An Evaluation of the Microcomputer as a Vision Screening Medium

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Abstract

A vision screening programme using a microcomputer as the presentation medium was instituted. Tests of acuity, accommodation, accommodative facility, stereoacuity, vertical and lateral phoria, positive and negative vergence limits and saccadic vision proficiency were included in the pilot study. These results were compared to the findings of a routine optometric examination. Repeatability and accuracy of the programme were evaluated. Results indicated which tests should be retained in the computer programme.

Résumé

On a utilisé un micro-ordonnateur pour monter un projet de dépistage visuel. Le programme comprend des tests d'acuité, d'accommodation, facilité d'accommodation, acuité stéréoscopique, phorie laterale et verticale, amplitude relative de convergence et la précision des saccades oculaires. Ces résultats ont été comparés aux données d'un examen optométrique regulier. La fidélité de repetition et la précision du programme ont été évaluées. Ces résultats ont determinés quels tests seraient maintenus au programme.

Introduction

Vision screening programs have taken many forms over the years. These have varied from the Snellen Chart used in most schools and public health units across the country, to professionally conducted programs like the Modified Clinical Technique (MCT).[1-5] With the introduction of computers into schools, a whole new medium exists with which to present vision screening programs. This new medium has the potential to offer many advantages over existing vision screening methods. A computer program would enable all of the testing to be done on one instrument, the computer. Instructions to the operator could be automatically presented when required. The computer could be used to do the testing, using animated graphics and text, and also to determine who should be referred for further evaluation. No paperwork would be required since the computer could keep track of all results on diskettes and could even write referral letters outlining test results. The net result would be a screening system which could be operated easily by people with no optometric background or computer experience, could be used for individual or mass screenings, and would be relatively inexpensive because the hardware is already present in schools.

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The purpose of this study was to develop and evaluate a vision screening program using the microcomputer as the presentation medium. The program was designed to evaluate the following areas: visual acuity, accommodation, accommodative facility, stereoacuity, vertical and lateral phoria, positive and negative fusional vergence limits, and saccadic version proficiency. It was programmed to run on an Apple II+ or IIe. These computers were chosen because most schools in Calgary use them.

Methods

The program was evaluated using the population of a Calgary elementary and junior high school. Eighty one students aged 7 to 16 were screened using the computer. The screening was done by a layman with no previous experience in visual assessment or computers. All 81 students were screened twice, a week apart. During the intervening week, all were given a complete optometric examination against which the screening results were evaluated.

The screening tests were carried out in dim light levels of 5 to 10 foot-candles. The exact procedures used to test the students are as follows:

1) *Visual Acuity:* Students stood 5.5 m away from the computer screen and wore glasses with cross polarized plano lenses. The top half of the screen was polarized opposite to the bottom half, so the

student saw the top half with one eye and the bottom half with the other. Acuity lines using tumbling E targets and representing 20/20 and 20/30 (6/6 and 6/9) were displayed on the top half of the screen, then the bottom half of the screen, thus testing each eye individually.

2) *Accommodation:* Students were checked for uncorrected hyperopia using a similar procedure as for visual acuity testing, but using 20/45 (6/13.5) acuity with a +2.00 cross polarized lenses. Again this tested each eye individually without the need to occlude the other eye.

3) *Accommodative Facility:* The students wore cross polarized lenses with +1.50 in the right lens and -1.50 in the left. Words were displayed alternately on the top half and the bottom half of the screen. Students were advised to read each word aloud when it was clear. The operator would then press a key on the computer, erasing that word and displaying the next on the other half of the screen. Ten words, or five cycles, were presented. The computer timed the test.

4) *Stereoacuity:* Students were seated 50 cm from the screen wearing plano cross polarized lenses with vertical prism to fuse the top and the bottom halves of the screen. Three rows of letters and numbers were presented on each half of the screen with two digits offset in each row to create crossed and uncrossed disparities. Students were asked to state which letter or number in each row appeared farther away than the others, and which appeared closer than the others. The disparities presented were 126, 63, and 32 seconds of arc. The operator pressed the number on the keyboard corresponding to the row correctly identified.

5) *Lateral distance phoria:* Students stood 5.5 m from the screen and wore plano cross polarized lenses containing a total of 4 dioptres vertical prism to dissociate the two eyes. They were asked to look at a stationary flashing arrow and to tell when a moveable flashing arrow was lined up vertically above it. The operator then pressed a key and the amount of phoria was calculated and recorded.

6) *Near lateral and vertical phorias:* These were measured simultaneously. Students were seated 55 cm from the screen and wore cross polarized lenses with 10 dioptres vertical prism in each (opposite to each other). One eye saw a small flashing cross which could be moved with a joystick. The other eye saw a larger cross with the center missing. Each was seen monocularly but superimposed by the prism. The small cross could be aligned to fit into the "hole" in the large cross. The students lined them up themselves using the joystick and pressed a button on it when they were finished. Again the phorias were then calculated and recorded by the computer.

7) *Fusional Vergence:* Vergence testing was done with the same setup, but with concentric rectangles used as targets. These were fused by the students, providing a 3-D image. The targets were slowly separated using the joystick until fusion could not be maintained and diplopia resulted or the 3-D effect was lost. Both convergence and divergence were evaluated in this way.

8) *Saccadic Versions:* Saccadic version testing was done with three tests. Two are similar to the Pierce saccadic tests and evaluate gross saccades. The other is intended to evaluate fine saccades. With the first two tests, numbers were displayed in two columns, one on each side of the screen. On the first test a series of dots ran from the number on the left to the number on the right at the same level. On the second test no dots were provided. Students were asked to read the number on the left, then right, then to drop down a row and to repeat the procedure until finished. The third test consisted of a series of short vertical lines which the students were asked to count without pointing at them. All three tests were timed by the computer.

Results

To evaluate the effectiveness of the program it was necessary to assess how repeatable the results were, as well as assessing how accurately the program identified those students who do, and do not, have the conditions being screened for.

To assess the reliability or repeatability of the results, correlation coefficients were calculated using the results of both screening sessions. Ideally, there should be a perfectly linear relationship between the results of the two screening sessions. A pass or fail result on the first session should be repeated on the second session. Table 1 shows the reliability coefficients for the screening subtests. Visual acuity, stereoacuity, accommodative facility, near lateral phoria, and the positive fusional vergence limit tests all show very good repeatability. Distance lateral phoria, near vertical phoria, the accommodative test for hyperopia, and the negative fusional vergence limit tests show moderately good repeatability.

Table 1
Screening Test Reliability

	PHI Coefficient		
Test	**Age 7-16**	**Age 10-16**	**Age 7-9**
20/20 (6/6) VA	+0.6	+0.6	+0.6
20/30 (6/9) VA	+0.7	+0.7	+0.6
Stereoacuity	+0.5	+0.6	+0.3
Accommodation	+0.4	+0.4	+0.4
Accom. Facility	+0.5	+0.7	+0.4
Distance Phoria	+0.3	+0.5	-0.2
Near Phoria	+0.8	+0.9	+0.7
Vertical Phoria	+0.3	+0.4	+0.2
Pos. Fus. Vergence	+0.6	+0.5	+0.7
Neg. Fus. Vergence	+0.2	+0.3	+0.1
Saccadic Version	+0.7	+0.7	+0.6

To determine whether age had an effect on the reliability of the results, correlation coefficients were calculated for the students aged 7-9 and the students aged 10-16. These are also shown in Table 1. It can be seen that the reliability coefficient is

generally lower for the younger students. However, the visual acuity, near lateral phoria, saccadic version, and positive fusional vergence coefficients for the younger age group are still statistically significant at the .05 significance level. The accommodation and accommodative facility test reliability coefficients are significant at the .1 level. The remainder of the test results (distance lateral phoria, near vertical phoria, and negative fusional vergence limit) with lower coefficients are not statistically significant for this age group.

Table 2 represents the screening test validity coefficients. This was determined by correlating the results of the screening subtests with the results of the corresponding optometric tests performed under habitual conditions. The visual acuity screening test was evaluated against whether or not the student had any significant amounts of myopia or astigmatism. The accommodation test was evaluated against whether the student had any significant amounts of hyperopia. All other screening tests, except the saccadic version tests, were evaluated against the corresponding optometric test.

TABLE 2
Screening Test Validity

Test	PHI Coefficient Age 7-16
20/20 (6/6) VA	+0.5
20/30 (6/9) VA	+0.5
Stereoacuity	+0.5
Accommodation	+0.4
Acc. Facility	+0.7
Distance Phoria	-0.1
Near Phoria	+0.7
Vertical Phoria	-0.2
Pos. Fus. Vergence	+0.2
Neg. Fus. Vergence	+0.1

The visual acuity, stereoacuity, accommodative facility, and near lateral phoria tests all showed good correlation with the optometric tests. The test for hyperopia showed moderately good correlation. The tests for distance lateral phoria, vertical phoria, and positive and negative fusional vergence limits showed very poor correlation.

The saccadic version screening procedures were not evaluated against the optometric examination results because, short of having an eye movement monitoring device such as the Eye-Trac, a reliable objective assessment method does not exist. Instead, optometrists subjectively assess saccadic performance by watching for overshoots and undershoots while the patient alternately fixates targets. It was felt that comparing the screening results with non standardized subjective test results would not be satisfactory. Therefore age norms were developed for the screening test and students were failed if their results were greater than one standard deviation from the mean for their age.

Correlation coefficients give an indication of how accurately the screening test evaluated the population, but they do not indicate how many of those incorrectly screened were failed when they should have passed (false positives), or passed when they should have failed (false negatives). Table 3 provides this information, showing the sensitivity and specificity of those procedures which correlated well with the optometric examination. The pass/fail criteria used to determine the sensitivity and specificity of the screening results are shown in table 5. Sensitivity is the proportion of students who have the condition for which the test screened and who were correctly identified by the test. Specificity is the proportion of the students who do not have the condition and who were correctly identified by the test.[6,7,8] It can be seen that the sensitivity and specificity of all of these test procedures is good.

The predictive value of a positive test when all of the subtests are combined is 82%. This is the percentage of students who failed the screening and actually have a visual disorder. The predictive value of a negative test is 89%. This is the percentage of students who passed the whole screening program and do not have any visual disorder.[6, 8]

Table 3
Screening Test Sensitivity and Specificity

Test	Sensitivity (%)	Specificity (%)
20/20 (6/6) VA	94	74
20/30 (6/9) VA	84	86
Stereoacuity	95	82
Accommodation	80	90
Accom. Facility	93	95
Near Phoria	75	98

Positive Predictive Value for Complete Battery = 82%
Negative Predictive Value for Complete Battery = 89%

Discussion

This computer program is a prototype, developed to assess the effectiveness of using a computer for vision screening. As a result it was designed to test as many aspects of vision as possible. The intent was to determine which tests worked well and what criteria would be the most accurate at identifying visual conditions in the population. These could then be consolidated into a screening program which could be made available to schools, public health units, and other institutions which are presently using screening "systems" such as the Snellen Chart which are not comprehensive enough or accurate enough to provide a sound basis for referral or non-referral to optometrists.[2, 3, 5, 7, 11]

The results of this study show that the screening program accurately and reliably identified those children with significant amounts of myopia, astigmatism, hyperopia, poor stereoacuity, poor binocular fusion, poor accommodative facility, and near ocular alignment disorders. Table 4 shows the overall effectiveness of the program in these areas. When compared against the results of the optometric examination, only eight students were incorrectly failed and only four were incorrectly passed. The

other sixty-nine were correctly identified. It must be remembered that the screening results were compared against the results of the optometric tests done under habitual conditions.

Table 4
Overall Results of Screening Program Compared to Results of Optometric Examination for All 81 Students

		Optometric Evaluation	
		Fail	Pass
Screening Evaluation	Fail	36	8
	Pass	4	32

The screening procedures which did not work well were the distance lateral phoria, the near vertical phoria, and the positive and negative fusional vergence limits. The distance lateral phoria showed fairly good repeatability, but was not accurate when compared with the optometric results. For both screening sessions, the maximum phoria measured was one prism dioptre. Although 4 dioptres of vertical prism was used to attempt to dissociate the eyes, enough peripheral fusion was maintained to keep the eyes from actually doing so. The result was that most students were found to be orthophoric when measured this way, regardless of the phoria results obtained from the optometric examination.

The near vertical phoria was found to have no correlation with the results of the optometric examination. The problem appears to be due to poor control of fixation distance. Each child was initially placed the correct distance from the computer screen, however no device was used to ensure that this distance was maintained. The goggles the students wore contained 20 dioptres of vertical prism to fuse the two halves of the screen. With this much prism, a movement of just 2.5 cm would cause a 1 dioptre error in the phoria measurement. When dealing with vertical phorias this is a significant error. Better control of fixation distance should remedy this problem.

A good correlation was not found between the results of the fusional vergence limit screening tests and the optometric evaluation of fusional vergence limits. The reason seems to be in the administration of these tests. The animation was programmed so that the targets could only be separated at one speed, which turned out to be a little too fast for many of the students to maintain fusion. Therefore the operator separated the targets by an increment, asked the student if the targets were still fused and single, and continued in this process until diplopia resulted or the 3-D effect was lost. The increment of separation was controlled by the operator and may have varied from student to student. The fact that the near lateral phoria screening measurement correlated so closely with the optometric test indicates that variables such as peripheral fusion were not a significant factor in that test, and shouldn't be in this test either since conditions were exactly the same. In theory then, the fusional vergence tests should correlate just as well as the lateral phoria did if the animated separation were to be slowed down and made smoother to more closely simulate the Risley prism separation used in the optometric test.

The accommodation test to screen for hyperopia showed only moderately good correlation when the reliability and validity were evaluated, yet the sensitivity and specificity were very good. This seems contradictory at first glance, but is explained when it is realized that there were very few hyperopic children in the population. The screening accurately identified 8 of the 9 hyperopic eyes in the population. Twenty of the eyes which were not significantly hyperopic were incorrectly identified, indicating these students could read the acuity line when they shouldn't have been able to. These students were hyperopic and close to, but not over, the cut off point used to identify significant amounts of hyperopia, shown in table 5. These "errors" lowered the correlation coefficients, but because all but one were false positives and the population of true negatives was so large, the sensitivity and specificity remained high.

Table 5
Pass/Fail Criteria

Condition	Screening	Optometric Exam
Myopia/Astigmatism	≥ 20/20 (6/6) VA or ≥ 20/30 (6/9) VA	≥ -0.50D myopia or ≥ -1.00D astimagtism
Hyperopia	≤ 20/45 (6/13.5) VA through +1.50D	≥ +1.50D hyperopia
Accommodative Facility	< 6 cycles/minute	< 6 cycles/minute
Stereoacuity	> 63 sec. arc.	> 60 sec. arc
Distance Esophoria	> 5 prism dioptres	> 5 prism dioptres
Distance Exophoria	> 5 p.d.	> 5 p.d.
Near Esophoria	> 6 p.d.	> 6 p.d.
Near Exophoria	> 10 p.d.	> 10 p.d.
Vertical Phoria (N & D)	≥ 2 p.d.	≥ 2 p.d.
Saccadic Vergence	> 1 S.D. from age means	

The visual acuity test was used as an indication of the amount of myopia and astigmatism present. Two different letter sizes were used and each was evaluated separately to determine which size provided the best referral criterion. Both sizes had the same validity; however, the 20/30 (6/9) letters provided slightly higher repeatability and more equal sensitivity and specificity. Therefore it was deemed to be the most accurate and reliable referral criterion.

The screening program was designed to minimize the amount of knowledge an operator would require to carry out the screening accurately. The operator who carried out the screening was a unversity student in a non-health care field with no previous experience with computers. His preparation for the screening consisted of having the program demonstrated to him. When the program was run, instructions for the operator were automatically presented at appropriate times and the results of the testing were automatically recorded. The use of

cross polarized lenses in sports frames with elasticized head bands, and the cross polarized screen over the monitor eliminated the need to use an occluder or hand held lenses. All of this served to make the role of the operator simpler and easier. He did not have to watch the children closely to make sure they were not peeking around an occluder, did not have to worry about accurately recording and organizing results and did not have to worry about memorizing test protocol. The operator reported no difficulty in understanding how to carry out the tests, or in actually doing the screening, despite the difficulties encountered with the fusional vergence tests.

An unexpected bonus to using the computer as the presentation medium was that the students were interested in what was being done and anxious to participate and use the computer. It was common to have students poke their heads into the room between classes and ask when they could have their eyes tested. As a result, compliance with the operator's instructions was very good, although he did find it easier to work with the children over eight years old because he could communicate with them better.

A lot of tests were put into the program, but because all of the testing was done on one machine and was done automatically in orderly succession, the time taken on each student was relatively short. We averaged 15 minutes per student but that included the time taken to send each student back to class and have another sent to the examination room. The average testing time was closer to 10 minutes. Obviously, sending students in groups to the screening area would speed the process up. For large student populations several computers could be set up and run simultaneously, thereby permitting the screening of far more students per hour than with one station.

Conclusion

The purpose of a screening program is actually not to diagnose visual disorders, but rather to identify those persons in a population who have a high probability of having a visual disorder so that these individuals may be referred for a comprehensive diagnostic assessment and, if necessary, treatment. The screening procedures utilized in this study did this accurately and repeatably for the following conditions: myopia, astigmatism, hyperopia, anisometropia, binocular fusion, stereoacuity, accommodative facility, near ocular alignment, and saccadic version performance. A good screening program must not only be accurate and repeatable, it must also be fast, inexpensive, and easy to use for individual and mass screenings. This study shows that a computer-based vision screening program presently can fulfil all of these requirements.

Acknowledgement

The author would like to thank June Adams, Ph.D. for her assistance with the statistics. This study was supported by a grant from the Canadian Optometric Education Trust Fund.

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