The Influence of Uncontrolled Variables in Paediatric Assessment of Visual Acuity: Do we only Measure Visual Acuity?

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Abstract

This paper aims to acknowledge the influence of test design features on visual acuity measurements in normal preschool children and to recognise this as an uncontrolled variable in research. Visual acuity and test duration time were measured and evaluated for three different visual acuity test types; Cambridge Singles, Cambridge Crowding Cards and the logMAR chart. Each test type has varying design features including the number of optotypes presented. The results indicate that the mean acuity decreased with the increased number of optotypes displayed. The design specifications and testing procedure were considered to be influential in these results as the age of the subject and test type influenced test duration time. This may imply that the acuity means are not solely reflective of the integrity of the visual system but the psychological processes used for each test type and these vary with age. However, test design and examination procedure become only uncontrolled variables when not acknowledged in comparisons made between tests in children of the same age or between age groups using the same test type.

Key words:
design specifications, test performance, psychology.

Introduction

Westheimer [1] considered that with the examination of any sensory threshold several intractable problems exist. These being the design specifications of the instruments used, other sensory/motor and cognitive functions, the scale of measurement and the technique of obtaining threshold values. From a research perspective, these "intractable problems" could simply be classed as "uncontrolled variables", which derive from the test stimulus and method of measurement that inturn influences the psychological functions used in the process of visual acuity (VA) assessment.

It may be questioned why these uncontrolled variables have not been addressed more often in the literature, particularly within paediatric research. Unfortunately, research conducted to validate test design has generally used "normal" adults and/or older children as subjects [2,3]. Therefore, researchers have generally not had the opportunity to observe these uncontrolled variables in the population for which the test has been designed [2]. Validity of VA tests on an older population may be explained and justified on the basis of their high compliance and reliability in comparison with preschool children's variable and poor reliability [2,4]. However, this assumes that adult acuity is in agreement with preschool children's acuity and that the methodology of examination and test performance is identical for both age groups.

Fern [2] and Simons [5] suggested that the level of visual acuity recorded per age group was reflective of the developmental tasks stipulated by test design rather than acuity itself. Design specification should be influenced by the type of acuity the test aims to measure and the age group for which the test is to be used. Yet design specifications are dependent upon which aspect of acuity is affected by particular anomalies, and the developmental stages of visual and cognitive function. To acquire such information is dependent upon the design characteristics of the objective test. Hence, the dichotomy that explains why infant's and preschool children's true visual capacity is underestimated and inadequately assessed, which highlights the difficulty in trying to correlate age to level of visual function. Sonsken[6] mentions that there has been little appreciation of the developmental factors associated with test design. It is important to consider then, that what is thought to be measured may not necessarily be reflected in the measurement itself. Instead, the measurement is an index of the design characteristics and the method of assessment, which in turn may reflect the psychological development of the child examined. It can then be asked, do we only measure acuity? This paper is aimed at specifically acknowledging the influence of test design features on VA measurements in normal preschool children and to recognise this as an uncontrolled variable in research.

Method

Subjects:

Forty-three subjects, 21 males and 22 females between the ages of three and five years were recruited from two preschools.

Apparatus:

The three visual acuity tests used were: the Cambridge Singles (the Cambridge Singles is part of the Cambridge Crowding Card Kit and is similar to the Sheridan and Gardiner Single Letter Test); Cambridge Crowding Cards; and the logMAR Chart. The matching board used for the Cambridge Singles and Crowding Cards was also used with the logMAR Chart. Detachable adhesive letter plates were constructed for the letters F, P, E, D, R, N, U, Z (which were specific to the logMAR Chart) in a similar fashion to those used in the Cambridge Singles and Crowding Card Kit. Letters were placed on the matching board in an identical and non–linear arrangement for each test.

Procedure:

A pre-examination training session was conducted for all visual acuity tests per subject, to ensure that the subjects were able to comprehend the process of identification by matching and were familiar with the letter optotypes and testing procedure. An attempt was made not to point to the letters during the examination, however, with the logMAR chart only, each letter was pointed to throughout the assessment of acuity. Care was taken to be consistent and to minimise occlusion of the blank area beneath each letter. Three and four year old children were classed by age into Categories 1 and 2, respectively. Test and eye orders were randomized. Acuity tests were conducted at a distance of three metres. Re-tests occurred two weeks later at the same time of day under identical examination conditions. The lighting level in each examination room was recorded to be equal to or greater than 350lux. For each visual acuity measurement, test duration time was recorded. The criterion for establishing test duration time was from the beginning of the pre-examination teaching session to the level of threshold acuity recorded. For each visual acuity test the ability with which the subjects could perform the test was observed.

Design analysis: The principal aim was to ascertain the influence of test features and subject age on intra-test agreement. The dependent variables measured were visual acuity and time. The mean acuity and test duration times were calculated for each test type. Time was recorded on an interval scale and was also analysed by a two factor ANOVA. Analysis could then determine whether the age and test type influenced visual acuity measurements and whether interaction between these independent variables existed.

Results

Visual Acuity:

The mean VA of the Cambridge Crowding Cards was between that of the Singles and logMAR Chart (Table 1). On retesting the mean acuity for each test type did not change (Table 1).

Time:

The mean duration time for each test type decreased on second examination and was longest for both first and second examinations with an increase in the number of optotypes displayed (Table 2). Intraclass Correlation Coefficient (ICC) value for the first examination (0.03) and second examination (0.12) indicates that the test performance increases are equivalent across all three VA tests.The two factor repeated measures ANOVA indicated that the main effects for age (first exam F=4.70, df=1,41 p=0.036; second exam F=23.65, df=1,43 p=0.0001) and test type (first exam F=131.20, df=2,82 p=0.0001, second exam F=172.07, df=2,86 p=0.0001) were significant on 1st and 2nd

Table 1

Mean Visual Acuity for each VA Test Type; 1st & 2nd Exam

Singles		Crowding Cards		Chart	
first	second	first	second	first	second
6/5	6/5	6/9	6/9	6/12	6/12

examination (Table 3). Thus, the age of the subject and the type of VA test used did influence test duration time on first and second examination. However, there was no interaction between age and test type on either first (F=0.31, df=2,82 p=0.879) or second examination (F=2.70, df=2,86 p=0.0721) (Table 3). Therefore, the effect of age did not influence the effect of test type with the test duration time.

Observations:

Subjects examined with the logMAR Chart commented that they did not like the smaller letters because they were more difficult to see and seemed further away. With the Cambridge Crowding Cards subjects frequently had to have test instructions repeated throughout the examination and visually scanned all letters on the test display card. Half of the subjects excluded from the study were three years of age and could not complete the Cambridge Crowding Card VA test.

Discussion

The influence of psychological functions in visual assessment is not often acknowledged within the ophthalmic and orthoptic literature. This may have resulted from Duke-Elder's opinion that behavioural concepts of perception would eventually be discredited [7]. However, some authors have begun to acknowledge its importance [2,5,8,9] giving specific attention to the influence of test design on test performance.

Test performance can be evaluated in terms of test duration and Ehrlich [10] suggested that it may reflect the degree to which psychological processes are used. Tables 1 and 2 illustrate that as the number of optotypes displayed increased, the mean acuity decreased, whereas the test duration time increased. This may imply that the psychological processes used with the logMAR chart differ to those used with the Cambridge Crowding Cards, which inturn differ to those used with the Single letters. The varying test duration times per VA test type were found to be age related, which suggests that these processes are developmental and could be learnt as test duration time decreases on second examination. Furthermore, the interaction p values between age and test type differ greatly between first and second examination, which suggests a significant learning effect (Table 3). This implies that the acuity means do not solely reflect the integrity of the visual system but also the psychological processes used for each test type. Interestingly, the low ICC values indicate that not one test type can be favoured over another in terms of test performance. The learning effect was of the same degree for each VA test type. This is important in relation to test selection for clinical evaluation of VA and supports an argument for test selection not to be solely based on test performance. For example, clinicians may prefer the administration of Single letters because it is quick and easy to administer. However, the results may be questionable in relation to the detection of amblyopia and the learning effect between first and second examination would be similar to that associated with a VA chart, which is a better test for the detection of amblyopia [10].

Time Means of VA Tests (sec)

	first Exam	second Exam
Singles		
Ages 3—4	135.0	118.2
Ages 4—5	116.4	95.4
All Ages	125.7	106.8
Crowding Cards		
Ages 3—4	192.6	169.8
Ages 4—5	168.6	117.6
All Ages	180.6	143.7
Chart		
Ages 3—4	335.4	118.2
Ages 4—5	304.2	217.8
All Ages	319.8	245.4

Table 2

Mean Time of VA Tests in seconds

The observation of test performance is commonly thought to be factored into the interpretation of acuity measurements in a clinical environment under the umbrella of clinical judgment. However, in studies where different acuity test types are compared, particularly in the validation of test types, emphasis on observations of test performance has been minimal in comparison to acuity statistical analysis. It is not important clinically to know exactly what type of psychological functions are involved when acuity is

Age and Test Type '*p*' values of Time

	first Exam	second Exam
Age (A)	0.036	0.0001
Test Type (T)	0.0001	0.0001
A.T. Interaction	0.879	0.0721

Table 3

Age and Test Types

examined but to be aware of any perceptual anomalies that may exist with particular test designs.

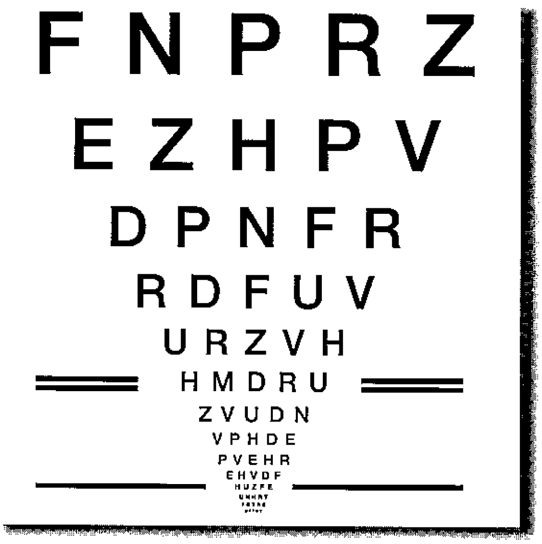

Figure 1

LogMAR Chart

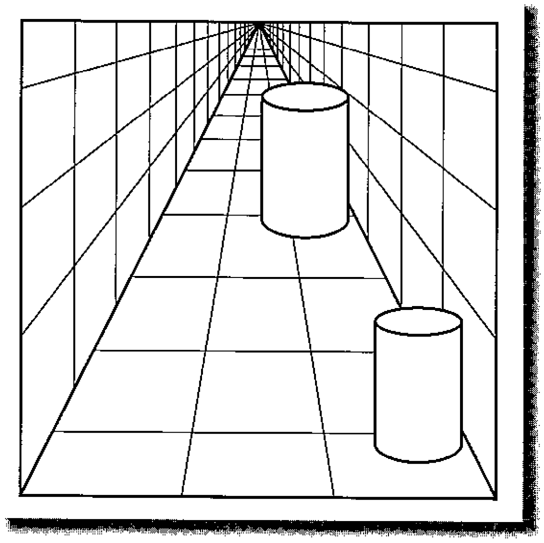

Figure 2

Corridor Illusion

With the logMAR chart, subjects often made the comparison of letter sizes between visual acuity levels and often commented that they did not like the smaller letters because they were more difficult to see and seemed further away than the larger letters. The perception of distance influences image size and the further away the image is perceived the smaller the image is thought to be [11]. This perception anomaly was most likely to have been invoked by the logarithmic scaling of letter size and an equal number of letters per acuity level, which has created an inverted passage to infinity (Figures 1 & 2). Richards [12] describes this as the "Corridor Illusion" where two identical objects of the same size are located separately in a passage to infinity and appear to be at different distances. It may be hypothesised that when comparisons are made between VA levels and perceived letter size, the subjects may be less inclined to attempt to resolve the smaller letters because they are thought to be smaller than they actually are. This psychological phenomenon associated with the logMAR chart may then partly account for its low acuity mean and suggests its measurements may not reflect threshold acuity. The observation of letter size comparison when acuity was measured with the chart would support the use of flip over acuity tests with preschool children, which have been incorporated into more recent designs such as the Sonsken-Silver Acuity System [9] and the Glasgow Acuity Cards [4]. In particular, it may further explain the results in the study by Jayatunga [13] where threshold acuity for the Sonsken-Silver Acuity System was 6/6 while on the MK2 Chart it was 6/9 despite both having a linear display with equal and standard spacing between optotypes.

The surrounding letters displayed in the Cambridge Crowding Card test are, in theory, to be ignored in the process of resolution and recognition of the centre letter. The designers used different surrounding letters from those displayed on the answer board to avoid confusion in the process of identification and matching of the central letter displayed [14]. However, it was considered that the display presentation was visually confusing and conceptually difficult for preschool children which may explain why half of the excluded subjects (all three years old) could not complete the Cambridge Crowding Card test on first examination. The Cambridge Crowding test card and answer board each displayed a total of five letters and although the configuration of letters was different, opposing mental processes were required in the matching strategy when the subject fixated between the Cambridge Crowding Card display and the answer board. That is, the subject was instructed to only look at the centre optotype on the Cambridge Crowding Card display yet asked to visually search all five letters on the answer board to identify "the same" central letter.

It may be considered that the poor reliability and test ability of preschool children is possibly a reflection of the design specifications that inturn influence the psychological aspects of visual function. Clinicians need to be aware of the research background of acuity tests in order to interpret their results appropriately. McDonald [3] emphasises that any new VA test should be supported with examination times, estimates of reliability, preliminary norms and percentage success rates but most importantly these statistics should be specific for various age groups.

Conclusion

The design specifications of visual acuity tests only become uncontrolled variables when comparisons are made between tests when subjects are of the same age group or between age groups when acuity is measured with the same test type. If the same test type is clinically used sequentially to monitor vision in a subject then the design specifications are not considered uncontrolled variables, but are still thought to influence the measurement of vision. With paediatric assessment of acuity, each clinician should ask whether the acuity measured is reflective of acuity itself and/or other factors. It is important not to assume that an acuity measured with one test will be the same when measured with another acuity test due to each test having a different design specification and testing procedure. These and other uncontrolled variables need to be specifically addressed in further research into the examination of acuity in preschool children. Until this occurs the distinction between what is thought to be assessed and what has been measured will remain undifferentiated.

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