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THE GOODWIN ACUITY TEST, AN INNOVATIVE TECHNIQUE FOR SCREENING CHILDREN

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The Goodwin Acuity Test, An Innovative Technique for Screening Children

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Abstract

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Introduction

Normal vision is an essential process in the development of children. There is also a high prevalence of vision disorders in this population which if undetected could interfere with a child's ability to perform to his potential (US Public Health Service, 1994; Optometric Clinical Practice Guide: Pediatric, 1994). It has been reported that 5-10 percent of preschool children have undetected vision problems (Hunt, 1993). In 1994, the U.S. Public Health Service reported "refractive errors are the most common vision disorders among children, occurring in 20 percent by 16 years of age" (U.S. Public Health Service, 1994). The American Academy of Ophthalmology (AAO), the American Optometric Association (AOA), and the American Academy of Pediatrics (AAP) recommends screenings at birth, 6 months of age, at 3 1/2 years, and at age 5 years and older (AAO, 1988; Hunt, 1993). Often screenings are not done until a child enters kindergarten or first grade at age 5 or 6. Some conditions such as amblyopia require early detection and prompt intervention and are best treated at 3-4 years of age (Jacob et al, 1988). A more effective method of screening young children might improve vision care for this important age group.

A visual screening separates those who may need medical attention from those who do not . Ideal qualities of a screening procedure is that it should be simple, fast, inexpensive, valid, reliable, and productive (Lippmann, 1962). Currently, many vision screenings fall short in at least one of these areas. The Orinda Study considers one of the better screenings to be the Modified Clinical Technique (MCT), which includes visual acuity at far and near, cover testing, stereoacuity, retinoscopy, and ophthalmoscopy (Blum et al., 1959). However, the MCT requires a trained optometrist or ophthalmologist so untrained personnel would not be able to administer this screening (Blum et al., 1959). In a 1995 study of inner city visual screenings of preschool children, Williamson et al. found that "the only effective screening test for the detection of amblyopia was visual acuity". A

more effective screening that could easily be administered by untrained school personnel would have to include a visual acuity test for near and far.

Of all the visual functions that need to be evaluated, visual acuity is one of the most important and most simple to determine. "Visual acuity is a measure of the smallest retinal image of which the form can be appreciated." (Duke-Elder cited in Harrison, 1975). There are numerous visual acuity tests for young children and they vary in the level of acuity that they can elicit and the method of testing. Some of the visual acuity charts developed for young children include the Screening Test for Young Children and Retardates (STYCAR), the Sheridan-Gardiner modification of the STYCAR, HOTV, tumbling E, Landolt C and various picture charts. The problem with tumbling E or Landolt C is that children often have left-right directionality confusion (Simon, 1983). Sometimes children are unable to physically match the direction of the E or C. Pictures recognition charts require the child to be familiar with the objects on the chart and to verbally name the object. Picture charts are also harder to correlate with the standard letter acuity optotypes (Simon, 1983). The Allen Picture Chart only measures down to 20/30, so the level of acuity measured is limited. The HOTV, a modified version of the STYCAR, utilizes a matching task where the child points to the near card of the letter that matches the letter held up in the distance. The HOTV has a higher testability and acuity than the tumbling E.

Acuity norms for children age 2 to 7 years of age varies greatly. Some studies have found normal adult acuities of 20/20 in preschool children, while others report 20/20 is not achieved until after age 7 (Fern and Manny, 1986). There is no standardized visual acuity test. Fern and Manny (1986) found that "Visual acuities reported for 3-year-olds range from 6/6 to 6/18 and those for 6-year-olds range from about 6/5 to 6/11." Visual acuity tests can elicit a variety of acuity levels depending on the type of presentation (single optotype or line), and distance used. Several studies have found that isolated letter acuities are better than line charts or isolated

letters with contour bar surrounds (Lippmann, 1971; Fern and Manny, 1986). Sheridan found visual acuity of 6/4.5 in both eyes of 64 % of 5 year olds and 61% of 6 year olds with isolated letters presented at 6 meters but the children had been prescreened for 20/20 acuity (Fern and Manny, 1986). A more standardized testing method would help to establish acuity norms for the young. Most agree that the distance visual acuity norms of 4-5 year olds is at least 20/30 although, a Swedish study suggests 20/25 be used (Simon, 1983). According to Fern and Manny (1986), both the HOTV and the STYCAR elicited 20/20 visual acuity's in 3 year olds. As one can see, there is variability in the norms for visual acuity in this age group. A 3 meter test distance is suggested by several studies to keep young children engaged and attending to the task. At 6 meters or 20 feet, children pay less attention to stimuli and easily distracted. The National Academy of Sciences' National Research Council recommends testing at 3-4 meters for young children (Simon, 1983). It is reported in the literature, that young children do not cooperate as well for tests requiring attention to distance targets (Marsh-Tootle et al., 1994).

Most screenings in the literature utilize monocular acuities rather than binocular acuity. A line or two acuity difference between the two eyes can help to detect amblyopia or some visual anomaly. In a screening, Lippmann reports that binocular acuity is not necessary, though in rare cases binocular acuity may be lower than monocular acuities (e.g., hyperopic anisometropia, suppression of the better eye). In these cases however, the screening will still pick up the decreased monocular visual acuities (Lippmann, 1971).

Many modifications have been made to acuity tests to engage the child and increase testablity. The Tumbling E has been utilized in the Do as I do Clown, changed into black birds or added to animals. The Landolt C has been integrated into the broken wheel test. Devices to administer screening tests have been reported in the literature. Some of the devices are the Keystone stereoscope, Michigan Preschool

Test, the Titmus Vision Tester, Scolatest, and a modified view master (Lippmann, 1971; Jacob et al., 1988; Keller, 1982). Often these tests are near devices that simulate distance viewing. When the patient is in the device, accommodation is stimulated which can decrease the visual acuity in instrument. Therefore, an instrument that uses real distances in real space is preferable. Most agree that screening devices should be easy to use, easy to transport, and relatively inexpensive.

The Goodwin Acuity Test (GAT), utilizes a matching exercise on an educational robot. The Playskool Alphie®, with which many children are familiar, is an educational toy that uses cards with pictures of a sequence of 3 objects in one column which are then matched in sequence to pictures of the objects in the second column (Figure 1). These pictures were replaced with letters of different visual acuity demands. The robot provides feedback with sounds and lights indicating correct or incorrect answers. In this experiment, kids are asked to look at a line of three letters and push buttons on the robot that matched the sequence. Since this technique is based on matching, it is not necessary for children to know the alphabet or verbally identify the targets. Various acuity charts can be used, such as Snellen, Tumbling E, Landolt C's, or Allen pictures. For this experiment, a distance and near logMAR chart with Sloan letters was created and utilized. Different cards make it possible to test both distance and near acuity.

The goal of our study is to determine the potential for the GAT as a screening tool. The GAT was evaluated in the areas of acuities obtained, time of administration, and relative enjoyment of the children. A secondary goal of this project was to analyze a new 4 meter and 33 centimeter visual acuity chart. The charts were created employing optometric principals but were intended specifically for use with the Playskool Alphie®. The GAT utilizes a motor output matching game rather than the usual verbal output expected from the child. Children push buttons to match the letters seen. Our hypothesis is that the administration of the

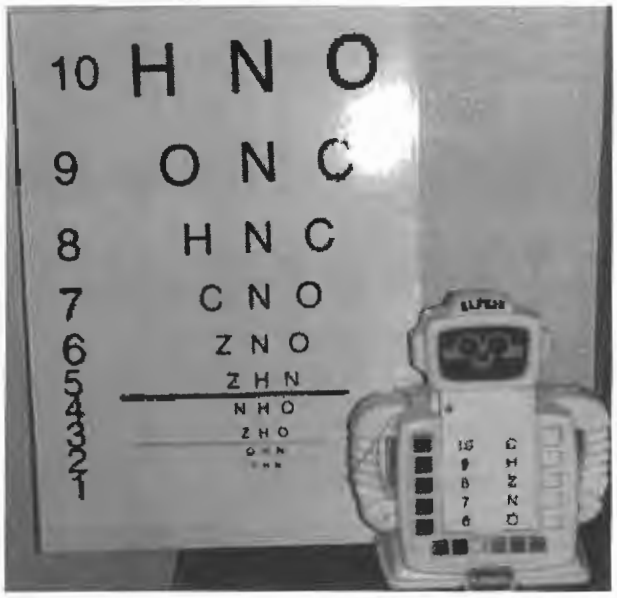


Figure 1. Playskool Alphie® with 4 meter acuity chart and matching card.

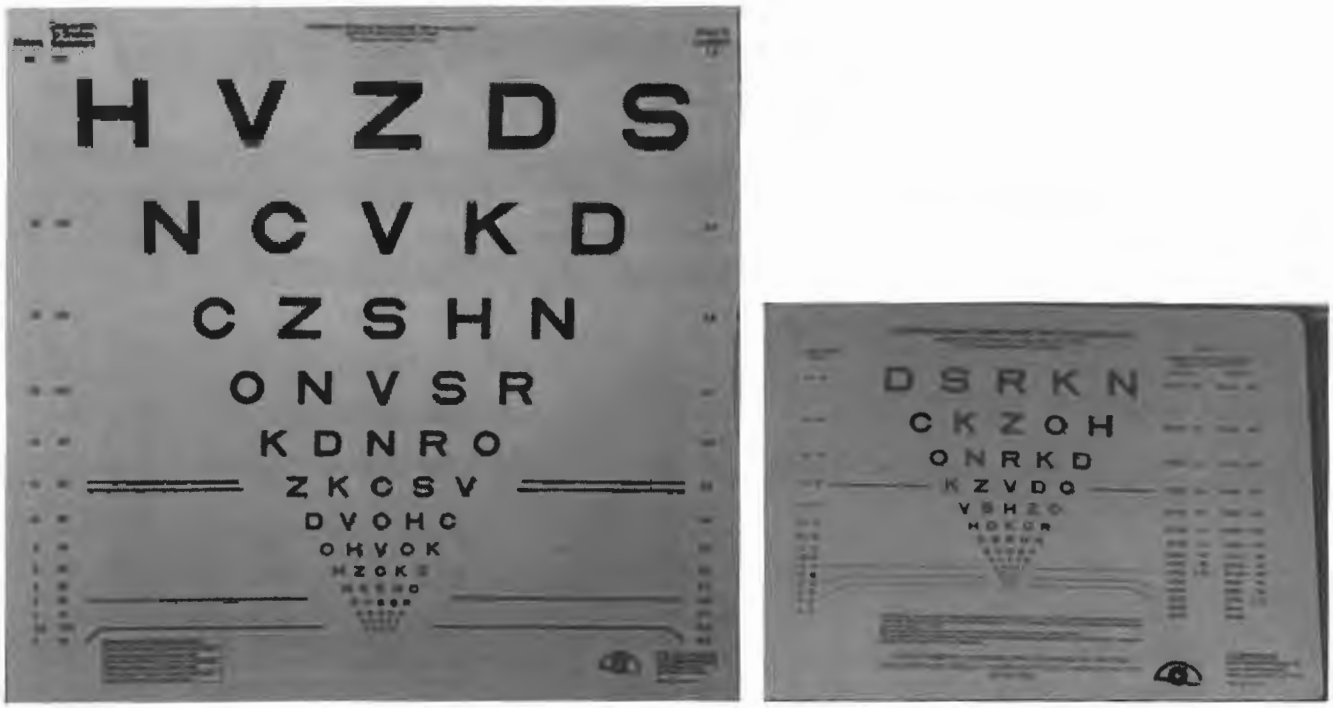


Figure 2. The Snellen charts used were the 4m and 40 cm Lighthouse Visual Acuity Test (2nd edition), both are modified ETDRS charts with Sloan letters.

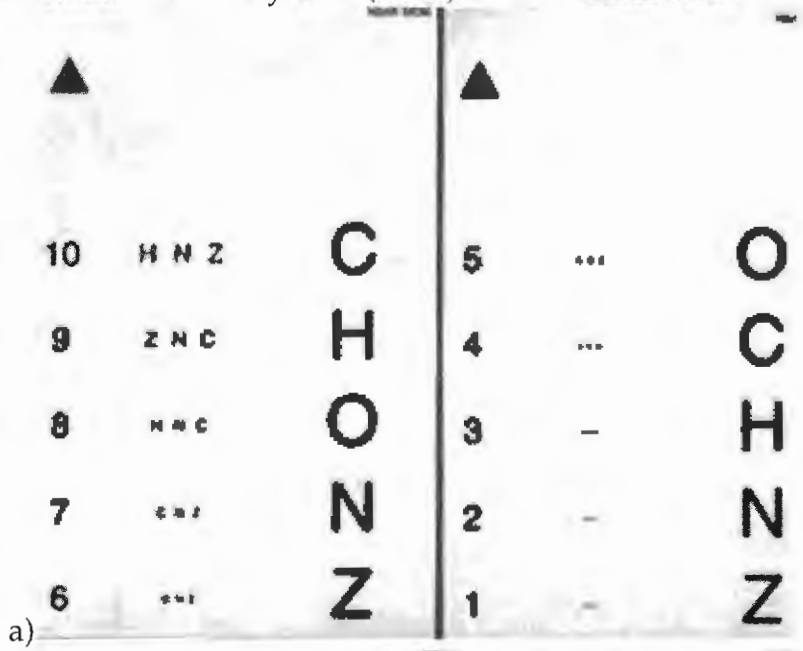
GAT would be faster and more enjoyable than Snellen with comparable visual acuity results.

Methods

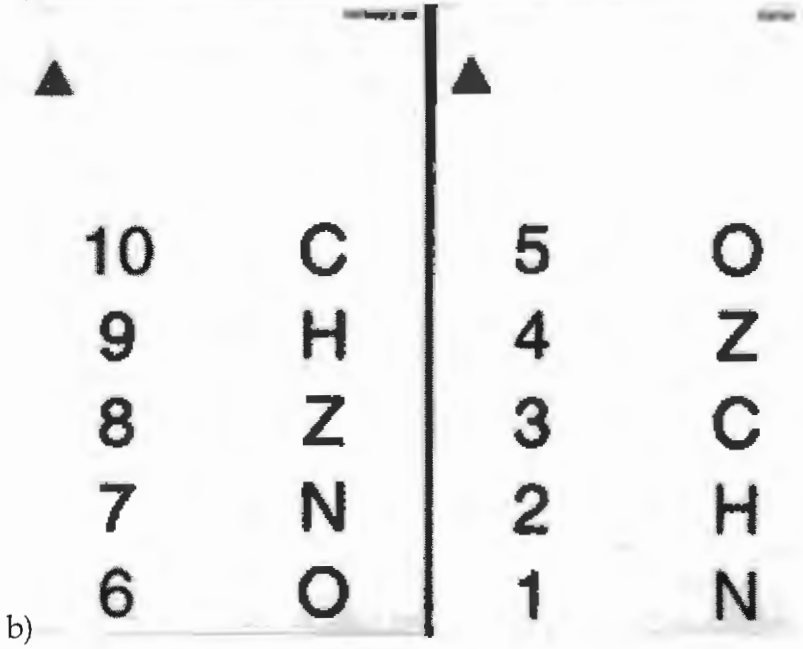
Data was collected at a Pacific University College of Optometry screening of the first grade classes of Washington Elementary in Woodburn, Oregon. Twenty-five first graders ranging in ages 6.4 years to 8.8 years were screened with the Modified Clinical Technique. There were 10 males and 15 females with an average age of 7.1 years. One female subject did not complete GAT testing at near so these results are based on the remaining 24 subjects. Time was not recorded for one male subject for the GAT at near so all analysis of time are based on the remaining 23 subjects. During the screening, visual acuity was measured by 3rd year optometry students and one optometrist and administration time was recorded for each test distance and device. For our study, we measured the acuity of the right (OD) and left (OS) eye at both far and near with the GAT and a Snellen type chart. The Snellen charts used were the 4m Lighthouse Distance Visual Acuity Test (2nd edition) and the 40 cm Lighthouse Near Visual Acuity Test (2nd edition) which are Early Treatment of Diabetic Retinopathy Study (ETDRS) logMAR charts modified with Sloan letters (Figure 2). A string was attached to the Alphie® and to the Lighthouse Near Acuity Test to monitor the near testing distance.

The Goodwin Acuity Test charts were created with Helvetica font on a personal computer (PC) with Word Perfect for both 4 meters and 33 centimeters. Helvetica font has no serifs. On the far chart, there were 10 lines of 3 letters with acuities ranging from 20/20 to 20/160 with logMAR spacing (Figure 3) (Bailey and Lovie, 1976). Each of the lines of acuity were numbered from 1 (20/20) to 10 (20/160). The near cards used with the distance chart replaced the first column of 3 letters with the acuity line number from the 4 meter acuity chart and the second column of

Figure 3. Goodwin Acuity Test (GAT) 4 meter chart with the Alphie®.



a)



b)

Figure 4. *a.* GAT 33 cm charts. *b.* GAT 4m matching charts.

letters were 20/400 letters. The near acuity cards had 5 lines so 2 cards were necessary, one from 20/20 to 20/50 and the second from 20/63 to 20/160 (Figure 4). The matching single letter choices in the second column were 20/400 letters. The charts were printed on a Hewlett Packard Laser Jet 4mp printer with 600 dpi resolution and laminated. The Alphie® is able to recognize a predetermined sequence, so the letters on the chart had to be arranged in the same order.

Only 5 of the 10 Sloan letters could be used at a time for the GAT charts so the Sloan letters H, O, C, N, and Z were chosen. Paired Sloan letters were used because they can easily be confused with each other, therefore decreasing the likelihood of guessing. Ideally, test objects should contain various contours including horizontal, oblique, vertical and curved so that they have to be clearly focused in all meridians to be recognized (Sloan, 1951). Sloan letters test all meridians and have letter pairs of relative similar difficulty, since it has also been recognized that not all letters are of equal difficulty. (Wong and Kaye, 1989). Both the 4 m and 40 cm ETDRS Lighthouse Charts were from Lighthouse Low Vision Products of Long Island, New York. These charts utilize all 10 Sloan letters so they include H, O, C, N, Z, V, S, D, K, and R. For the distance chart, the 10 acuity lines from 20/20 to 20/160 were used.

With the Goodwin Acuity Test at near and far, the child was told they were going to play a matching game. They were to push the buttons of the letters on the column on the right side of the Alphie® that matched the row of 3 letters on the left side starting at the 20/40 (line 4) acuity line. After each push of the button, the Alphie® played happy music if the answer was correct and unhappy music if the answer was incorrect. The newer model of the Alphie® talked and congratulated the student if the answer was correct and encouraged them to try again if the answer was wrong. If the child was unable to see the 20/50 line, the second near acuity card (20/63-20/160) was used. During the 'Snellen' distance and near acuity testing, the child started calling out the 20/40 line and was asked to read across each acuity line

until they got one incorrect or got to 20/20. Our pass criteria was 20/30 or better for both distances or a difference in acuity between the two eyes. If a child was 20/20 at distance, the child was asked to read the 20/40 line with +1.50 diopter lens in place to check for hyperopia. The illuminance of the room measured with a GE type 213 light meter was 35 foot candles for each distance and near chart.

Two visual acuity stations were set up and distinguished by number and color. A red #1 was used for the ETDRS station and a blue #2 for the GAT station. Each station had one person who performed both near and far visual acuity testing, while a second person timed and recorded the administration time and visual acuities. The administration time recorded combined the time for both eyes at each distance and included instruction time for the test. The examiner of each test was unaware of the results of previous testing. A third station was set up with a coordinator who sent the child to the appropriate station. The acuity coordinator assigned an order to each student based upon the fully balanced 4-item Latin square design to ensure that each of the four possible sequences in which the subjects could be run through the test battery were equally represented. The Latin square design ensures that testing order does not affect the subject's performance. The testing sequence consisted of four combinations of ETDRS distance, ETDRS near, GAT distance, and GAT near (see Table 1). In our study, the right eye was always tested first.

Order	*First Test*	*Second Test*	*Third Test*	*Fourth Test*
A	ETDRS distance	ETDRS near	GAT distance	GAT near
B	ETDRS near	GAT distance	GAT near	ETDRS distance
C	GAT distance	GAT near	ETDRS distance	ETDRS near
D	GAT near	ETDRS distance	ETDRS near	GAT near

Table 1. Order of testing based on 4-item Latin square design.

When the coordinator assigned a child with an order, he also explained to each child that there would be two different tests and that they would be asked which one they liked better when they were finished. After the child made it through all

four acuity checks, he was sent back to the coordinator who administered the verbal questionnaire. The questionnaire consisted of two questions: 1) Did you like the blue or red test better? 2) Which test was easier? After the visual acuity test, the first grader was sent to the next station in the MCT battery.

Results

There is no statistically significant difference in the visual acuity measured between the Goodwin Acuity Test and ETDRS charts. Using a repeated measures analysis of variance, visual acuities did not differ significantly for chart used ($p=0.33$) or test distance ($p=0.096$) (Table 2). There is no significant difference in acuity between the right and left eye ($p=0.904$). At 4 meters, the ETDRS and the GAT logMAR visual acuities are similar between the two eyes (Table 3 and Figure 5). Combined OD and OS distance acuity is approximately 0.18 or a Snellen equivalent of 20/30. At near, the combined GAT logMAR acuity of 0.098 (20/25) is better than the ETDRS acuity of 0.167 (20/30) (Table 3 and Figure 5). The near acuity for both charts is almost significantly better ($p= 0.059$) than the far charts.

Effect	F-ratio*	p value**
Chart	0.98	0.333
Distance	2.98	0.096
Eye	0.004	0.904
Chart x Distance	3.86	0.059
Chart x Eye	0.16	0.692
Distance x Eye	1.38	0.251
Chart x Distance x Eye	0.20	0.666

Table 2. Anova repeated measures comparison of visual acuities.
*Degrees of Freedom (df) = (1,23), **significant if $p \leq 0.05$.

Visual Acuity	OD	OS	Combined	OD	OS	Combined
ETDRS 4 m	0.174	0.192	0.183	$20/30^{+1}$	20/30	$20/30^{+1}$
GAT 4 m	0.181	0.195	0.188	20/30	20/30	20/30
ETDRS 40 cm	0.167	0.166	0.167	$20/30^{+2}$	$20/30^{+2}$	$20/30^{+1}$
GAT 33 cm	0.108	0.088	0.098	20/25	20/25	20/25

Table 3. Visual acuities in logMAR and Snellen equivalent for right eye, left eye and both eyes combined.

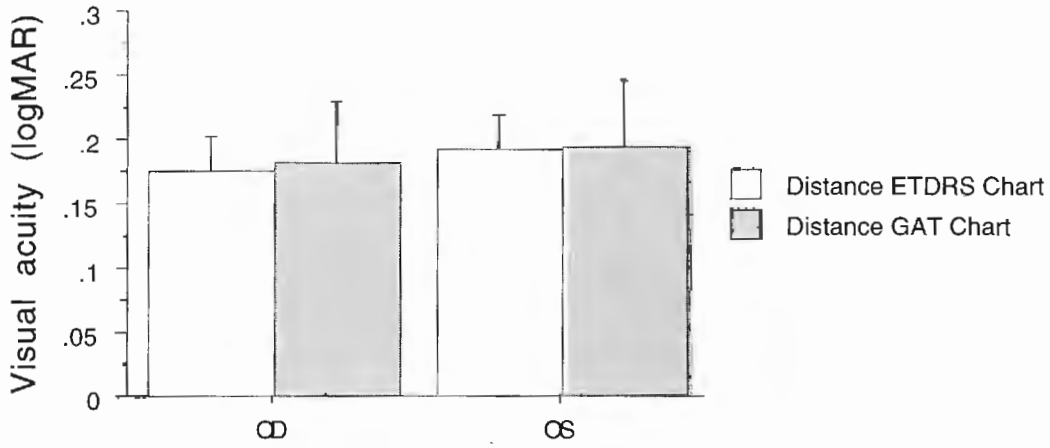


Figure 5 Visual acuity measured at 4 meters with the ETDRS and GAT.

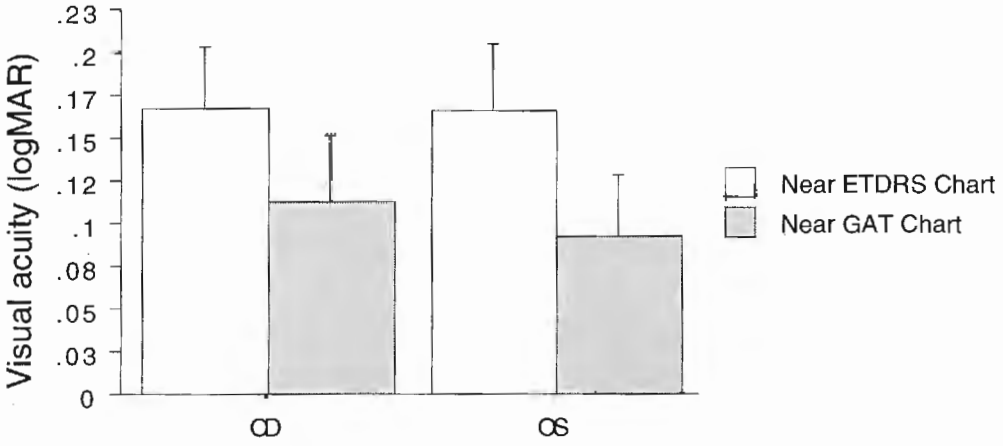


Figure 6 Visual acuity measured at 40 centimeters for the ETDRS and 33 cm for the GAT.

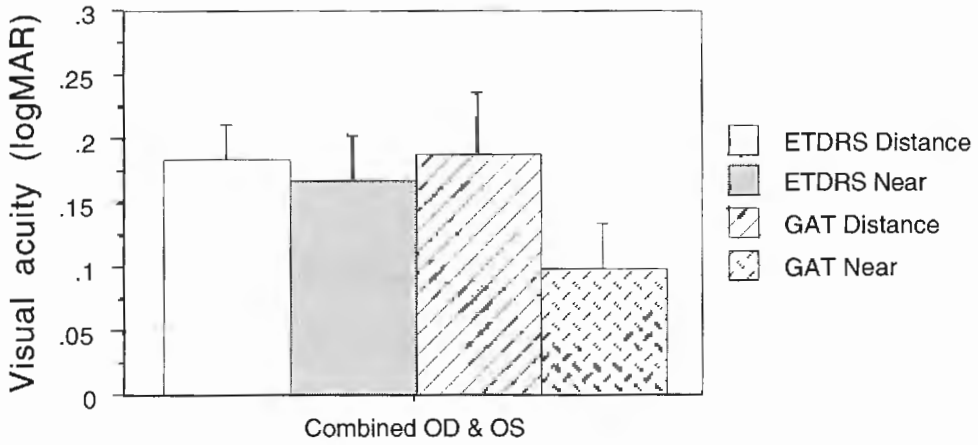


Figure 7. Combined OD and OS visual acuity data for all distances.

Administration time for the GAT and ETDRS is significantly different. Testing time analyzed using a repeated measures of variance analysis between the two charts was statistically significant ($p \leq 0.05$) (Table 4). The ETDRS required approximately 2 minutes to administer at each distance of 4 meters and 40 centimeters and the GAT required about 4 minutes at each distance (Figure 8 and Table 5). Each chart itself has no significant time difference when given at far or near. If the near and distance test time were combined, the ETDRS takes 4.29 minutes to administer and the GAT requires 7.36 minutes.

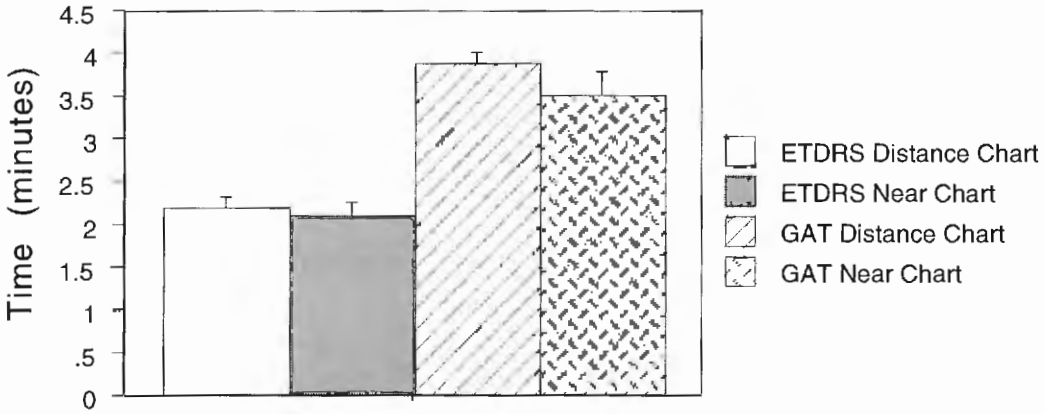


Figure 8. Administration time at 4 m and 40 cm with the ETDRS, and 4 m and 33 cm with the GAT.

Effect	F-ratio*	p value**
Chart	98.48	0
Distance	1.26	0.274
Chart x Distance	1.06	0.316

Table 4. Anova repeated measures comparison of administration time between the charts, distance and chart plus distance. *Degrees of Freedom = (1,22). **significant if $p \leq 0.05$.

Chart	Far time (minutes)	Near time (minutes)	Combined time (minutes)
ETDRS	2.20	2.09	4.29
GAT	3.86	3.50	7.36

Table 5. Comparison of an administration time between charts at distance, near and the combined distance and near.

We evaluated test order [early (A, B) vs. late (C, D)] based on Latin Square protocol and found no significant effect in test order, $F(1,21) = 2.22$ and $p = 0.148$. Thus, we conclude that any differences are not due to learning effects or fatigue.

In the verbal questionnaire, 80% of the first graders liked the GAT better than the standard Snellen-like logMAR test (Figure 9a). About 68% of the students thought that the GAT was easier than the ETDRS (Figure 9b). One first grader thought both tests were easy and one thought that neither test was easy.

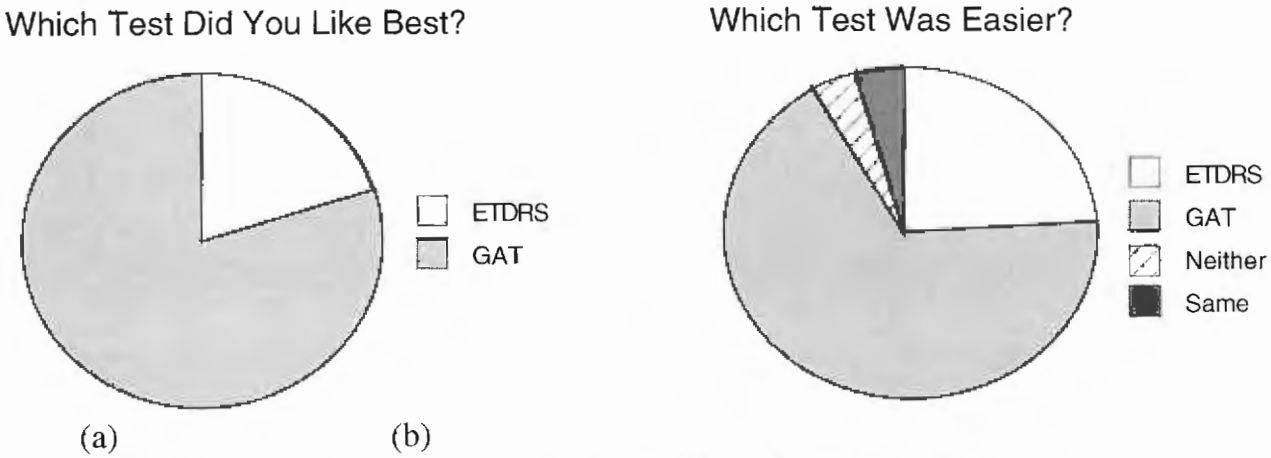


Figure 9. Questionnaire results. (a)Which test liked the best. (b) Which test was easier.

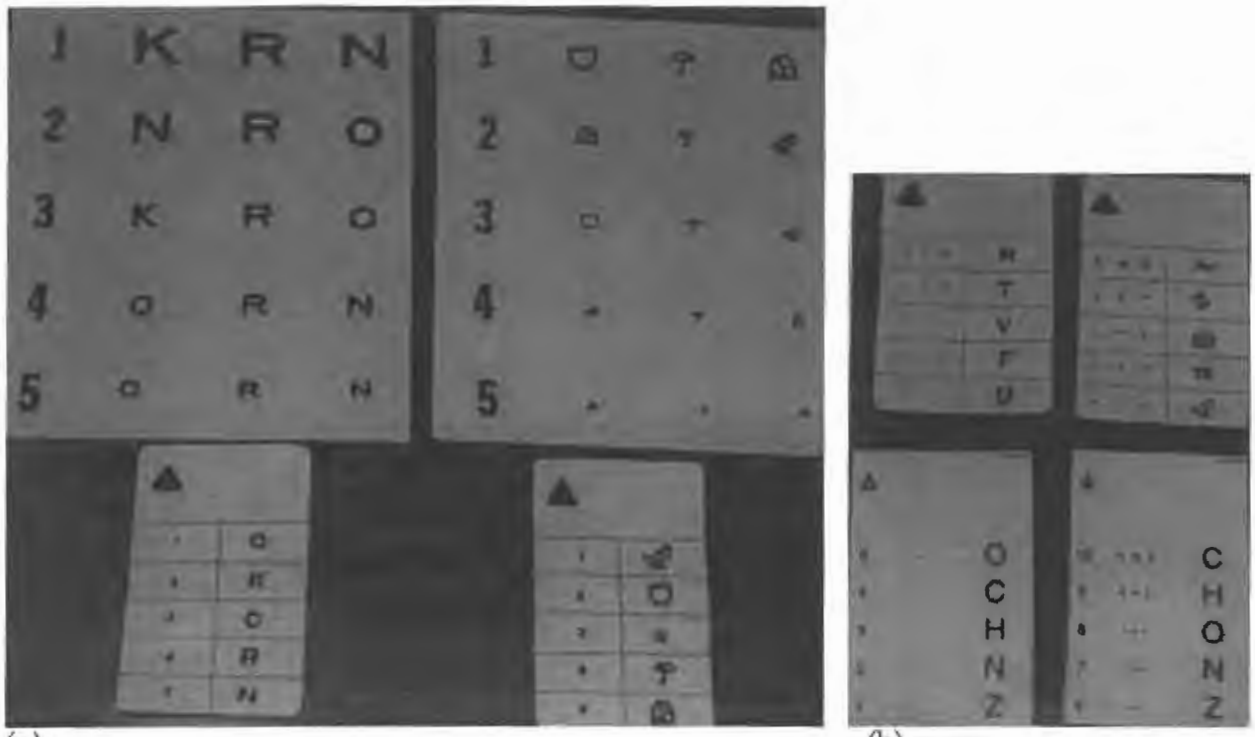
Of the 25 first graders screened, approximately 8 students failed the screening. Seven of these students did not pass visual acuity however, they failed one other criterion in the screening battery. The one other criterion failed by 6 of the 7 was refractive error and one first grader had poor ocular motility. The eighth student who failed the screening, passed the visual acuity test but failed the hyperopia and refractive error criteria.

Discussion

The optometric standard for measuring visual acuity is the Snellen chart. Therefore, any chart used as a substitute to measure visual acuities must produce

comparable results. As we originally hypothesized, the visual acuities measured with the Goodwin Acuity Test did correlate to the ETDRS 'Snellen' type results. Statistical analysis of acuity reveals no significance with $p< 0.05$. The visual acuity of the right and left eye combined for the 4m ETDRS logMAR is 0.183 (20/30) and the GAT is 0.188 (20/30). For the near chart, combined visual acuity is 0.167 logMAR (20/30) for ETDRS and 0.98 logMAR (20/25) for the GAT. These acuities include the 7 first graders that failed visual acuities which may have reduced the mean acuity found. For the 6-7 year old, acuities of 20/30-20/25 are within the normal range reported in other studies. There was no statistically significant difference in the acuity measured with both charts.

A second aspect of our hypothesis, was that administration of the GAT would be quicker than Snellen. However, we found that GAT administration time took longer than the standard screening method, thereby proving our hypothesis false. This longer administration time negatively affected our screening and would affect other screenings the same way. The backlog of students at the visual acuity station was also due to the 4-item Latin square design which required children to go back and forth between the GAT and ETDRS near and far stations. In addition, due to this study, visual acuity at far and near had to be administered twice. We discontinued administering the GAT because the screening was so backed up. The GAT testing time was longer because the Playskool Alphie® would play a tune between each button pushed in the 3 letter sequence. Most children could match vocally or point faster than waiting for the Alphie® to reset for the next letter in the row. A few of the children expressed some annoyance with the wait time or tried to push the next button before the robot had finished it's tune. The children may have been unsure of how to use the GAT initially since we failed to put the column and row lines on the charts. The original Goodwin Acuity Test charts had lines so the matching activity was more clear (Figure 10 a and b).



(a) (b)

Figure 10. *a.* The original GAT distance charts. *b. Top,* the original GAT near charts. *Bottom,* the new GAT near charts.

Figure 11. The original GAT near charts with isolated letter presentation. Each chart is a single acuity level.

Some first graders did not go to the acuity station first due to the nature of screenings. Since there was quite a long wait at the acuity stations, kids went to the other stations like ocular motility, ophthalmoscopy and retinoscopy. However, sufficient time was given to recover from retinal bleaching. We believe that even though the GAT took longer to administer, the charts themselves were useful. Without the Alphie®, GAT charts are similar to the STYCAR. In one study, 5-6 year olds required 1.4 minutes testing time with the STYCAR at 20 ft, though it is not clear whether monocular acuities were tested and whether training time was included (Lippmann, 1971). Construction of the GAT charts was based on a logMAR spacing with three letters per line. Three letters per line provides a balance between too many letters, which requires more time than necessary, and too few letters, which would not provide statistical significance (Wong and Kaye, 1989). Acuity charts such as Bailey-Lovie and ETDRS that have many letters require more time than necessary. As Wong and Kaye (1989) discussed, "The statistical considerations given above suggest that 2 letters per character size is sufficient to achieve significance ($p<0.01$) when measuring visual acuity. If a subject reads both letters correctly, there is little point in presenting more letters on that line, because significance has already been reached." One weakness of the Sheridan-Gardiner or STYCAR test is that a single optotype letter is presented, therefore may fail to pick up amblyopia. The charts we created included a crowding factor so that amblyopia could be picked up.

The third aspect of the GAT evaluated was interest and relative enjoyment. As hypothesized, the GAT was more fun for the children as was determined by a questionnaire. About 20 students (80%) liked the GAT better. The GAT seemed more like a game to the children since Alphie® gave constant feedback, kept the attention of the children, and motivated them to try the smaller letters. Most children enjoyed the matching game and 17 first graders (68%) thought the GAT was

easier. Lippmann found that children enjoy matching tasks more than the Tumbling E (Lippmann, 1971).

Screening the general pediatric population with the GAT is potentially as fast and reliable as a standard Snellen screening. During the screening, some first graders unsure of the letters of the alphabet utilized matching which is more accurate than calling out the wrong letter. There were some Hispanic children that we were unable to communicate with but they figured out how to match the letter seen. During the screening, one multiple handicapped child unable to speak was able to match letters by pointing or pushing the buttons on the Alphie®. We isolated letters so he could push buttons in the correct order. For special populations, especially ones that were unable to communicate verbally, there could be charts created for the GAT that allowed matching of isolated letters. Single letter optotype near charts are available in the original GAT charts (Figure 11) and these cards have a square at the top of the card. Each card represents a single acuity level and the child simply matches all 5 letters in the column. The Alphie® keeps the child attending while, giving them constant musical or verbal feedback at every step.

The GAT can be used in a number of ways. It can still be used with the Alphie® to help young children feel more comforTable, and it's music and buttons can be disregarded or the acuity charts can be used without the Alphie®. When difficulty arises with young children unsure of their alphabet or unable to speak English, one could quickly switch to a matching task. Preschool children or special handicapped populations would be engaged by the Alphie's ® lights, music, and verbal encouragement and the slower pace may be more helpful. Further testing on more students, and a variety of age groups is necessary to assess whether this could be a new standard screening device for preschool children.

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Appendix

Table A. Raw visual acuity (VA) and time data.

Q1: Did you like the Blue or Red test better? (35 foot candles illuminance)
Q2: Which test was easier? Minutes:seconds:100th of second

		Birth date	Order		Dx(time)	ETDRS VA	Nr (time)	VA	Dist	GAT VA	Near	VA	Q#1	Q#2
1	female	11-5-89	A	OD	0.12	25-1	0.8	125	0.9	150	0.9	150	GAT	Neither
		7.4		OS	0.12	25-1	0.8	125	0.933	150-1	0.833	125-1		
					2:43:66		**1:42:10**		**3:00**		**1:50**			
2	female	9-16-89	B	OD	0.06	25+2	0.02	20-1	0	20	-		GAT	ETDRS
		7.6		OS	0.16	32+2	0.08	25+1	0	20	-			
					1:49:56		**1:20:50**		**3:02**		-			
3	female	3-15-90	C	OD	0.22	32-1	0.04	20-2	0.3	40	0.1	25	GAT	GAT
		7.0		OS	0.22	32-1	0.06	25+2	0.2	30	0.033	20-1		
					2:44:68		**3:28:50**		**2:37:69**		**4:04:03**			
4	female	3-3-90	D	OD	0.18	32+1	0.2	30	0.2	30	0.2	30	GAT	GAT
		7.0		OS	0.2	32	0.1	25	0.2	30	0	20		
					1:32:44		**1:44:18**		**3:22**		**3:46**			
5	female	8-24-90	A	OD	0.24	32-2	0.26	40+2	0.933	>160	0.333	40-1	GAT	Same
		6.6		OS	0.24	32-2	0.22	30-1	0.6	80	0.2	30		
					1:51:19		**1:37:34**		**4:16**		**1:34**			
6	female	3-29-90	B	OD	0.02	20-1	0.16	30+2	0	20	0	20	ETDRS	GAT
		6.11		OS	0	20	0.02	20-1	0	20	0	20		
					2:26		**1:25:09**		**3:57:44**		**2:42:79**			
7	male	2-9-90	C	OD	0.2	32	0.14	25-2	0.233	30-1	0.066	25+1	GAT	GAT
		7.1		OS	0.2	32	0.5	60	0.2	30	0.333	40-1		
					3:14:12		**2:27:57**		**4:05**		**2:58:64**			
8	female	2-28-90	D	OD	0.16	32+2	0.12	25-1	0.133	25-1	0	20	GAT	GAT
		7.0		OS	0.18	32+1	0.14	25-2	0.133	25-1	0	20		
					1:36:62		**1:44:25**		**2:57:88**		**3:25:40**			
9	female	11-20-89	A	OD	0.08	25+1	0.06	25+2	0.133	25-1	0	20	GAT	GAT
		7.4		OS	0.2	32	0.08	25+1	0.066	25+1	0	20		
					2:00:31		**1:32:91**		**4:03**		**2:57:49**			
10	female	12-31-89	B	OD	0.08	25+1	0.02	20-1	0	20	0	20	GAT	GAT
		7.2		OS	0.28	40+1	0.08	25+1	0.233	30-1	0.166	25-2		
					1:40:56		**2:31:78**		**4:09:75**		**3:40:90**			
11	female	5-14-90	C	OD	0.14	25-2	0.1	25	0.133	25-1	0	20	GAT	GAT
		6.10		OS	0.22	32-1	0.12	25-1	0.166	30+1	0.1	25		
					2:45:88		**3:31:43**		**4:05:54**		**3:28:96**			
12	female	9-11-89	D	OD	0.18	32+1	0.12	25-1	0.2	30	0.366	50+1	GAT	GAT
		7.6		OS	0.16	32+2	0.22	32-1	0.066	25+1	0	20		
					2:15:44		**3:37:53**		**3:35:48**		**8:05:00**			
13	male	10-31-89	A	OD	0.14	25-2	0.16	30+2	0.133	25-1	0	20	GAT	GAT
		7.4		OS	0.14	25-2	0.2	30	0.2	30	0.066	25+1		
					2:04:37		**1:22:22**		**4:22:22**		**2:56:60**			
14	female	10-30-89	B	OD	0.22	32-1	0.12	25-1	0.133	25-1	0	20	GAT	GAT
		7.4		OS	0.14	25-2	0.06	25+2	0.1	25	0	20		
					1:41:40		**1:48:75**		**3:56:29**		**2:21:51**			
15	male	10-15-89	D	OD	0.18	32+1	0.58	80+1	0	20	0	20	GAT	GAT
		7.5		OS	0.16	32+2	0.52	60-1	0	20	0	20		
					1:45:79		**3:53:65**		**3:38:46**		**3:00:00**			
16	male	2-9-90	A	OD	0.48	63+1	0.32	40-1	0.133	25-1	0.066	25+1	GAT	ETDRS
		7.1		OS	0.44	50-2	0.24	32-2	0.2	30	0	20		
					3:11:87		**1:26:28**		**4:58:07**		**3:42:48**			
17	male	8-3-90	B	OD	0.1	25	0.12	25-1	0	20	0.133	25-1	GAT	GAT
		6.7		OS	0.1	25	0.14	25-2	0	20	0.1	25		
					2:08:97		**2:02:35**		**4:54:41**		**3:20:00**			
18	female	9-4-89	C	OD	0.68	100+1	0.18	30+1	0.333	40-1	0.066	25+1	GAT	ETDRS
		7.6		OS	0.68	100+1	0.22	30-1	0.933	>160	0.066	25+1		
					3:48:88		**2:30:00**		**3:16:46**		**5:10:01**			
19	male	1-22-90	D	OD	0.06	25+2	0.04	20-2	0.033	20-1	0.1	25	ETDRS	ETDRS
		7.2		OS	0.08	25+1	0.02	20-1	0.1	25	0	20		
					1:46:13		**1:17:41**		**3:53:50**		*			
20	male	6-15-90	A	OD	0.14	25-2	0.06	25+2	0.1	25	0	20	ETDRS	GAT
		6.9		OS	0.06	25+2	0.04	25+3	0.133	25-1	0	20		
					2:23:44		**1:16:66**		**3:37:41**		**3:20:79**			

Table A. Raw visual acuity (VA) and time data.

21	male	11-6-90	B	OD	0.08	25+1	0		20	0.1	25	0.1	25	GAT	GAT
		6.4		OS	0.06	25+2	0.02	20-1		0.1	25	0.1	25		
					1:53:46		**2:00:50**			**3:54:06**		**3:13:19**			
22	female	7-15-88	D	OD	0.18	32+1	0.06	25+2		0.233	30-1	0.033	20-1	ETDRS	ETDRS
		8.8		OS	0.24	32-2	0.04	20-2		0.1	25	0.1	25		
					1:18:72		**1:24:94**			**3:48:78**		**4:42:53**			
23	male	1-26-90	A	OD	0.22	32-1	0.2		30	0.166	30+1	0.133	25-1	ETDRS	ETDRS
		7.1		OS	0.26	40+2	0.2		30	0.2	30	0.1	25		
					2:15:56		**2:49:75**			**5:31:35**		**4:05:99**			
24	female	3-13-90	C	OD	0.08	25+1	0.12	25-1		0	20	0.1	25	GAT	GAT
		7.0		OS	0.08	25+1	0.02	20-1		0	20	0	20		
					2:09:75		**1:41:56**			**3:46:49**		**2:48:03**			
25	male	5-18-90	D	OD	0.12	25-1	0.18	32+1		0	20	0	20	GAT	GAT
		6.10		OS	0.18	32+1	0.02	20-1		0	20	0	20		
					1:43:50		**1:58:40**			**3:43:81**		**3:20:41**			

Table B. VA and time by chart and distance; and questionnaire results.

	males=10, females=15; 8 failed screening										
		Order	Birth Dates	Time (sec)	Time (min)	OD VA	OS VA	OD + OS	Q#1	Q#2	Q#1	Q#2
1	ETDRS DX	A	7.4	164.00	2.73	0.12	0.12	0.12	GAT	Neither	2	4
2	ETDRS DX	B	7.6	110.00	1.83	0.06	0.16	0.11	GAT	ETDRS	2	1
3	ETDRS DX	C	7.0	165.00	2.75	0.22	0.22	0.22	GAT	GAT	2	2
4	ETDRS DX	D	7.0	92.00	1.53	0.18	0.2	0.19	GAT	GAT	2	2
5	ETDRS DX	A	6.6	111.00	1.85	0.24	0.24	0.24	GAT	Same	2	3
6	ETDRS DX	B	6.11	146.00	2.43	0.02	0	0.01	ETDRS	GAT	1	2
7	ETDRS DX	C	7.1	194.00	3.23	0.2	0.2	0.2	GAT	GAT	2	2
8	ETDRS DX	D	7.0	97.00	1.62	0.16	0.18	0.17	GAT	GAT	2	2
9	ETDRS DX	A	7.4	120.00	2.00	0.08	0.2	0.14	GAT	GAT	2	2
10	ETDRS DX	B	7.2	101.00	1.68	0.08	0.28	0.18	GAT	GAT	2	2
11	ETDRS DX	C	6.10	166.00	2.77	0.14	0.22	0.18	GAT	GAT	2	2
12	ETDRS DX	D	7.6	135.00	2.25	0.18	0.16	0.17	GAT	GAT	2	2
13	ETDRS DX	A	7.4	124.00	2.07	0.14	0.14	0.14	GAT	GAT	2	2
14	ETDRS DX	B	7.4	101.00	1.68	0.22	0.14	0.18	GAT	GAT	2	2
15	ETDRS DX	D	7.5	106.00	1.77	0.18	0.16	0.17	GAT	GAT	2	2
16	ETDRS DX	A	7.1	192.00	3.20	0.48	0.44	0.46	GAT	ETDRS	2	1
17	ETDRS DX	B	6.7	129.00	2.15	0.1	0.1	0.1	GAT	GAT	2	2
18	ETDRS DX	C	7.6	229.00	3.82	0.68	0.68	0.68	GAT	ETDRS	2	1
19	ETDRS DX	D	7.2	106.00	1.77	0.06	0.08	0.07	ETDRS	ETDRS	1	1
20	ETDRS DX	A	6.9	143.00	2.38	0.14	0.06	0.1	ETDRS	GAT	1	2
21	ETDRS DX	B	6.4	113.00	1.88	0.08	0.06	0.07	GAT	GAT	2	2
22	ETDRS DX	D	8.8	79.00	1.32	0.18	0.24	0.21	ETDRS	ETDRS	1	1
23	ETDRS DX	A	7.1	136.00	2.27	0.22	0.26	0.24	ETDRS	ETDRS	1	1
24	ETDRS DX	C	7.0	130.00	2.17	0.08	0.08	0.08	GAT	GAT	2	2
25	ETDRS DX	D	6.10	104.00	1.73	0.12	0.18	0.15	GAT	GAT	2	2
			Mean	131.72	2.20	0.1744	0.192	0.1832	5 ETDRS	6 ETDRS	20%	24%
			Std Dev	36.32	0.61	0.14	0.14	0.13	20 GAT	17 GAT	80%	68%
			Median	124.00	2.07	0.14	0.18	0.17		1 neither		4%
			Mode	101	1.68333333	0.18	0.16	0.17		1 same		4%
			Min	79.00	1.32	0.02	0.00	0.01				
			Max	229.00	3.82	0.68	0.68	0.68				
		Order	Time	Time (sec)	Time (min)	OD VA	OS VA	OD + OS	Sex	Screening		
1	GAT DX	A	3:00:00	180.00	3.00	0.9	0.933	0.9165	female	Fail		
2	GAT DX	B	3:02:00	182.00	3.03	0	0	0	female			
3	GAT DX	C	2:38:00	158.00	2.63	0.3	0.2	0.25	female			
4	GAT DX	D	3:22:00	202.00	3.37	0.2	0.2	0.2	female			
5	GAT DX	A	4:16:00	256.00	4.27	0.933	0.6	0.7665	female	Fail		
6	GAT DX	B	3:57:00	237.00	3.95	0	0	0	female	Fail		
7	GAT DX	C	4:05:00	245.00	4.08	0.233	0.2	0.2165	male	Fail		
8	GAT DX	D	2:58:00	178.00	2.97	0.133	0.133	0.133	female			
9	GAT DX	A	4:03:00	243.00	4.05	0.133	0.066	0.0995	female			
10	GAT DX	B	4:10:00	250.00	4.17	0	0.233	0.1165	female	Fail		
11	GAT DX	C	4:06:00	246.00	4.10	0.133	0.166	0.1495	female			
12	GAT DX	D	3:35:00	215.00	3.58	0.2	0.066	0.133	female			
13	GAT DX	A	4:22:00	262.00	4.37	0.133	0.2	0.1665	male			
14	GAT DX	B	3:56:00	236.00	3.93	0.133	0.1	0.1165	female			
15	GAT DX	D	3:38:00	218.00	3.63	0	0	0	male	Fail		
16	GAT DX	A	4:58:00	298.00	4.97	0.133	0.2	0.1665	male	Fail		
17	GAT DX	B	4:54:00	294.00	4.90	0	0	0	male			
18	GAT DX	C	3:16:00	196.00	3.27	0.333	0.933	0.633	female	Fail		
19	GAT DX	D	3:54:00	234.00	3.90	0.033	0.1	0.0665	male			
20	GAT DX	A	3:37:00	217.00	3.62	0.1	0.133	0.1165	male			
21	GAT DX	B	3:54:00	234.00	3.90	0.1	0.1	0.1	male			
22	GAT DX	D	3:49:00	229.00	3.82	0.233	0.1	0.1665	female			
23	GAT DX	A	5:31:00	331.00	5.52	0.166	0.2	0.183	male			
24	GAT DX	C	3:46:00	226.00	3.77	0	0	0	female			
25	GAT DX	D	3:44:00	224.00	3.73	0	0	0	male			
			Mean	231.64	3.86	0.18116	0.19452	0.18784				
			Std Dev	39.23	0.65	0.24	0.26	0.24				
			Median	234.00	3.90	0.13	0.13	0.13				
			Mode	234	3.9	0	0	0				
			Min	158.00	2.63	0.00	0.00	0.00				
			Max	331.00	5.52	0.93	0.93	0.92				

Table B. VA and time by chart and distance; and questionnaire results.

		Order	Time	Time (sec)	Time (min)	OD VA	OS VA	OD + OS	Q#1	Q#2	Q#1	Q#2
1	ETDRS Nr	A	1:42:00	102.00	1.70	0.8	0.8	0.8				
2	ETDRS Nr	B	1:20:00	80.00	1.33	0.02	0.08	0.05				
3	ETDRS Nr	C	3:28:00	208.00	3.47	0.04	0.06	0.05				
4	ETDRS Nr	D	1:44:00	104.00	1.73	0.2	0.1	0.15				
5	ETDRS Nr	A	1:37:00	97.00	1.62	0.26	0.22	0.24				
6	ETDRS Nr	B	1:25:00	85.00	1.42	0.16	0.02	0.09				
7	ETDRS Nr	C	2:28:00	148.00	2.47	0.14	0.5	0.32				
8	ETDRS Nr	D	1:44:00	104.00	1.73	0.12	0.14	0.13				
9	ETDRS Nr	A	1:33:00	93.00	1.55	0.06	0.08	0.07				
10	ETDRS Nr	B	2:32:00	152.00	2.53	0.02	0.08	0.05				
11	ETDRS Nr	C	3:31:00	211.00	3.52	0.1	0.12	0.11				
12	ETDRS Nr	D	3:38:00	218.00	3.63	0.12	0.22	0.17				
13	ETDRS Nr	A	1:22:00	82.00	1.37	0.16	0.2	0.18				
14	ETDRS Nr	B	1:49:00	109.00	1.82	0.12	0.06	0.09				
15	ETDRS Nr	D	3:54:00	234.00	3.90	0.58	0.52	0.55				
16	ETDRS Nr	A	1:26:00	86.00	1.43	0.32	0.24	0.28				
17	ETDRS Nr	B	2:02:00	122.00	2.03	0.12	0.14	0.13				
18	ETDRS Nr	C	2:30:00	150.00	2.50	0.18	0.22	0.2				
19	ETDRS Nr	D	1:17:00	77.00	1.28	0.04	0.02	0.03				
20	ETDRS Nr	A	1:17:00	77.00	1.28	0.06	0.04	0.05				
21	ETDRS Nr	B	2:00:00	120.00	2.00	0	0.02	0.01				
22	ETDRS Nr	D	1:25:00	85.00	1.42	0.06	0.04	0.05				
23	ETDRS Nr	A	2:50:00	170.00	2.83	0.2	0.2	0.2				
24	ETDRS Nr	C	1:42:00	102.00	1.70	0.12	0.02	0.07				
25	ETDRS Nr	D	1:58:00	118.00	1.97	0.18	0.02	0.1				
			Mean	125.36	2.09	0.1672	0.1664	0.1668				
			Std Dev	48.31	0.81	0.18	0.19	0.18				
			Median	104.00	1.73	0.12	0.10	0.11				
			Mode	102	1.7	0.12	0.02	0.05				
			Min	77.00	1.28	0.00	0.02	0.01				
			Max	234.00	3.90	0.80	0.80	0.80				

		Order	Time	Time (sec)	Time (min)	OD VA	OS VA	OD + OS	Q#1	Q#2	Q#1	Q#2
1	GAT Nr	A	1:50:00	110.00	1.83	0.9	0.833	0.8665				
2	GAT Nr	B	-	-	-	-	-	0				
3	GAT Nr	C	4:04:00	244.00	4.07	0.1	0.033	0.0665				
4	GAT Nr	D	3:46:00	226.00	3.77	0.2	0	0.1				
5	GAT Nr	A	1:34:00	94.00	1.57	0.333	0.2	0.2665				
6	GAT Nr	B	2:43:00	163.00	2.72	0	0	0				
7	GAT Nr	C	2:59:00	179.00	2.98	0.066	0.333	0.1995				
8	GAT Nr	D	3:25:00	205.00	3.42	0	0	0				
9	GAT Nr	A	2:57:00	177.00	2.95	0	0	0				
10	GAT Nr	B	3:41:00	221.00	3.68	0	0.166	0.083				
11	GAT Nr	C	3:29:00	209.00	3.48	0	0.1	0.05				
12	GAT Nr	D	8:05:00	485.00	8.08	0.366	0	0.183				
13	GAT Nr	A	2:57:00	177.00	2.95	0	0.066	0.033				
14	GAT Nr	B	2:22:00	142.00	2.37	0	0	0				
15	GAT Nr	D	3:00:00	180.00	3.00	0	0	0				
16	GAT Nr	A	3:42:00	222.00	3.70	0.066	0	0.033				
17	GAT Nr	B	3:20:00	200.00	3.33	0.133	0.1	0.1165				
18	GAT Nr	C	5:10:00	310.00	5.17	0.066	0.066	0.066				
19	GAT Nr	D			-	0.1	0	0.05				
20	GAT Nr	A	3:21:00	201.00	3.35	0	0	0				
21	GAT Nr	B	3:13:00	193.00	3.22	0.1	0.1	0.1				
22	GAT Nr	D	4:43:00	283.00	4.72	0.033	0.1	0.0665				
23	GAT Nr	A	4:06:00	246.00	4.10	0.133	0.1	0.1165				
24	GAT Nr	C	2:48:00	168.00	2.80	0.1	0	0.05				
25	GAT Nr	D	3:20:00	200.00	3.33	0	0	0				
			Mean	193.40	3.50	0.1123333	0.091542	0.1019375				
	For GAT time n=23		Std Dev	77.05	1.28	0.20	0.18	0.17				
	For GAT VA n=24		Median	200.00	3.33	0.07	0.02	0.05				
			Mode	177	2.95	0	0	0				
			Min	94.00	1.57	0.00	0.00	0.00				
			Max	485.00	8.08	0.90	0.83	0.87				