by the United Nations Development Programme [30]. The population of Mozambique if officially just under 24 million and growing rapidly [31], and life expectancy is currently 50.2 years but rising. The eyecare system is severely under-resourced. There are only 15 ophthalmologists, and the first nine optometrists in the country graduate in 2013. Due to the human resource and equipment shortages, eye-care services are centralised and typically only available at provincial hospitals. There is no current opportunistic or planned glaucoma detection system, and there is evidence to suggest that there are currently no operational visual field screeners in the country (unpublished situational analysis report of the International Agency for the Prevention of Blindness 2012, currently being used to draft the next National Eyecare Plan for Mozambique).

The vast majority of the population in Mozambique remain poorly educated. Although primary school education is "compulsory" in law, the mean schooling years of adults is currently as little as 1.2 years [31]. The majority of working adults (unemployment rate 21%) are typically engaged in manual labour, with little or no experience of, or access to, computers. For a computer driven test such as the MMDT, the lack of computer familiarity among the target population poses a potential challenge to the feasibility of the device for population screening and glaucoma detection. The current study is of fundamental importance, therefore, and provides critical evidence as to potential value of the device in terms of its universal applicability in such a challenging and developing environment.

Of the 164 individuals originally recruited, four subjects were excluded on the basis of their GPTD values (either in excess of the GPTD normative value of 3.0, or a GPTD difference between repeat tests in excess of 3.0), while 16 others demonstrated a FP rate in excess of the accepted 15% cut-off. The majority of those excluded were computer naïve, suggesting that the test could prove challenging for up to one quarter of all computer naïve persons. Although each of the excluded individuals verbally confirmed and practically demonstrated their test understanding, it was observed, for the majority of excluded participants, that the source of difficulty was not a lack of understanding of the test, but an inability to effectively use the computer mouse (used as a response button during the test) for the extended period of the test. To optimise the reliability of test results, the study investigators would recommend that a custom designed and simple push button response system, that would require less manual dexterity and coordination, should replace the mouse in future versions of the test.

For the remaining 144 participants, test understanding and performance was entirely satisfactory. Intra-sessional repeatability was clinically acceptable, with the vast majority of subjects achieving close-to or identical repeat test values (for 95% of individuals, the natural variation in GPTD values would be expected to be less than 1.2, even for computer naïve observers). Importantly, performance across all three test-measures was approximately equal among computer-naïve and computer-familiar subgroups. Computer-naïve observers, it seems, are capable of providing MMDT suprathreshold screening (ESTA 99.5) results that are as reliable, as fast and as repeatable as those familiar with computers.

The possible effects of selection bias (i.e. a professional, educated computer-familiar cohort compared to a non-professional, less educated computer-naïve cohort) and age related confounding, perhaps merit brief discussion. Although age differences exist between the two groups, these were not of statistical or clinical significance in relation to test performance. Importantly, the achievement of broadly similar performance levels by the older, less educated computer-naïve group

compared to their younger computer-familiar counterparts, lends further credence as to the viability of the test for community screening.

Additional limitations which should be factored into any substantive analysis of the study outcomes include: the lack of perimetry or tonometry results to definitively rule out the presence of glaucoma among study participants; the lack of standardisation of room illumination conditions; and the exclusion of approximately 10% of study participants due to a high false positive rate, which is presumed to be a consequence of difficulty using the computer mouse. These limitations are very much reflective of the operating environment likely to be encountered in any screening programme initiated with the device in a developing country such as Mozambique, where no visual field screeners or adequate community healthcare facilities exist. It remains to be tested, however, whether a push button response device, as recommended, might improve the false positive rate among computer-naïve users.

While significant work remains to be done in terms of providing evidence, in a developing world environment, whether the MMDT can fulfill all the prerequisites of a screening device (such as high sensitivity and specificity, differential diagnostic efficacy, predictive capacity and validity), the current study suggests that the test task is easily understood regardless of prior computer experience, and has the potential to be incorporated into a clinical test environment in the developing world.

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