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Abstract

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cardiff acuity, cycles per degree, minimum detectable, minimum resolvable, optotype, preferential looking

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A CLINICAL COMPARISON OF VISUAL ACUITY BETWEEN THE CARDIFF ACUITY TEST AND THE SNELLEN ACUITY TEST UNDER KNOWN LEVELS OF BLUR

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ABSTRACT
The Cardiff Acuity test was compared to the Snellen Acuity test by measurements taken through 1, 2 and 3 diopters of blur. The Cardiff acuities were taken with both minimum resolvable and minimum detectable criterion. Acuity readings were obtained from 59 eyes (59 subjects) at a distance of 1 meter. Poor correlations were found between Snellen acuities and Cardiff acuities at all levels of blur ($r \leq 0.50$). Minimum detectable with Cardiff gave the highest (best) acuities followed by minimum resolvable with Cardiff and Snellen measuring the lowest (worst) acuities for each level of blur.

Key Words
Cardiff acuity, Cycles per degree, Minimum detectable, Minimum resolvable, Optotype, Preferential Looking, Snellen Acuity, Teller Cards, Visual acuity

INTRODUCTION

Optometrists are able to make reasonable assumptions about how well a patient can or cannot see based on their clinical experience with Snellen acuity measurements. Snellen acuity is the common language of Optometrists and the one with which other health care providers are most familiar. Currently, no testing procedure exists for the pediatric population that correlates reasonably with Snellen acuities. Such a test would undoubtedly be useful to practitioners. It would provide an underlying cohesiveness and facilitate communication between Optometrists and other health care practitioners.

Presently, the most used and well standardized test for infants, toddlers and non-communicative patients is the Teller Preferential Looking test. This test is based on the fact that a child will preferentially look at a striped pattern over a grey field of equal luminance[1]. The Teller Acuity Card test has gained popularity because of its ease of application and well established norms. While levels of age expected acuities have been established for the Preferential Looking test, these do not correlate well with Snellen acuity and thus no inferences can be made between the two tests[3,10,12,15].

A relatively new visual acuity test, the Cardiff Acuity test, developed for infants and toddlers uses a paradigm similar to Teller. While both tests utilize disappearing optotypes, Cardiff is unique in that it's optotypes form commonly recognized shapes. Thus, Cardiff cards can also be used to test for minimum resolvable as well as minimum detectable acuity.

In the study conducted by the developers of the Cardiff test, it demonstrated that, when compared to Snellen, Cardiff acuities were consistently better than the matched Snellen but showed lower visual acuities than the matched Preferential looking in a population of 7 adults and 24 children ranging in age from 1 - 3.5 years[16]. In 1995, a pilot study by Bass, Ramsey and Robertson at Pacific University College of Optometry found similar results in an adult population. The results of their study also suggested that as Snellen Acuity worsens, it does so at a greater rate than those obtained with Cardiff Acuities[2]. One might infer that a linear correlation does not exist between the two tests. If true, Cardiff cards may fail to adequately identify those individuals with decreased visual acuities as the Snellen testing would. Such a characteristic may be cause for concern as Cardiff cards would ideally be used in the non-communicative population. An obvious difference between Cardiff and Snellen is that Snellen is a minimum resolvable test whereas Cardiff is a minimum detectable test. In the above mentioned study, Cardiff was presented with a minimum detectable criterion. A question left unanswered by their study was whether a minimum

resolvable criterion used with Cardiff would compare more closely to Snellen Acuity.

The purpose of this study is to address both questions raised by the 1995 pilot study. To do so, Snellen and Cardiff acuities are taken through known levels of myopic blur. This will establish whether the rate of decrease between Snellen and Cardiff acuity is correlated. In addition, both minimum detectable and minimum resolvable acuities are taken with Cardiff to determine if minimum resolvable yields acuities more comparable to Snellen.

METHOD

Subjects

The subjects were first year optometry students at Pacific University who were required to fulfill a research requirement through participation in one authorized experimental study. Subjects were selected for participation if they were correctable to 20/20 visual acuity, monocularly, on a standard projected Snellen chart at 20 feet and if they were between the ages of 18 to 40 years. A total of 59 subjects were tested, ranging in age from 21 to 30 years. They were composed of 33 males and 26 females.

Materials

Three different visual acuity charts were used during the testing process. First, a second edition Lighthouse Near Visual Acuity Test utilizing modified EDTRS with Sloan letters was used in conjunction with a typoscope isolating only the 1.0 M demand of letters, representing a 20/20 Snellen equivalent demand at one meter.

The second visual acuity chart used was a Bailey-Lovie chart calibrated for a 4M, 2M, and 1M testing distance. At a one meter testing distance, this chart measured acuity thresholds from 20/800 to 20/40 Snellen equivalent in 0.1 LogMAR increments. This chart was chosen because it matched the linear 0.1 LogMAR incremental scaling of the Cardiff acuity test. These first two charts are both obtainable from Lighthouse low vision products.

The final visual acuity test utilized during testing was the Cardiff visual acuity test. The Cardiff test consists of optotype visual acuity targets with one threshold per card. Each card is oriented vertically with one half of the card presenting a resolvable optotype and the other half without an optotype but equal in contrast and luminance. There are 33 cards total, 3 at each demand level, progressing from 20/200 to 20/20 Snellen equivalent targets in 0.1 LogMAR intervals at a one meter testing

distance. The Cardiff visual acuity test is available from The University of Wales. Control lenses and dioptric vergence demands were presented using a B & L green phoropter.

Procedure

Subjects were tested at the Pacific University Family Vision Center's Pediatric Service in Forest Grove, OR. The room, illuminance, materials, and examiners were held constant for each subject. The two examiners were fourth year optometry students at Pacific University. A strict testing protocol was followed with one examiner recording each subject's response while the second examiner presented each stimuli. Only one eye, the right eye, of each subject was tested. All procedures were performed at a one meter distance. Testing began with the subject seated in the examination chair, behind the phoropter, in which the best distance correction for the right eye was placed and the left eye was occluded.

Pre-testing was then conducted to determine the lens offering the maximum plus to 20/20 Snellen acuity at one meter. The Lighthouse near visual acuity chart, isolating the 1.0M line, provided the target. The patient was instructed to respond when the target letters were too blurry to resolve as the experimenter added plus lenses to their distance correction in 0.25 diopter steps. The subject was then asked to respond to the lens which offered a recovery of half of the target line as the experimenter reduced the plus lenses in 0.25 diopter steps. The first, or maximum, plus lens that allowed resolution of half of the target line was used as the control lens for the rest of the testing session.

This pre-test was developed as a means of controlling and monitoring changes in accommodative posture through out testing. At the end of each session, this pre-test was repeated as a post-test. Any subject whose post-test lens value differed from the pre-test value by greater than 0.50 diopters was excluded from analysis due to the evidence of accommodative fluctuation during testing.

The experimental phase of testing consisted of measuring visual acuity threshold with both the Lighthouse low vision chart and the Cardiff acuity cards through +3.00, +2.00, and +1.00 diopter levels of blur imposed over the control lens, in that order.

With +3.00 diopters of blur added to the control lens in the phoropter the subject was first asked to call out the lowest or smallest line of letters on the Lighthouse low vision chart that they could identify even if it appeared blurry. The smallest line of letters which the subject could

correctly identify at least 3 out of the 5 letters was recorded as the Snellen acuity for that level of blur.

Each subject was next presented with all 33 Cardiff acuity cards, in a predetermined random order, and asked for a response. The subjects were told that if they were able to identify the figure or picture on the card that they should name it. If they were unable to resolve the figure but could identify whether the figure was placed on the top or the bottom of the card, they should respond "top" or "bottom". Lastly, if the subject was unable even to determine where the figure was placed on the card, they were asked to respond with the word "nothing".

If the subject correctly identified the figure of the card the response was recorded as 'resolvable'. If the subject correctly responded to the location of the figure (top or bottom) but was unable to name or incorrectly named the figure, the response was recorded as 'detectable'. Finally, if the subject responded with 'nothing' or incorrectly identified the location of the figure, the response was recorded as '0'. This experimental procedure was repeated through +2.00 diopters over the control lens and then again through +1.00 diopter over the control lens.

Two Cardiff acuity measures were determined from this process at each level of blur, a minimum detectable threshold and a minimum resolvable threshold. There were three Cardiff cards for each acuity level, so a two-thirds threshold criterion was employed for each acuity level. This allowed a 1 in 4 chance of the subject meeting the criterion for detection with guessing alone. Thus, when scoring, each subject's minimum detectable acuity was recorded as the smallest demand level in which the two-thirds criterion for detection was met and in which all larger demands met the criterion as well. Consequently, each subject's minimum resolvable acuity was also recorded as the smallest demand level in which the two-thirds criterion for resolution was met and in which all larger demand levels met the criterion as well.

At the end of testing and scoring, there were a total of 9 acuity measures for each subject; one Snellen acuity, one minimum resolvable Cardiff acuity, and one minimum detectable Cardiff acuity measure at each of the three levels of dioptric blur. Three of the subjects were excluded from analysis because they failed the post-test of maximum plus to 20/20 Snellen acuity at one meter. Their post-test value differed from their pre-test value by greater than 0.50 diopters and was considered to be evidence of accommodative fluctuation during testing.

RESULTS

All acuity measures were converted to cycles per degree values for analysis. Statistical analysis was performed using the Stat-Vue software package. The mean visual acuity and standard deviation were calculated for each acuity measured. Figures 1, 2, and 3 display these values. Figure 1 shows the mean acuities measured by Snellen, Cardiff resolvable, and Cardiff detectable under +1.00 diopter of blur. The error bars indicate one standard deviation above and below the mean. Under this condition, the Snellen chart measured the lowest mean acuity at 8.43 CPD (20/71 Snellen equivalent (SE)). Cardiff resolvable had the next lowest mean acuity at 14.38 CPD (20/42 SE). Cardiff detectable measured the highest acuity at 16.30 CPD (20/37 SE).

Figure 2 shows the mean acuities measured by Snellen, Cardiff resolvable, and Cardiff detectable under +2.00 diopters of blur. In this condition, the Snellen chart also measured the lowest mean acuity at 4.25 CPD (20/141 SE), Cardiff resolvable next lowest at 9.96 CPD (20/60 SE), and Cardiff detectable the highest at 12.10 CPD (20/50 SE).

Figure 3 shows the mean acuities measured by Snellen, Cardiff resolvable, and Cardiff detectable under +3.00 diopters of blur. Again the Snellen chart measured the lowest mean acuity at 2.39 CPD (20/251 SE), Cardiff resolvable the next lowest at 6.55 CPD (20/92 SE), and Cardiff detectable highest acuity at 8.92 CPD (20/67 SE).

The acuity data were compared using a one factor ANOVA repeated measures test. They were then compared for significance using the Scheffe F-test with 0.10 level of significance. This comparison showed that under each testing condition (+1.00,+2.00, and +3.00 diopters of blur), the three tests (Snellen chart, Cardiff resolvable, Cardiff detectable) resulted in acuity measures that were significantly different from each other. It also showed that each single test measured a significantly different visual acuity under each different level of dioptric blur.

The three tests were then analyzed for possible correlations using linear regression. Table 1 shows which tests were compared and the resultant r^2 value. None of the tests showed a strong correlation ($r^2 > 0.50$) with another test. Cardiff resolvable did not show a significantly higher correlation to Snellen than Cardiff detectable under any of the testing conditions. Moreover, neither did Cardiff resolvable and Cardiff detectable significantly correlate with each other under any of the testing conditions.

Under all three levels of blur, Cardiff resolvable response strategy measured an acuity closer to that of the Snellen chart than the Cardiff

detectable response strategy. Both Cardiff resolvable and Cardiff detectable resulted in standard deviations larger than that of the Snellen chart. Each test showed an increasing standard deviation with a reduction in the level of blur under which it was conducted, except for Cardiff resolvable. This test had its lowest standard deviation at one diopter of blur.

DISCUSSION

It is appearant from the results of this study that acuities taken with Cardiff do not correlate well with Snellen acuities even when obtained with a minimum detectable criterion. In addition, the rate of acuity change between Snellen and Cardiff acuity is not correlated. In fact, no correlation could be found between Cardiff minimum detectable and Cardiff minimum resolvable. It would seem that these three tests of acuity measure different aspects of visual functioning.

The pilot study conducted by Bass, Ramsey and Robertson in 1995 demonstrated that Cardiff minimum detectable acuity correlated more favorably to Snellen than did Teller acuity measurements. Building on this finding, the present study found that Cardiff minimum resolvable correlates better to Snellen than Cardiff minimum detectable, although not at a significant level.

It had been our hope that a relationship between Cardiff and Snellen could be established through this study. While such a correlative relationship failed to materialize some important characteristics of Cardiff testing did. Practicioners utilizing Cardiff testing need to be aware of this procedures' propensity to give a large standard deviation which tends to increase at poorer acuity levels, thus creating uncertainty and ambiguity at a time when reliable measures of acuity are needed most. This is true of both minimum detectable and minimum resolvable, although to a lesser degree with minimum resolvable. Combine this finding with the fact that Cardiff acuities, minimum detectable and minimum resolvable, decrease at a much slower rate than do Snellen visual acuities under conditions of induced myopic blur, and it becomes clear that one could easily fail to identify an individual with a significant visual problem. Obviously this would be of concern when attempting to diagnose and treat conditions such as amblyopia.

Before drawing a conclusion on the usefullness of Cardiff acuity measures in the pediatric population a similar study needs to be conducted with more age appropriate subjects. It may be that due to less visual experience, social and psychological immaturity or because of reduced attention span that no difference between Cardiff minimum detectable and resovable will be found. This remains to be seen. At present Cardiff

Acuity cards are a viable tool in the testing of the pediatric population, but results may not be comparable to Snellen acuities.

Table 1. Correlation of Snellen, Cardiff resolvable, and Cardiff detectable visual acuity measures for each testing condition.

TEST 1	TEST 2	r^2
+3.00 DS		
Snellen	Cardiff Resolvable	0.199
Snellen	Cardiff Detectable	0.148
Cardiff Resolvable	Cardiff Detectable	0.479
+2.00 DS		
Snellen	Cardiff Resolvable	0.175
Snellen	Cardiff Detectable	0.263
Cardiff Resolvable	Cardiff Detectable	0.508
+1.00 DS		
Snellen	Cardiff Resolvable	0.300
Snellen	Cardiff Detectable	0.147
Cardiff Resolvable	Cardiff Detectable	0.283

Figure 1. Comparison of acuity measures taken by snellen, cardiff resolvable, and cardiff detectable methods under +1.00 diopters of blur

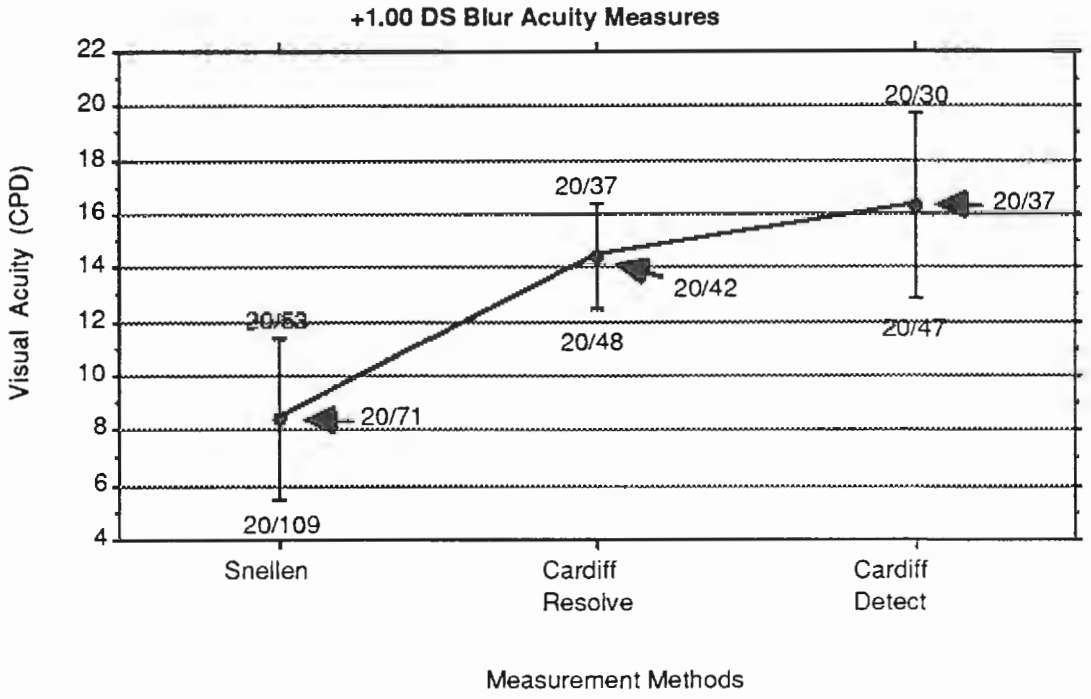


Figure 2. Comparison of acuity measures taken by snellen, cardiff resolvable, and cardiff detectable methods under +2.00 diopters of blur

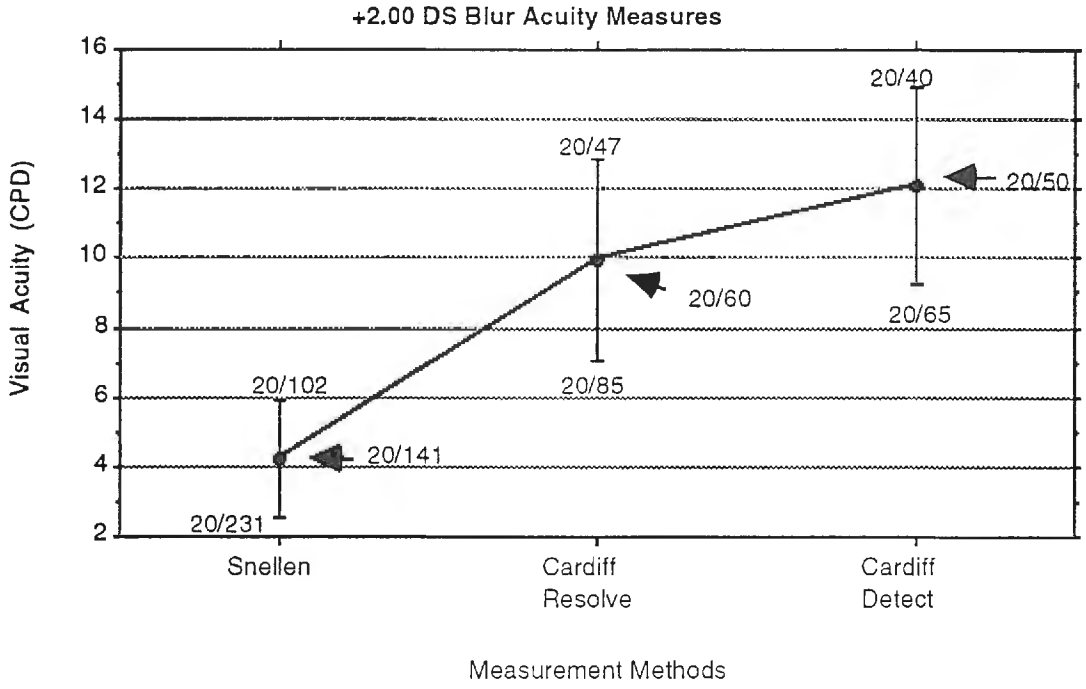
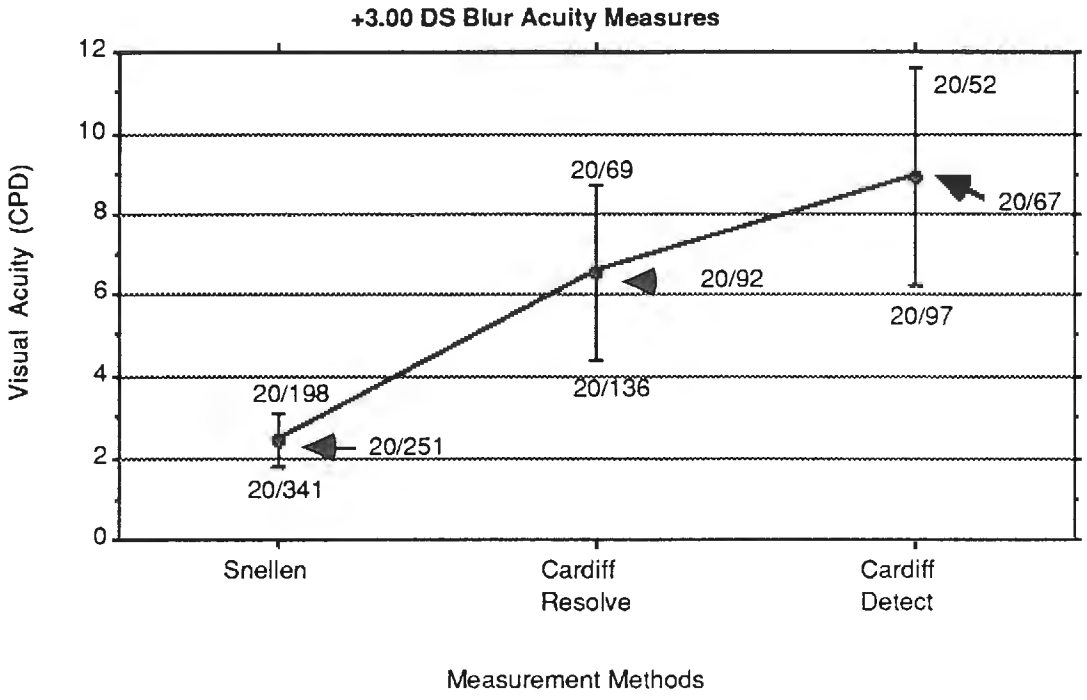


Figure 3. Comparison of acuity measures taken by snellen, cardiff resolvable, and cardiff detectable methods under +3.00 diopters of blur



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