INITIAL NORMS USING THE Wayne Saccadic Fixator

Eye-Hand Coordination and Visual Reaction Times

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ABSTRACT

This study was undertaken to establish standard performance scores for eye-hand coordination skills and visual reaction times as measured by the Wayne Saccadic Fixator. To date, only a few studies have been published that provide data for the Fixator. Most of these have evaluated professional and amateur athletes. This project measured the skills of 277 children between the ages of 6 and 18. Only children with normal saccadic, pursuit, binocular coordination, and focusing skills were included. Sixteen adults ranging in age from 21 to 29 with a mean age of 25 were also included for comparative purposes. Although a large degree of variability occurred within each age group, a direct relationship between age and scoring ability was established. We will also discuss some of the reasons for the variability in performance that was observed.

KEY WORDS

eye-hand coordination, visual reaction time, saccades, Wayne Saccadic Fixator

The Wayne Saccadic Fixator[a] (WSF) consists of a 29-inch square panel containing 33 red light switches. The instrument is controlled by a computer chip that generates a variety of patterns of lights to which a subject responds by pushing the lighted switch to extinguish the light. Numerous combinations of display patterns, speed, and response situations can be programmed to challenge the skills of the subject in a variety of ways. In fact, the WSF is supplied with over 50 preprogrammed procedures to both train and evaluate patient performance. By measuring and observing the individual's performance, inferences can be made about the child's eye-hand coordination, visual reaction times, peripheral awareness and eye movement skills.[1] Limited published data exists with attempts to establish performance norms for the WSF. In 1983, Sherman[2] published data on expected visual preaction and reaction scores based on a study using 371 amateur and professional athletes. Appler and Quimby's paper,[1] published in 1984, tested 1,251 children to establish performance standards on the WSF for students in grades one through five. Both of these studies, however, utilized an earlier version of the Fixator that contained only 16 lights arranged in a 22-inch circle. Kirscher[3,4] has published data from two studies of women tennis players, using the current Fixator model with 33 lights.

This study was undertaken to establish standard performance scores on the WSF for children between the ages of 6 and 18 with normal eye tracking skills. It was hypothesized that performance scores on the WSF would be age dependent.

METHODS

The subjects chosen for this study included 277 children between the ages of 6 and 18 and sixteen adults between the ages of 21 and 29. The average age for the adult group was 25 years. The age distribution for these subjects has been summarized in Table 1.

All subjects in the study were evaluated on the WSF following a comprehensive optometric examination. Only those individuals with normal saccadic and pursuit eye movement skills were chosen for this study. Saccadic and pursuit skills were evaluated by either the King Devick Test[b] or by observational scores based on criteria developed by Maples[5] on the

NSUCO's Oculomotor Test. An observational score of 4 or 5 on the NSUCO Test or a score within one standard deviation of the age mean on the King Devick Test was considered acceptable for this study. All children were reading on grade level. None of the subjects had complaints of asthenopia following near work. If eyeglasses were normally worn, the child was tested while wearing his habitual correction. All subjects had less than 5 diopters of esophoria or exophoria at 40 cm. None of the subjects had a tropia. The sample group was multi-racial. No distinction was made between those children who were active athletically and those who were not. None of the adults included in this study were active athletically.

Procedure #18 measures visual reaction time with two light stimuli. When the test begins, the light in the 9 o'clock position is on. The child controls the start of the test by depressing that light with his finger tip when he is ready to begin. When the 9 o'clock light is depressed, it goes off, and the 3 o'clock light immediately illuminates. The child must then depress that light with the same hand as quickly as possible. The procedure was first demonstrated by the examiner and the child was then given two practice attempts. Each attempt consisted of depressing the illuminated 9 o'clock light, followed by depressing the 3 o'clock light. A 10-second break was taken between each attempt. The recorded reaction time was the mean of three further tries. If the child missed the 3 o'clock light, the attempt was not scored and the child was allowed to repeat the attempt. If more than two misses occurred, the child was not included in the study. The distance between the 9 o'clock and the 3 o'clock light is 71 cm (28 inches).

TABLE 1.

AGE (years)	FEMALES	MALES	TOTAL
6	9	9	18
7	13	10	23
8	10	15	25
9	13	13	26
10	18	15	33
11	14	14	28
12	10	8	18
13	9	12	21
14	11	12	23
15	10	9	19
16	6	5	11
17	6	8	14
18	10	8	18
21 to 29	8	8	16
Total Number (N)		293	

Table 1. Age distribution by subjects in the study.

A similar measurement was taken using a variation of the WSF's preprogrammed Procedure #41. In this procedure, however, the WSF computer program controls the start of the test and the child must be in a state of readiness to anticipate the start. In this Release/Locate/React (R/L/R) Test, the subject depresses and holds the green, centrally located, start button, while observing the red target light in the 9 o'clock position. When this light illuminates, the child must release the start button and depress the 9 o'clock light with the same hand. The time delay between depressing the start button and the illumination of the target light varies randomly so that the child cannot anticipate the start of the test. Two times are displayed on the WSF for this procedure. The first is the time to react to the visual stimulus (the 9 o'clock light) as measured by the release of the green start button; the second measures the time to move to and depress the stimulus light. The distance between the green start button and stimulus light is 73.5 centimeters (29 inches). Again, each subject was given two practice attempts. Each attempt consisted of releasing the start button and depressing the 9 o'clock light with the same hand. A 10-second break was taken between each attempt. If the child missed the 9 o'clock light, the attempt was not scored and the child was given another try. The recorded score was the mean of three further attempts. (The actual parameters programmed into the WSF for this exercise were: Activities: 13; Time: 13; Speed: 0; Pattern: 1; Lights: 1; Time Out: 0.)

Procedure #21 provides a combined measure of the subject's eye-hand coordination, visual reaction time, and peripheral awareness skills as measured on the WSF. During this 30-second evaluation, lights are randomly illuminated and the child must respond by depressing the illuminated light before it extinguishes. This is an auto-paced WSF procedure; the lights are automatically presented as opposed to a self-paced procedure in which a new light is presented only after the illuminated light is depressed. To perform this task the subject must first locate the light, using either his peripheral or parafoveal vision. He must then react by quickly depressing the light with his finger tips. Since the light is illuminated for a brief period of time, accurate eye-hand coordination and fast visual reaction times are needed. If the child reacts to the light but misses it, the light will not stay illuminated long enough for a second attempt.

The following instructions were given to each subject, "When you see the light come on, I want you to depress the light with your finger tips as quickly as possible. Try to get as many lights in 30 seconds as you can. Your score will depend on how many lights you get and how fast you get the lights."

The child was allowed to use either hand or both, or even switch during the test. The procedure was first demonstrated to the child by the examiner. The subject was then allowed to practice for 15 seconds before three 30-second test cycles were given. Each time the subject scored a light, the speed of presentation (measured in lights per minute) of the target lights automatically increased. If, for example, the lights were being presented at 60 per minute, the subject would have one second to respond to an illuminated light. At 90 lights per minute, the subject would have 0.67 seconds to respond to the target light. The maximum speed of presentation is 200 lights per minute (equaling a presentation time of 0.30 seconds). As lights are scored and the speed increases, the subject must react more quickly as the test progresses. Each time a light is missed, the speed of presentation decreases. If the child misses several lights at the end of a 30-second test cycle, it is possible that the final speed displayed will not equal the maximum speed attained during the test. The score obtained on each of the three 30-second test intervals was the product of the number of lights scored and the final speed of presentation of the lights. The final score recorded for each child was the mean of the three 30-second test cycles.

The center light of the WSF was placed at the subject's eye level for all measurements. The subject stood at arm's length from the WSF.

Appler and Quimby's study[1] on the WSF indicated a relationship between the ambient room illumination and the scores

TABLE 2.

PROCEDURE #18

Evaluates visual motor reaction time between two stimulus lights with the child initiating the start of the test.

R/L/R PROCEDURE

Evaluates the time to respond to a visual stimulus and then react to the target light. The WSF initiates the start of this test.

PROCEDURE #21

Lights are randomly and automatically presented for 30 seconds. The time of presentation of each target light decreases with each light scored and increases with each light missed.

Table 2. Test Procedures Evaluated on the Wayne Saccadic Fixator.

TABLE 3.

AGE (years)	MEAN TIME	STD. DEV.	MIN. AVE.	MAX. AVE.
6	0.75	0.12	0.54	0.95
7	0.65	0.09	0.48	0.79
8	0.62	0.07	0.50	0.83
9	0.56	0.09	0.41	0.72
10	0.51	0.08	0.39	0.71
11	0.52	0.08	0.36	0.66
12	0.49	0.08	0.34	0.64
13	0.49	0.12	0.37	0.82
14	0.47	0.07	0.36	0.68
15	0.44	0.04	0.34	0.51
16	0.47	0.05	0.41	0.54
17	0.44	0.04	0.34	0.50
18	0.47	0.04	0.34	0.53
21 to 29	0.45	0.03	0.41	0.57

Table 3. Standard deviations and range of scores for reaction times as measured on Procedure #18. All values are in seconds.

obtained on the WSF. Their study suggested that higher scores were obtained when room illumination was lower and, therefore, contrast between the target light and background was higher. All testing for this study was done under overhead fluorescent lighting. The level of illumination on the WSF as measured by a Cambron Spot Meter was 15 foot-candles. A summary of the three test procedures that were evaluated on the WSF is presented in Table 2.

TABLE 4.

AGE	RELEASE TIMES MEAN TIME	STD DEV.	MIN. AVE.	MAX. AVE.	REACTION TIMES MEAN TIME	STD. DEV.	MIN. AVE.	MAX. AVE.
6	0.42	0.04	0.33	0.48	0.46	0.05	0.38	0.57
7	0.41	0.06	0.29	0.50	0.48	0.06	0.30	0.58
8	0.36	0.04	0.28	0.41	0.45	0.04	0.35	0.51
9	0.38	0.06	0.28	0.49	0.43	0.04	0.32	0.51
10	0.34	0.05	0.28	0.44	0.38	0.05	0.30	0.48
11	0.31	0.04	0.25	0.38	0.36	0.04	0.29	0.42
12	0.30	0.04	0.24	0.38	0.36	0.03	0.31	0.42
13	0.31	0.05	0.22	0.42	0.41	0.05	0.32	0.49
14	0.32	0.04	0.25	0.41	0.37	0.05	0.30	0.47
15	0.30	0.02	0.25	0.37	0.39	0.06	0.28	0.54
16	0.26	0.02	0.23	0.31	0.37	0.04	0.31	0.46
17	0.25	0.03	0.20	0.30	0.38	0.03	0.32	0.43
18	0.27	0.03	0.23	0.35	0.38	0.03	0.35	0.58
21 to 29	0.26	0.03	0.26	0.31	0.36	0.04	0.32	0.49

Table 4. Standard deviations and range of values for release and reaction time scores on the R/L/R Procedure. All values are in seconds.

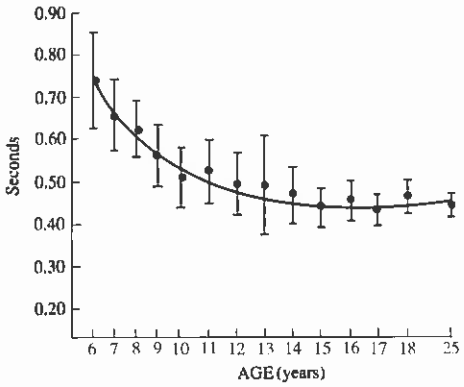

Figure 1. Relationship between reaction time and age for all subjects on the Wayne Saccadic Fixator Procedure #28. Standard deviations are plotted vertically.

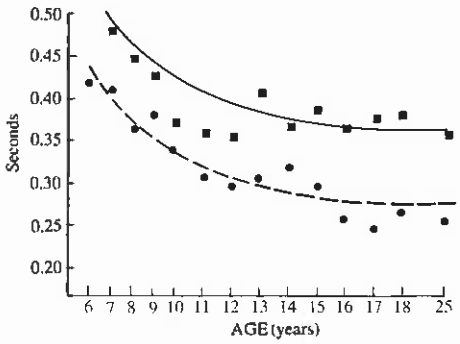

Figure 2. Relationship between the release and reaction times and age as measured on the Wayne Saccadic Fixator. Broken line = release times with data points plotted as circles. Solid line = reaction times with data points plotted as squares.

RESULTS

The results of the measurements on Procedure #18 and the R/L/R Procedure are presented in Tables 3 and 4 and Figures 1 and 2. The data demonstrates an inverse relationship between age and visual reaction time. The scores for all three measurements peaked in the preteen years (approximately age 12). Based on these measurements, one would expect children over the age of 13 to have a visual reaction time response on Procedure #18 of about 0.47 seconds. On the R/L/R Procedure, release times for children over 13 years of age of 0.27 seconds are expected, followed by reaction times of about 0.37 seconds (see Figure 2). The coefficient of correlation (r) between age and reaction time for Procedure #18 was -0.64 ($p<.0001$) and r^2 was 0.41. An r^2 value of 0.41 suggests that 41% of the variability in reaction time scores as measured on the WSF Procedure #18 can be accounted for by age. The r value between the release time and age was -0.69 ($p<.0001$) and r^2

TABLE 5.

AGE (years)	MEAN SCORE	STD. DEV.	MIN. SCORE	MAX. SCORE	MEAN FINAL SPEED	STD. DEV.	MEAN # of lights	STD. DEV.
6	364	126	190	612	47.9	12.3	7.7	4.3
7	546	276	219	1182	48.4	10.2	11.3	3.4
8	632	248	254	1219	50.6	15.8	12.5	4.2
9	831	187	519	1163	60.6	14.9	13.7	2.2
10	963	306	531	1870	64.2	16.9	15.0	3.7
11	1082	417	516	2343	71.2	13.8	15.2	4.1
12	1290	463	258	2241	71.3	9.7	18.1	2.1
13	1354	406	577	2177	74.0	12.7	18.3	5.3
14	1547	467	762	2455	77.0	15.6	20.1	4.9
15	1733	357	1158	2276	77.4	16.7	22.4	3.8
16	1896	365	1482	2741	82.8	13.6	22.9	4.7
17	1977	508	1164	3037	80.4	15.8	24.6	5.8
18	1967	299	1454	2447	87.0	14.4	22.6	5.1
21 to 29	2070	359	1688	2928	87.7	15.6	23.6	4.5

Table 5. Performance scores for all subjects for Procedure #21. The mean score = mean final speed x mean number of lights. (Mean score has been rounded to nearest integer.)

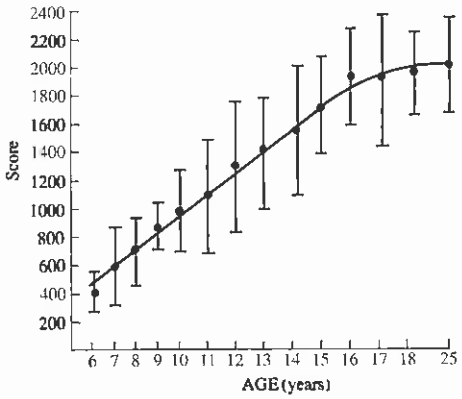

Figure 3. Relationship between performance scores and age using the Wayne Saccadic Fixator Procedure #21. Includes data for both the male and female subjects. Standard deviations are plotted vertically.

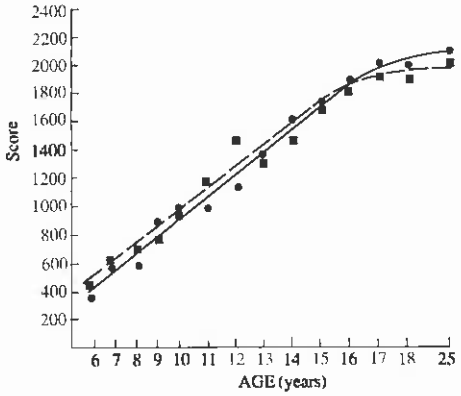

Figure 4. Relationship between performance scores and age for male versus female subjects on the Wayne Saccadic Fixator Procedure #21. The male data is plotted with dots and represented by the solid line. The female data is plotted with squares and represented by the broken line.

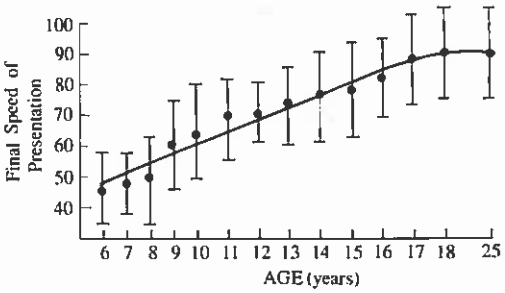

Figure 5. Relationship between final speed of light presentation and age for all subjects for the Wayne Saccadic Fixator Procedure #21. Standard deviations are plotted vertically.

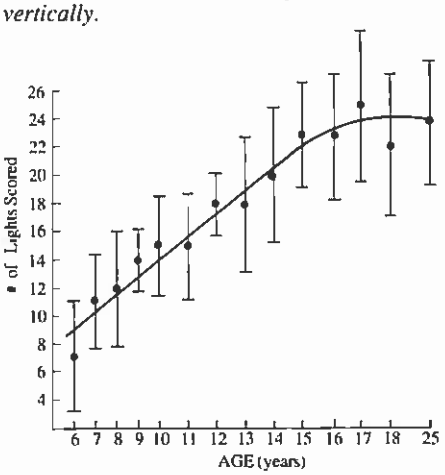

Figure 6. Relationship between the number of lights scored and age for all subjects on the Wayne Saccadic Fixator Procedure #21. Standard deviations are plotted vertically.

was 0.48. The r value for the reaction time following the release of the start button and age was -0.46 ($p<.0001$) and r^2 was 0.22. The t test indicated that there was no significant difference between the mean scores for the male and female populations on the visual reaction times.

The performance scores obtained for Procedure #21 are displayed in Table 5 and Figures 3 through 6. The scores for both male and female subjects combined are presented in Figure 3. As expected, there is a direct relationship between the performance scores as measured by the WSF and age. The mean score attained begins to plateau toward the end of the teen years (approximately age 18). The actual score recorded for this procedure is the product of the final speed of presentation of the lights and the number of lights scored. It is evident from Figures 5 and 6 that both of these components are age related and both reach a maximum toward the end of the teen years. The results obtained for the adults included in this study are consistent with the conclusion that maximum scores on this procedure are reached in the late teen years. The coefficient of correlation (r) between the performance scores and age was 0.82 ($p<.0001$) and $r^2 = 0.67$. The coefficient of correlation between the final speed of light presentation and age was 0.67 ($p<.0001$) ($r^2 = 0.45$) and between number of lights scored and age was 0.78 ($p<.0001$) ($r^2 = 0.61$).

The performance scores for the male versus female subjects on Procedure #21 are displayed in Table 6 and Figure 4. The scores for each sex are very consistent, both following a direct relationship with age and with both plateauing in the late teen years. A cursory analysis of this data would seem to indicate that the female subjects tended to score higher than the male until the preteen years, after which the male subjects scored higher. This interpretation would be consistent with the common belief that females tend to develop manual dexterity and eye-hand coordination skills at an earlier age than males. However, the t test, used to compare the means of the male and female scores for each age group, indicated no

TABLE 6.

AGE (years)	MEAN MALE SCORE	MEAN FEMALE SCORE
6	344	391
7	542	551
8	562	679
9	872	789
10	987	933
11	983	1169
12	1125	1496
13	1378	1336
14	1618	1481
15	1754	1709
16	1916	1872
17	2019	1946
18	2008	1915
21 to 29	2095	2091

Table 6. Performance scores for males and females for Procedure #21.

significant difference at any age level. The calculated t values varied from 0.24 (p = 0.81) to 1.16 (p = 0.25) when the sexes were compared across ages.

Table 7 indicates that the performance scores for Procedure #21 do not necessarily increase with experience. Thirty percent of the subjects scored lower on the third trial than on their first trial. When the second trial is compared to the third, 47% of the subjects scored lower on the third trial. The decreased performance on subsequent trials might be explained by decreasing motivation during the test, different degrees of difficulty in the random light patterns generated by the WSF computer, and, in some cases, by the child's fatiguing during the test. These results do, however, stress the importance of averaging multiple trials when evaluating a child as opposed to taking a single measurement.

Data for the standard deviations and ranges of scores for Procedure #21 presented in Table 5 reveal a wide range of variance in eye-hand coordination scores within each age group. For example, 10-year-old children average 963 points but within this age group average individual scores vary from 531 to 1870 points. The range of scores for all children in this study vary between 190 and 3037 points. The mean score for all children was 1170 points and the standard deviation was 603. Table 7 also demonstrates that an individual score

TABLE 7.

		Average Difference In Individuaal Scores Between Trials
Third Trial Score > First Trial Score	70%	339
Third Trial Score < First Trial Score	30%	257
Third Trial Score < Second Trial Score	53%	260
Third Trial Score > Second Trial Score	47%	340

Table 7. Comparison of performance scores on Procedure #21 between the first and third trials for all subjects and the second and third trials for all subjects.

can vary on the average by as much as 340 points from one trial to the next. With this amount of individual and age group variation in scores, it becomes difficult to establish precise pass-fail criteria for Procedure #21.

DISCUSSION

The data collected in this study indicate a direct relationship between age and visual performance, and age and visual reaction time as measured on the WSF. This relationship was also demonstrated in the study by Appler and Quimby.[1] Unfortunately, since their study used an older model with only 16 lights, the actual scores cannot be compared.

In my vision therapy clinic, these expected scores are used as preliminary guidelines for acceptable performance on the WSF. Children scoring less than the age-expected averages and especially those scoring below one standard deviation are considered at risk. The performance on the WSF must be viewed in conjunction with the child's ability on other gross motor and visual motor integration tests.

Just as important as the scores obtained, however, are the observations made of how the child performs during the testing. Numerous strategies were noted as the children were tested on Procedure #21. Some preferred to use only their dominant hand while other children alternated hands in a random manner. The children who scored best were those who fixated centrally, made minimal head and body movements, and relied on their peripheral visual input and accurate saccadic eye movements to find the illuminated lights. High scorers developed a rhythmic, fluid motion of their arms and hands as they responded to the lights. Some children made excessive head and body movements during the procedure to scan the board for target lights. These children typically scored the lowest. Some children, in fact, kept their heads in almost constant motion while trying to scan for lights. Some kept their hands in front of them during the test, never learning that their hands were blocking some of the lights. Others responded to a light on the side of the board by a head or eye turn and did not learn to look back centrally to get prepared for the next light. They often missed subsequent lights being illuminated on the opposite side of the board. Thus, performance scores were dependent upon the child's ability to learn the best strategy for problem solving in this new visual motor learning situation.

It was noted earlier that performance scores on Procedure #21 increased with age until the late teen years. However, reaction time scores plateaued during the preteen years. This result was surprising since reaction time is a major component of performance on Procedure #21. Reaction time does not appear to be the limiting factor, however, for performance scores on Procedure #21.

Procedure #18 and the R/L/R test both measure a reaction time in response to a visually presented stimulus. The distance the child must move his hand in response to the light is approximately the same (71 cm vs. 73 cm). However, the mean reaction time scores for these tests are statistically different, 0.53 seconds for Procedure #18 and 0.40 seconds for the R/L/R Procedure ($t = 20.82$, p .0001). In Procedure #18, the child must first look at and press the light in the 9 o'clock position, then make a head or eye turn to the light in the 3 o'clock position before reacting to it. On the R/L/R test, the child depresses the green start button, looks at the light in the 9 o'clock position and reacts to the light when it illuminates. No prior head or eye movement is required. Thus, the faster

reaction time on the R/L/R test is expected.

It would be ideal to take data such as that presented in this study and use it as a pass-fail criteria for performance on the WSF. However, because of the wide variance in performance scores on Procedure #21 found within each age group and for many individuals, additional research needs to be conducted. For example, do children who are active in sports, karate lessons, computer games, gymnastics, etc. score higher than those who are not? How does motivation and desire to succeed affect these results? Do children who are active in organized sports score higher than those who are not? How consistent is a child's performance when measured from one day to the next? What effect does vision therapy have on a child's score? These factors need to be considered to better interpret expected performance levels by children on the WSF.

Arm length is also a factor when evaluating a child on the WSF. Younger and smaller children often had no choice but to move their bodies in order to react and reach the light stimuli. Therefore, small children may appear to score low on the WSF when, in fact, their visual motor integration skills and visual reaction times are at age level.

Although the light patterns generated on Procedure #21 are random, it became apparent that some patterns were easier than others. In some cases, several lights during the 30-second test time would be presented very close together. This would allow the child to either score several lights very quickly or to miss several lights if the child was not looking in the right direction. In other cases the pattern would be more difficult if the light presentation pattern was scattered. After completing this study, I would suggest that several standard Procedure #21 test presentation patterns be preprogrammed and available on the Fixator for evaluating purposes rather then relying solely on the random patterns currently generated.

ACKNOWLEDGMENTS

I wish to thank my associate, Thomas E. Kraemer, O.D., for his help in collecting data for this study.

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Date accepted for publication:
October 2, 1990

ON THE COVER

Wayne Saccadic Fixator courtesy of Arthur B. Corish, O.D., and Julie Ryan, O.D., Irvine, Calif.