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TECHNICAL NOTE

A METHOD FOR VISUAL ACUITY COMPARISON OF NON-PARAMETRIC AND HETEROSCEDASTIC DATA

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ABSTRACT

The expression of electrophysiological Visual Acuity as an equivalent subjective score in a population requires a regression model. Where data are not normally distributed, and/or heteroscedastic, then a linear regression is not appropriate, and so an alternative method is presented-the Passing and Bablok (PB) regression. The choice of units, and conversion between them is also discussed given PBs need for common units, and the likelihood of a normal distribution given this choice of units is considered.

INTRODUCTION

The relationship between electrophysiological Visual Acuity (VA) and its subjective counterpart are a topic of discussion (Hamilton 2021; Mackay 2022a; Mackay 2022b). A recent technical note in IJRAMR described methods for deriving linear regression equations from paired VA outcomes of local studies, then combining them in a meta-analysis (Mackay, 2022c). The author outlined modification of the sequence, and cut-offs of statistical tests from the original Step VEP/subjective VA regression model (Mackay, 2008) to allow a wider range of studies to be included. The original method was applied to measurements from a paediatric Neuro-Ophthalmological cohort, and a subgroup of those with Cortical Visual Impairment (CVI). Different coefficients of regression in these three published studies suggests that the relationship between electrophysiological and subjective VA varies with either age or the degree of visual impairment (or both). Multivariate Regression Modelling (MRM) of the full paediatric dataset also established that subjective test modality further influences the relationship, and required derivation of distinct equations for Optotypes and Preferential Looking Cards (Mackay 2022a). In a clinical study, it is possible that pre and perinatal factors, motor abilities, other visual parameters, maternal health, and the technical aspects of electrophysiological recording will also influence the VA relationship. However statistical power (Newsom, 2021) limits the number of predictors that can be identified from a single study; the concept that presented the original need for systematic review and meta-analysis (Gough, 2012; Biostat 2017). An equation of the form 'Subjective VA = A x VEP VA +B' was the outcome of the original model by Mackay et al. (2008) employing Bland-Altman analysis ((BA-A) Bland, 1986)) and linear regression (University of Liverpool, 2005). BA-A depends on both data series being normally distributed and was the original reason for choosing 'LogMAR' units; they just happen to be the convention for most acuity cards too. LogMAR is calculated by taking the Log_{10} of the smallest element angle eliciting a measurable response during a series of VEP recordings. Historically, in some clinical studies, the total number of correctly identified letters (optotypes) during subjective testing created a continuous variable. In contrast, the last complete line to be correctly identified from a chart presented in LogMAR increments (ETDRS, 1991)) creates an ordinal variable. Given the modest range of VEP stimuli available on most systems, using the smallest element pattern eliciting a response may also create an ordinal rather than a continuous variable. And so the data may not be automatically comparable to subjective test data. Extrapolation of the stimulus element size vs VEP amplitude to noise level (using units of either 'cycles per degree' or 'minutes of arc') ensures the outcome is a continuous variable. A larger choice of element sizes during VEP testing would create an essentially continuous outcome variable, increasing the number of direct methods of comparison to other extrapolated VEP studies and specific subjective studies. However, the test duration is likely to be increased and so additional stimuli should be presented sparingly-perhaps using the Step VEPs successive approximation algorithm. In my experience of testing paediatric patients and adult volunteers, normal VA typically resulted in a VEP threshold of three minutes of arc, while those

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with severe visual impairment had thresholds of 480 minutes of arc, or only light perception. A continuous scale of measurement, rather than an ordinal one, provides more resolution, with the potential to show vital nuances in maturation studies, or treatment monitoring. Presenting continuous, but non-parametric data on a Log scale would allow initial visualisation of the measurements and correlation with other studies. However it would be inappropriate to proceed with Linear regression if either dataset has a non-parametric distribution. In this situation, a 'Passing and Bablock (PB) regression' could be attempted (Passing, 1983). PB does not require the variables to be normally distributed, or even that the residuals demonstrate homoscedasticity. However, it does assume that the data were measured on a continuous scale and that that the variables have a linear relationship (Bilic-Zulle 2011, NCSS 13) which may require both measurements to have the same units. To achieve this, Subjective VA could be expressed as a minimum angle of resolution by calculating the exponent (with base 10) of the Log MAR score with the resolution of letters rather than lines. A method of calculating 95% confidence intervals around this regression line is presented (Dufey 2020). Such calculations are straightforward steps for a statistician prior to modelling. The outcome of PB will be an equation allowing local electrophysiological data to be expressed in terms of its subjective equivalent, ideally in the units that the staff of the organization are comfortable with. The equation will have a coefficient for the VEP term and a constant term; however, the model's immunity to heteroscedasticity may render the latter unnecessary.

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Abbreviations:

PB: Passing and Bablock Regression, **IJRAMR:** International Journal of Advances in Multidisciplinary Research, **CVI:** Cortical Visual Impairment, **MRM:** Multiple Regression Model, Log **MAR:** Log (10) minimum angle of resolution.

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