MODIFIED LOGMAR CHART: CONSIDERATION FOR GREATER CROWDING IN AMBLYOPIA DETECTION

BY

MUHAMMAD HARIS TARIQ

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Kulliyah of Allied Health Sciences
International Islamic University Malaysia

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ABSTRACT

Early diagnosis of amblyopia is an important factor in saving child's vision. Thus, precise assessment of visual acuity is pivotal. Existing charts such as Snellen and logMAR charts that are widely used in clinical settings differ in their features, being questioned on their standard and too complicated to be used in paediatric and special needs population. The crowding effects are important clinically in detecting amblyopia. To overcome these weaknesses, this study aims to develop a new portable modified logMAR chart with 0.5 letter width separation between the letters, which potentially produces greater crowding and also makes it children friendly. As such, it is suggesting a sensitive test in diagnosing amblyopia or any other visual abnormalities. The modified logMAR chart was designed and created using Microsoft PowerPoint 2016, version 1709 (Build 8528.2139) for 64bit Windows 10 operating system (Copyright ® Microsoft Corp. The US). The chart can be presented via a portable electronic device. Each letter size was calculated at 3meters viewing distance which subtended visual angle of 0.16º to 0.01º (range from 0.0 logMAR (6/6) to 1.0 logMAR (6/60)). Each presentation of the chart consists of 44 slides that are presented in random order of acuity level. Each slide has 3 letters with 0.5 letter width separation to produce greater crowding as compared to conventional charts (conventional logMAR: one letter width separation). The visual acuity of 17 normal participants for reliability (mean age: 24.30 ±1.50), 17 normal participants for repeatability (mean age 24.70 ±2.0), 10 normal participants for mimicking anisometropic amblyopia (mean age 19.6 ±1.4), 10 normal participants for mimicking strabismic amblyopia (mean age 21.20 ±2.00) and 17 amblyope participants (mean age 12.20 ± 1.50) participants were measured using the modified logMAR and conventional logMAR charts. Then, the crowding magnitude was calculated. The modified logMAR chart was proven to be reliable and repeatable compared to conventional logMAR chart (Bland-Altman: Mean difference -0.0006 ±0.05 with 95% CI ±0.01, RM ANOVA: $p>0.05$). One-Way ANOVA analyses showed no statistically significant differences in visual acuities ($p>0.05$) and crowding magnitude ($p>0.05$) in mimic amblyope participants between charts, while in amblyope participants paired *t* test analyses also showed a non-significant difference ($p>0.05$) in crowding magnitude between charts except in strabismic amblyopes ($p<0.05$). Modified logMAR chart consistently produced greater crowding than conventional logMAR chart. This study conclude that newly developed portable modified logMAR chart is suitable to be used in clinical settings and as a visual screening tool for detecting amblyopia or any visual abnormalities.

خلاصة البحث

مقياس قوة النظر (Visual acuity) هو المقياس الأكثر استعمالاً لتقييم كفاءة الجهاز البصري في الأبحاث العلمية والفحص السريري. تُستعمل عادة مخططات معروفة للقياس البصري مثل مخطط سنيلين (Snellen chart) ومخطط لوغ-مار(logMAR). وقد ذكرت الدراسات السابقة أن مخطط سنيلين ومخطط لوغ-مار بها نقاط ضعف. حيث أن مخطط سنيلين به ثغور تصميمية تتمثل في مصداقية دقته وطريقة التعامل مع التكرارات في مقياس قوة النظر. بينما الرسم البياني لمخطط لوغمار معقد بشكل كبير. وللتغلب على نقاط الضعف هذه، تم في الدراسة الحالية تطوير وإجراء تحسين على مخطط لوغمار الأصلي. تم تصميم مخططين متطورين من مخطط لوغمار الأصلي. في المخطط الأول تكون المسافة بين الأحرف بمقدار حرف واحد وتم ترميزه بـ(ML_1)، ومخطط آخر بمقدار نصف حرف وهو الهدف الرئيسي من البحث (ML_0.5). أُجريت في الدراسة الحالية ثلاث تجارب: في التجربة الأولى، بحثنا في مصداقية الدقة والتكرارات للمخططين ML_1 و ML_0.5 مقارنةً مع مخططي سنيلين و لوغمار. شارك في التجربة 26 شخصاً (أشخاص سليمي النظر، معتدل ومتوسطي انحراف النظر). مخططي ML_1 و ML_0.5 أظهرا نتائج جيدة في اختبار الدقة والتكرارات مقارنة بمخطط لوغمار الأصلي. في التجربة الثانية، قمنا بعملية التغميش على 10 مشاركين (بإدخال درجات التشويش أو الغبش، D0، D0.5، D1.0، D2.0)، والحول في 10 مشاركين (بدرجات الانحراف المختلفة، 0°، 2.5°، 5°، 10°) ومقارنة حدة وآثار ازدحام الحروف في مخططات لوغمار الأصلي، ML_1، و ML_0.5. وأظهرت النتائج أنه لم يكن هناك فرق ذو دلالة إحصائية في قوة النظر وحجم الازدحام بين مخطط لوغمار الأصلي، ومخططي ML_1 و ML_0.5. على الرغم من أن مخطط ML_0.5 أظهر ارتفاعاً عالياً في اختبار الدقة وأظهر دائماً حجم ازدحام أكبر في كل مستوييّ الغبش وعدم المركزية (اللاتمركزية). في التجربة الثالثة، كان هناك 17 مريضاً، لديهم ضعف في الرؤية المركزية للعين (الغمش أو مرض العين الكسولة). قارنا بين مرضى الغمش وغمش المحاكي. وأظهرت النتائج أن مرضى الغمش أظهروا نفس النمط كما في غمش المحاكاة، مخطط ML_0.5 أظهر ازدحاماً أكبر مقارنة بمخطط لوغمار الأصلي.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Health Sciences in Optometry

…………………………………..
Norsham Binti Ahmad
Supervisor

…………………………………..
Firdaus Yusof Bin Alias
Co-Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Health Sciences in Optometry

…………………………………..
Mohd Zulfaezal Che Azemin
Internal Examiner

…………………………………..
Mohd Zaki Bin Awg Isa
External Examiner

This thesis was submitted to the Department of Optometry and is accepted as a fulfilment of the requirement for the degree of Master of Health Sciences in Optometry

…………………………………..
Noor Ezailina Binti Badarudin
Head, Department of Optometry and Vision Sciences

This thesis was submitted to the Kulliyyah of Allied Health Sciences and is accepted as a fulfillment of the requirement for the degree of Master of Health Sciences

…………………………………..
Suzanah Binti Abdul Rahman
Dean, Kulliyah Allied Health Sciences

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Firstly, it is my utmost pleasure to dedicate this work to my father, who granted me the gift of his unwavering belief in my ability to accomplish this goal. I hope I can repay back what you have done for me. Giving me everything just to comfort me. Thank you for your support and patience.

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LIST OF SYMBOLS

%	Percentage
p	Probability
n	Number of sample
<	Less than
>	Greater than
&	And
()	Bracket
±	Range
m	Meter
cm	Centimeter
/	Slash (Divide)
±	Range
_	Underscore
©	Copyright
Ɵ	Degree
D	Diopters
×	Multiply

LIST OF ABBREVIATIONS

IIUM	International Islamic University Malaysia
KAHS	Kulliyah of Allied Health Sciences
PS	Power and Sample size
VA	Visual acuity
SPSS	Statistical Package for Social Sciences
RM ANOVA	Repeated Measures Analysis of Variance
MAR	Minimum Angle of Resolution
WHO	Word Health Organization
SC	Snellen chart
SLM	Standard logMAR chart
ML_1	Modified logMAR chart one letter width
ML_0.5	Modified logMAR chart half letter width
SEM	Standard error of mean
CI	Confidence Interval
et al.	And others
IREC	IIUM Research Ethics Committee
ICC	Intraclass Correlation Coefficient

CHAPTER ONE

INTRODUCTION

1.1 OVERVIEW OF THE STUDY

Visual acuity (VA) is the resolving power of the eye which measures the eye's ability to see fine details. VA is the capacity to detect, resolve and recognize a letter, symbol or picture (depending on chart used) from its background and between the line separation at a specific distance of targets (Grosvenor and Grosvenor, 2007). VA is important for normal daily life where having good VA improves quality of life. There are several charts to measure VA that have been produced in the past and are now being used in the routine clinical practice which includes Snellen chart, logMAR chart, Sheridan Gardiner chart and Landolt C chart. Each chart differs in their properties such as spacing between letters, number of letters per line, crowding effects and viewing distance. VA assessment is the most common method of assessing any visual problem and it's the most effective way of diagnosing or detecting any vision problem in children (Traboulsi et al. 2008). The most common vision problems include hyperopia, myopia, astigmatism (Grosvenor and Grosvenor, 2007) and amblyopia (Williams et al. 2003). As such, this study developed a new portable modified logMAR chart which we postulate that it will be reliable and could be used in children, particularly in clinical setting in order to detect amblyopia as early as possible.

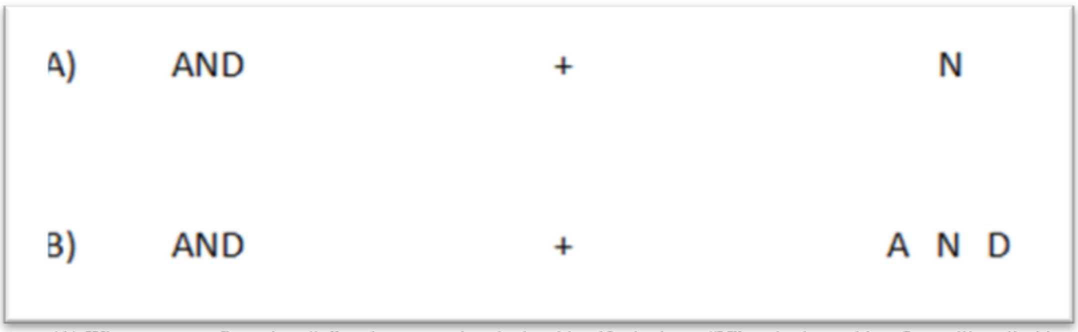
1.2 AMBLYOPIA

Amblyopia, or "lazy eye", is traditionally defined as a decrease in the best-corrected VA caused by pattern vision deprivation or abnormal binocular interactions during development in which no causes can be detected by the physical examination of the eye, and which in appropriate cases is reversible by therapeutic measures (Von Noorden, 1968). Amblyopia is the result of interruption to normal binocular development in young children, usually due to monocular (but also binocular) image degradation as a result of cataract (deprivation amblyopia), high uncorrected refractive error (anisometropia or isometropia), and/or disruption of normal binocularity, due to an eye turn or strabismus (strabismic amblyopia) (Von Noorden, 1968). Roughly 2.5% of world's adult population has amblyopia (Von Noorden, 1968).

Amblyopia results not only in decreased VA, but also causes a reduction in other visual functions such as deficits in contrast sensitivity (Levi and Harwerth, 1980), spatial localization (Levi and Klein, 1985a), fixation (Chung et al. 2015), ocular motility (Prakash et al. 1982), accommodation (Ciuffreda and Rumpf, 1985), attention (Hou et al. 2013), motion perception (Levi et al. 1984) and temporal processing (Huang et al. 2012). In addition, amblyopes suffer from abnormal spatial lateral interactions between spatial targets at the threshold and supra-threshold detection level (Levi et al. 2002; Bonneh et al. 2007) known as "crowding" (Flom et al. 1963a). As such, current study interests are to consider crowding effects and acuity threshold measurement by varying the critical spacing between the letter targets. Early detection of amblyopia is crucial as early therapies may improve prognosis (Lithander and Sjöstrand, 1991). Thus, this study investigated a newly developed portable modified logMAR chart which is postulated to be more sensitive (greater crowding produced) which in turn will benefit in diagnosing amblyopia and may help to reduce the morbidity of degrades vision due to amblyopia.

1.3 CROWDING

Under normal healthy viewing conditions, crowding does not pose any significant problem as we can foveate and use central vision to recognize targets (Wallace et al. 2013). However, crowding is a phenomenon that is of much of an importance when dealing with amblyopia, particularly in strabismic amblyopia (Bonneh et al. 2007). Crowding is the effect of nearby letters which causes difficulty in recognition of a target letter (Levi, 2008). As such, the acuity threshold increases (become poorer). When the VA of an amblyope is measured with an isolated letter chart (such as Sheridan Gardiner chart), the VA is found to be better as compared to crowded chart (more than 1 letter per row). Even, greater crowding is produced in closer separations of letters in a row (Formankiewicz and Waugh, 2013; Lalor et al. 2016). The crowding effect is displayed in Figure 1.1.



(A) When eyes are fixated on "+" and a person is asked to identify the letter "N" on both on sides. One will easily identify the single letter on the right instead of the letter "N" in the set of letters on the left "AND". This is due to crowding effect produced by the flankers. (B) When target and flankers are far away from each other, then the identification becomes easier as compared to the closer spacing. As such, "N" on the right side is easier to identify as compared to the left side (Levi, 2011).

Figure 1.1 Demonstration of crowding effect

1.4 OBJECTIVES AND HYPOTHESIS OF THE STUDY

1.4.1 General Objective

To develop a new reliable and repeatable portable modified logMAR chart, that is comparable to the standard logMAR chart (SLM). The new portable modified logMAR chart with half letter width separation (ML_0.5) is presented via visual display unit (computer or laptop) and could produce greater crowding effects as compared to SLM.

Specific objectives and hypothesis will be discussed later in each Experiment chapter.

1.5 RESEARCH QUESTIONS

Experiment 1

i. Does the ML_0.5 chart produce reliable, repeatable and comparable VA measurement with the SLM chart?

Experiment 2

ii. Does ML_0.5 chart reduce the VA and produce greater crowding magnitude than SLM in mimic anisometropic amblyopia and strabismic amblyopia?

Experiment 3

iii. Do the amblyopes show similar VA reduction and greater crowding effects in ML_0.5 as in Experiment 2 than SLM chart?

CHAPTER TWO

LITERATURE REVIEW

2.1 IMPORTANCE OF LOGMAR CHART

Snellen chart (SC) has been widely used in clinical setting for VA measurement (Lim et al. 2010). Albeit its wide usage, there are many limitations in terms of its reliability (McGraw et al. 1995) and repeatability (Gibson and Sanderson, 1980) in acuity measurement because of an inconsistent number of letters per line, letter size, separation between letters and separation between each row (Lovie-Kitchin, 1988; McGraw et al. 2000). Bailey and Lovie, (1976) stated that in most commercially available charts such as SC, the VA task is not the same in all acuity levels. The most common procedure in these charts is to use a test task with single or two letters for lower acuity levels while for higher acuity levels a test task of 8 or 10 letters. It is known that patients with amblyopia can read single letter more easily as compared to when letters are presented in a row (Burian, 1969). Thus, having a single letter in lower acuity levels and large number of letters in higher acuity levels cause variation in the test task. Flom et al. (1963a) reported that when letters are surrounded by nearby contours (flankers), they significantly degrade the visual performance of amblyopes. However, in SC there is no allocation for such effects. In addition to that, SC has an irregular letter size progression and a change in the test viewing distance will cause a significant variation in the acuity score.

The logMAR chart is designed to enable more accurate VA measurement as compared to other acuity charts particularly the SC (Bailey & Lovie, 1976). Each line of the logMAR chart comprises of the same number of test letters, which is five and uses a regular spacing between rows and letters (one letter width separation between the letters) and letters with equal legibility. There is a uniform progression in letter size between the rows. LogMAR charts can be used at varying distances as there is a uniform progression in letter size. Furthermore, logMAR chart may record acuity score where the final score is calculated based on the total number of letters that can be read by patient. Due to these design advantages, logMAR is usually utilized in scientific experiments and research compared to other charts. Clinically logMAR chart is not widely used because VA measurement with logMAR chart is time consuming, unfamiliar scoring system and unsuitable for children (Thomson, 2005).

2.2 MODIFICATION OF LOGMAR CHART

Previous studies have modified the logMAR chart in a variety of ways. A study by Rosser et al. (2001) recruited 16 males and 25 females with age range between 49-89 years old. They designed a modified printed version of logMAR chart and named it "reduced logMAR chart" (with three letters per row and maintained one letter width separation, surrounded by a crowding bar placed at 2.5 stroke widths from the edge of the letter). The reduced logMAR chart was displayed in a standard Lighthouse lightbox with testing distance at 6 m. They recruited participants with VA between 6/5 to 6/60 with diagnosis of cataract or early glaucoma. Their results showed that the reduced logMAR agreed well with ETDRS (Early Treatment Diabetic Retinopathy and Study) which is considered as a gold standard in acuity measurement. The mean difference between the VA performance of both charts was 0.00 logMAR with narrower 95% Confidence interval (CI) limits of agreement (-0.20, +0.20) suggesting that there was no bias. The test-retest variability results showed that the reduced logMAR achieved a test-retest variability score of ±0.24 logMAR compared to ETDRS ±0.18 logMAR.

Also, the VA testing time was considerably reduced while using the reduced logMAR chart. The time taken was reduced almost by half of that taken while using the ETDRS chart.

A study by Noushad and associates. (2012) used printed modified logMAR chart (one letter width separation and 3 letters per row) and compared the VA performance and the testing time with the standard ETDRS chart in 50 participants with emmetropia, myopia and cataract. They designed a printed version of the modified logMAR chart (one letter width separation with 3 letters per line). The testing distance was 4 m. The acuity ranged from +1.00 logMAR to -3.00 logMAR. Using the Bland-Altman analysis their results showed that the mean difference between modified logMAR and standard logMAR (ETDRS) was very minimal (0.01 ±0.06 logMAR) with a tight 95% CI limits of agreement (-0.10, +0.13). The test-retest variability (repeatability) also showed promising results with TRV scores of ±0.08 logMAR for SLM and ±0.10 for modified logMAR. A comparison of the testing time was carried out using a paired t-test. The mean time required to complete VA measurement using modified logMAR was substantially shorter compared to the standard logMAR. The mean testing time using standard logMAR was 51.05 seconds while using modified logMAR the mean testing time was 33.91 seconds, thus considerably reducing acuity measurement time because of the reduction in the number of letters per line.

A study by Bourne et al. (2003) was conducted to evaluate a printed modified logMAR chart that was designed to improve the estimation of VA in a population-based survey. Twenty-one participants which participated in a glaucoma survey were asked to be part of the study. The modified logMAR chart that they developed was named Reduced logMAR E chart (RLME). This chart comprised of three letters per line and one letter width separation between letters. They used tumbling E optotypes. In addition, there were consistent crowding bars placed at 2.5 stroke widths (half letter width separation between optotypes) from the edge of the optotypes. The results showed a great agreement between charts with a mean difference in VA 0.00 logMAR with 95% CI ±0.05.

A study conducted by Laidlaw et al. (2008) developed a digital visual acuity chart which they called COMPlog. The COMPlog had five letters per line with half letter separation between letters. In addition, a crowding bar was placed at half letter width separation around the letters. The test viewing distance was 3 m. The COMPlog was presented via a laptop PC running Microsoft Windows XP®. The laptop had a display of 21 inch with 1600x1200 resolution. The acuity chart was aimed to be used in children with amblyopia as well as in adults with normal and diseased eyes. They recruited 59 children undergoing amblyopic therapy and 70 adults with normal and diseased eyes. Acuity performance of COMPlog was compared with ETDRS chart. The results showed that there was no significant bias (mean difference 0.01 ±0.06 logMAR) in acuity performance between ETDRS and COMPlog in amblyopic as well as in adults group. Test-retest variability (TRV) of ETDRS and COMPlog was almost similar (±0.12 logMAR for ETDRS and ±0.10 for COMPlog) showing a comparable acuity performance between two charts.

Our study was aimed at developing a modified logMAR with half letter width separation between letters (ML_0.5). In order to make ML_0.5 portable, it was presented via an electronic device, as such making it easy to move around for remote visual screening purposes. In contrast, most of the previous studies has developed charts in printed version. Prior to that, our ML_0.5 has 3 letters per acuity level and each acuity level was presented separately thus making it child friendly. In comparison, the previously modified logMAR charts such as the charts developed by Noushad et al.