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Behavioral assessment of visual acuity in kittens

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Abstract

The visual acuity of kittens was determined behaviorally by training them to respond to high contrast, square-wave gratings with a modified Lashley jumping stand. Spatial frequencies between .25 and 12.00 cycles per degree were used and an average visual acuity of 5.0 cpd was found. This result conforms with values found by other investigators.

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BEHAVIORAL ASSESSMENT

OF

VISUAL ACUITY

IN

KITTENS

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Dr. Steven J. Cool, advisor

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ABSTRACT

The visual acuity of kittens was determined behaviorally by training them to respond to high contrast, square-wave gratings with a modified Lashley jumping stand. Spatial frequencies between .25 and 12.00 cycles per degree were used and an average visual acuity of 5.0 cpd was found. This result conforms with values found by other investigators.

INTRODUCTION

Previous studies assessing visual acuity in cats have been done by a number of investigators. The studies which employed a variety of behavioral methods for determining visual acuity (Berkley, 1970; Smith, 1970; Blake, Cool, and Crawford, 1974; Mitchell, et al, 1975; Jacobsen, Franklin, and McDonald, 1975) have obtained results closely paralleling those found by studies which employed visual evoked potentials (Berkley and Watkins, 1972; Freeman and Marg, 1975). The best spatial resolution reported by these investigators is between 5.0 and 6.0 cycles per degree.

We know that contrast sensitivity is a function of spatial frequency. Campbell, Maffei, and Piccolino (1972); Bisti and Maffei (1973); Blake, Cool, and Crawford (1975) found that increasing contrast increases the ability to distinguish higher spatial frequencies. Therefore, this study eliminated contrast as a variable and used high contrast spatial frequency gratings.

The purpose of this study was to establish baseline conditions for studies on kittens with abnormal binocular systems and the findings compared with those obtained on normal kittens.

APPARATUS

The apparatus employed was a modified Lashley jumping stand (see Figures 1 and 2). The stand was made of a black plywood box (38.5 x 71 x 166 cm) and cut away in front to 100 cm. Two trapdoors (35.5 x 35.5 cm) located 39 cm above the floor and separated by a central divider were held closed by pressure latches that could also be locked into the closed position by metal pins.

Photographic reductions of commercially prepared (Intergraphics, Kirkland Washington) high contrast, square-wave gratings served as the visual stimuli for the testing. Each grating had a homogenous grey photograph of matching luminance used with it. The gratings and grey photographs (12.5 x 19 cm) were laminated and placed on the closed trapdoors in matched pairs (see Figure 3). Uniform lighting was provided by two fluorescent (F40CW) cool white bulbs resting on top of the stand.

A wooden tunnel (38 x 17.8 x 10.7 cm) was centered directly in front of the stand and placed the kittens' eyes 37.5 cm above the stimuli.

TECHNIQUE

The six kittens used for the study were raised in the Pacific University College of Optometry animal care facility. This is a USDA approved, closed breeding colony. Training began at eight weeks of age and

Figure 1: The modified Lashley jumping stand with entrance tunnel visible from the front.

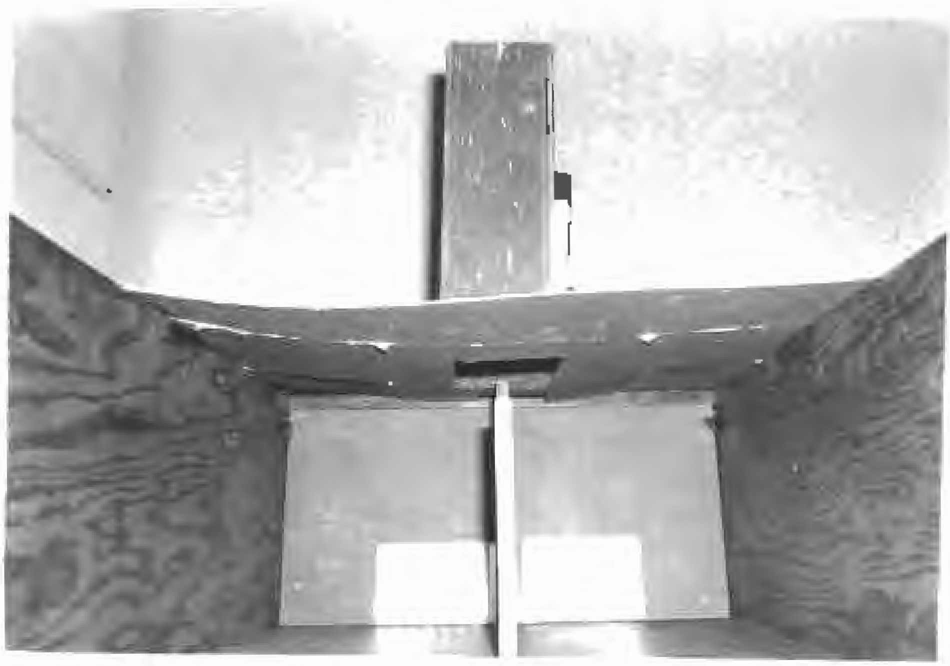

Figure 2: A top view of the jumping stand showing tunnel, entrance, and a set of photographs.

Figure 3: Top view of the matched grating and grey photographs placed on the trapdoors.

continued until the thirteenth or fourteenth week. Testing was then done until the kittens were eighteen or nineteen weeks old. The training sequence started with one door left open while the visual stimulus was placed over a closed, locked door. The grating was randomly placed right and left with no more than two placements on the same side. A kitten was placed into the tunnel and exited by jumping to one side of the stand. Correct responses were positively reinforced with food on a random schedule. Incorrect responses resulted in the kitten jumping to the floor of the "pit". When the kitten no longer hesitated jumping to the grating, the door with no grating was closed but remained unlocked. No visual stimulus of any kind was placed on this side during this phase. If the kitten jumped to this unlocked side, the trapdoor opened, dropping the kitten to the floor. The kitten was left in the pit for fifteen seconds before being removed. Regardless of the response given, the kitten always received a period of gentle petting before being placed into the tunnel again. Once this phase was mastered, the appropriate homogenous grey photograph was placed on the unlocked, closed side of the stand. The same procedure as above was followed with the trapdoor opening if the kitten jumped to the side with the grey plate.

After 100% accuracy was reached in this phase the kitten entered the testing sequence. During these trials, no positive reinforcement was given and both doors were locked so there was no negative reinforcement if the kitten was unable to distinguish the grating. To reinforce the procedure, training gratings were presented between test gratings. The grey side was left unlocked and positive reinforcement was given randomly with these training gratings.

Several modifications had to be made throughout the training and testing sequence as problems developed. Originally, four forms were used alternately with 21 gratings randomly placed left or right. A .5 cpd training grating was presented twice between each test. As testing progressed we found the cats had developed side preferences that required a period of retraining and a modification of our test sequence. Forms were devised with each test grating presented an equal number of times on the right and on the left (see Figure 4). This would result in a 50% correct response if the kitten could not truly distinguish the grating and was jumping based only on side-preference. The next modification was necessary because the kittens learned that reinforcement only came during the .5 cpd train gratings. This led to very accurate responses to that grating and a lack of attention paid to the test gratings. To correct this we began training with three gratings (.25, .50, 1.0) to prevent memorization of the train grating. Two of the three training gratings were still presented between tests (see Figure 5).

The final modification consisted of four forms with twelve to fifteen presentations each (see Figure 6). To prevent memorization of the pattern of two training gratings per one test grating, the number of training gratings varied between tests. Two training gratings of greater frequency difference (.50 and 2 cpd) were chosen instead of the previous three training gratings.

After modifying the procedure, the final method recommended for training and testing can be found in Appendix 1.

RESULTS

We chose a common cutoff criteria for visual acuity of 70% correct. We used this cutoff to analyze the data in two ways; a straight percentage

	Cat form 1			
Examiner				
Cat				
Date				
Trial	L	R	Correct	Incorrect
1	0.5	G9		
2	G9	0.5		
3	G2	12		
4	0.5	G9		
5	G9	0.5		
6	1	G10		
7	G9	0.5		
8	0.5	G9		
9	3	G12		
10	G9	0.5		
11	0.5	G9		
12	G10	6		
13	0.5	G9		
14	G9	0.5		
15	2	G1		
16	0.5	G9		
17	G9	0.5		
18	8	G5		
19	G9	0.5		
20	0.5	G9		
21	G1	4		

	Cat form 2			
Examiner				
Cat				
Date				
Trial	L	R	Correct	Incorrect
1	G9	0.5		
2	0.5	G9		
3	G12	3		
4	0.5	G9		
5	G9	0.5		
6	4	G1		
7	G9	0.5		
8	0.5	G9		
9	G5	8		
10	0.5	G9		
11	G9	0.5		
12	G1	2		
13	0.5	G9		
14	G9	0.5		
15	6	G10		
16	G9	0.5		
17	0.5	G9		
18	G10	1		
19	G9	0.5		
20	0.5	G9		
21	12	G7		

	Cat form 3			
Examiner				
Cat				
Date				
Trial	L	R	Correct	Incorrect
1	G9	0.5		
2	0.5	G9		
3	G5	8		
4	0.5	G9		
5	G9	0.5		
6	G12	3		
7	0.5	G9		
8	G9	0.5		
9	1	G10		
10	0.5	G9		
11	G9	0.5		
12	G1	4		
13	0.5	G9		
14	G9	0.5		
15	12	G2		
16	G9	0.5		
17	0.5	G9		
18	2	G1		
19	G9	0.5		
20	0.5	G9		
21	G10	6		

	Cat form 4			
Examiner				
Cat				
Date				
Trial	L	R	Correct	Incorrect
1	0.5	G9		
2	G9	0.5		
3	6	G10		
4	0.5	G9		
5	G9	0.5		
6	G10	1		
7	0.5	G9		
8	G9	0.5		
9	3	G12		
10	G9	0.5		
11	0.5	G9		
12	G7	12		
13	0.5	G9		
14	G9	0.5		
15	4	G1		
16	0.5	G9		
17	G9	0.5		
18	G1	2		
19	0.5	G9		
20	G9	0.5		
21	8	G5		

Figure 4: Testing forms presenting each test grating an equal number of times on the right and left side. A 0.5 cpd training grating was used.

	Cat	form 1/37.5		
Examiner				
Cat				
Date				
Trial	L	R	Correct	Incorrect
1	0.5	G10		
2	G1	1		
3	G1	12		
4	0.25	G9		
5	G1	1		
6	8	G1		
7	G10	0.5		
8	0.25	G9		
9	3	G10		
10	G10	0.5		
11	1	G1		
12	G2	6		
13	1	G1		
14	G10	0.5		
15	2	G1		
16	0.25	G9		
17	G1	1		
18	1.5	0.25		
19	G1	0.25		
20	0.5	G10		
21	G5	4		

	Cat	form 2/37.5		
Examiner				
Cat				
Date				
Trial	L	R	Correct	Incorrect
1	G10	0.5		
2	0.25	G9		
3	G10	3		
4	G1	1		
5	0.25	G9		
6	4	G5		
7	G10	0.5		
8	1	G1		
9	G12	1.5		
10	0.5	G10		
11	1	G1		
12	G1	2		
13	0.25	G9		
14	G10	0.5		
15	8	G1		
16	1	G1		
17	G9	0.25		
18	G2	6		
19	1	G1		
20	G10	0.5		
21	12	G1		

	Cat	form 3/37.5		
Examiner				
Cat				
Date				
Trial	L	R	Correct	Incorrect
1	G9	0.24		
2	1	G1		
3	G12	1.5		
4	0.5	G10		
5	G1	1		
6	G10	3		
7	0.25	G9		
8	G10	0.5		
9	8	G1		
10	1	G1		
11	G10	0.5		
12	G5	4		
13	1	G1		
14	G9	0.25		
15	12	G1		
16	G10	0.5		
17	0.25	G9		
18	2	G1		
19	G1	1		
20	0.5	G10		
21	G2	6		

	Cat	form 4/37.5		
Examiner				
Cat				
Date				
Trial	L	R	Correct	Incorrect
1	0.5	G10		
2	G1	1		
3	6	G2		
4	0.25	G9		
5	G10	0.5		
6	G1	8		
7	1	G1		
8	G9	0.25		
9	3	G10		
10	0.5	G10		
11	G1	1		
12	G1	12		
13	0.5	G10		
14	G9	0.25		
15	4	G5		
16	1	G1		
17	G10	0.5		
18	G1	2		
19	0.25	G9		
20	G1	1		
21	1.5	G12		

Figure 5: Testing forms used with three training gratings, 0.25, 0.50, and 1.0 cpd.

	Cat form 1.1/37.5			
Examiner				
Cat				
Date				
Trial	L	R	Correct	Incorrect
1	G1	2		
2	0.5	G10		
3	G1	12		
4	G1	2		
5	0.25	G9		
6	8	G1		
7	G10	0.5		
8	3	G10		
9	0.5	G10		
10	G2	6		
11	2	G1		
12	1	G1		
13	G10	0.5		
14	1.5	G12		
15	G5	4		

	Cat form 2.1/37.5			
Examiner				
Cat				
Date				
Trial	L	R	Correct	Incorrect
1	2	G1		
2	G12	1.5		
3	0.5	G10		
4	G10	3		
5	G1	2		
6	8	G2		
7	G1	2		
8	G5	4		
9	0.5	G10		
10	12	G1		
11	G1	2		
12	0.25	G9		
13	1	G1		
14	G10	0.5		
15	G2	6		

	Cat form 3.1/37.5			
Examiner				
Cat				
Date				
Trial	L	R	Correct	Incorrect
1	0.5	G10		
2	G10	3		
3	2	G1		
4	4	G5		
5	G12	1.5		
6	G1	1		
7	2	G1		
8	G2	8		
9	G9	0.25		
10	6	G2		
11	G10	0.5		
12	12	G1		

	Cat form 4.1/37.5			
Examiner				
Cat				
Date				
Trial	L	R	Correct	Incorrect
1	G10	0.5		
2	2	G1		
3	6	G2		
4	G2	8		
5	G1	1		
6	3	G10		
7	G10	0.5		
8	G1	12		
9	0.5	G10		
10	G1	2		
11	4	G5		
12	G9	0.25		
13	0.5	G10		
14	1.5	G12		

Figure 6: Testing forms presenting a varied number of training gratings between test grating. Training gratings used were 0.25, 0.50, and 1.0 cpd.

of correct responses at each acuity demand and a linear regression formula (inferential statistical procedure). Figure 7 contains tables of each kitten's data and Figure 8 the graphs of the data. To summarize the visual acuity level meeting the above criteria, "Hubel" passed at 1.5 cpd, "Wiesel" at 6.0 cpd, "Chip" at 1.5 cpd, "Dayle" at 3.0 cpd, "Descemet" at 3.0 cpd, and "Tubbs" at 3.0 cpd. Next, a linear regression formula was used to determine where a best fit line would cross the 70% criteria level. The individual results are the following: "Hubel" at 4.8 cpd, "Wiesel" at 5.4 cpd, "Chip" at 4.7 cpd, "Dayle" at 4.9 cpd, "Descemet" at 4.9 cpd, and "Tubbs" at 5.5 cpd. The average visual acuity was 5.0 cpd which conforms nicely with the visual acuity of cats found by other investigators.

DISCUSSION

In order to use this equipment to evaluate the visual acuities of subjects with functionally altered vision, it was first essential to "calibrate" the apparatus. This involved running normal, non-experimentally altered subjects through the testing sequence. By first using these subjects it was possible to verify that this equipment would provide "normal" acuity measurements, similar to those found by other investigators. Now that this "calibration" has been accomplished, the apparatus can be used for future studies of functional visual conditions.

Amblyopia is an abnormal visual condition of great concern to optometrists. Several forms of amblyopia occur in the human population. Uncorrected refractive error can cause conditions resulting in amblyopia. When high anisometropia, generally greater than two diopters, is present, the eye farthest from emmetropia is often suppressed. High astigmatism

"Hubel" #0024-92-3	
cycles per degree	% correct responses
0.25	100
1.00	100
1.50	100
3.00	58
4.00	67
6.00	58
8.00	50
12.00	42

"Wiesel" #0025-92-3	
cycles per degree	% correct responses
0.25	92
1.00	100
1.50	100
3.00	83
4.00	75
6.00	75
8.00	25
12.00	50

"Chip" #0026-92-3	
cycles per degree	% correct responses
0.25	100
1.00	100
1.50	100
3.00	67
4.00	42
6.00	50
8.00	58
12.00	50

"Dayle" #0027-92-3	
cycles per degree	% correct responses
0.25	100
1.00	100
1.50	83
3.00	75
4.00	42
6.00	58
8.00	66
12.00	50

"Descemet" #0028-92-3	
cycles per degree	% correct responses
0.25	100
1.00	100
1.50	92
3.00	75
4.00	67
6.00	50
8.00	42
12.00	50

"Tubbs" #0029-92-3	
cycles per degree	% correct responses
0.25	100
1.00	100
1.50	100
3.00	75
4.00	58
6.00	58
8.00	58
12.00	50

Figure 7: The tabulated data from each kitten showing the percentage of correct responses for each frequency tested.

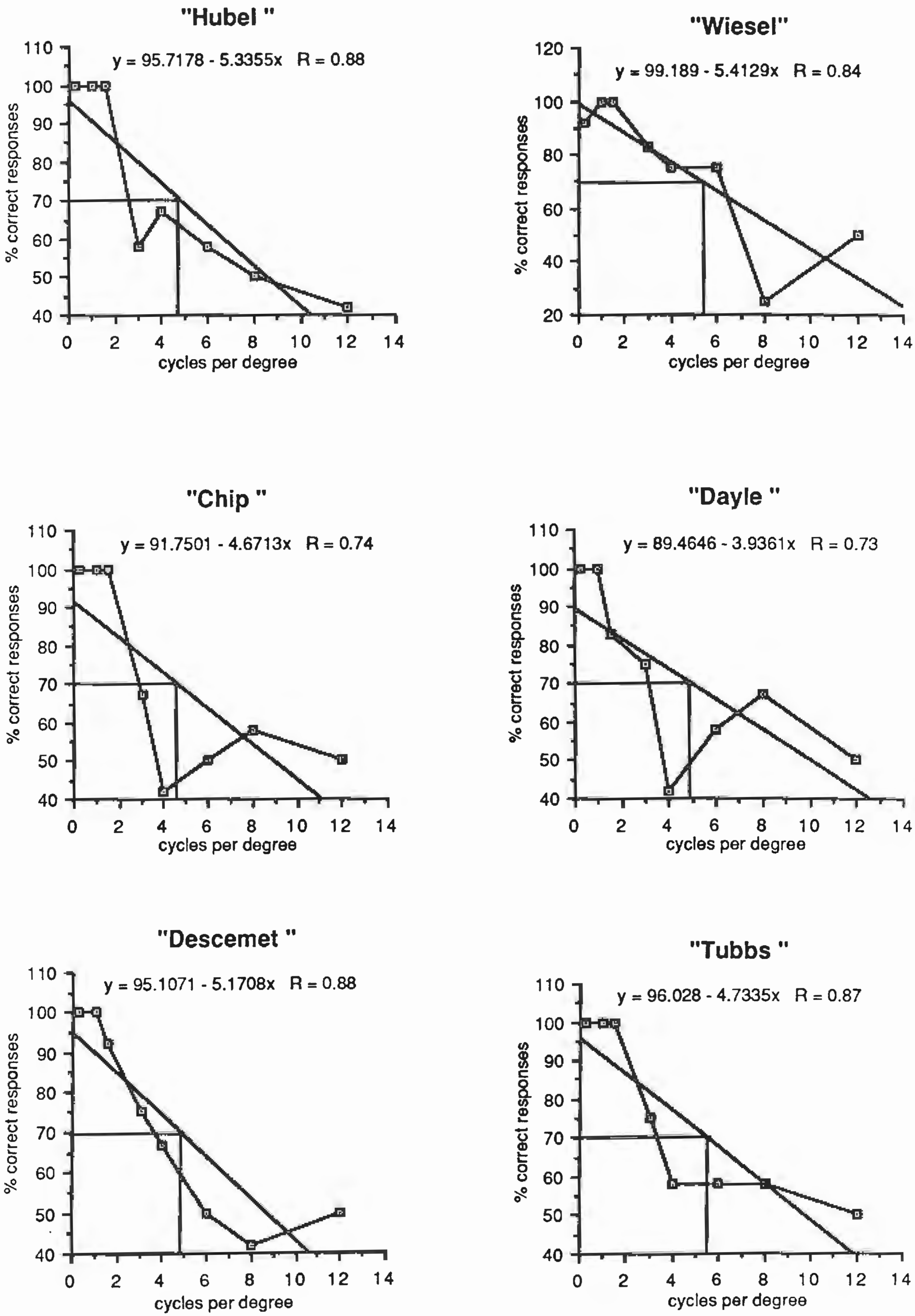

Figure 8: The graphical data from each kitten showing the percentage of correct responses for each frequency tested and a linear regression of the data.

can induce a meridional amblyopia with the patient being sensitive only to stimuli oriented with the astigmatism. Congenital cataracts can result in decreased visual function if they are not removed soon after birth so normal development can occur. Monocular patching for trauma or for binocular dysfunction at an early age may cause an amblyopia. Constant unilateral strabismus is another condition often found with amblyopia. Some question exists as to which is the cause and which the result, but a strabismic-caused suppression leading to amblyopia is possible.

Sensory deprivation induced in animals in a laboratory setting can mimic these "naturally" occuring amblyopias. Anisometropia can be induced with contact lenses or goggles. Astigmatism can be simulated using aperature goggles. Meridional amblyopia is induced by raising the animal in a selective environment, for example, one containing only stripes of one orientation. Strabismus can be caused by surgery on the extraocular muscles. Monocular occlusion of young animals from birth with opaque contact lenses or goggles can mimic any of the conditions causing suppression and amblyopia.

The apparatus tested can be used to quantify the amount of induced amblyopia by monitoring the decrease in visual acuity. It can also be used to quantify the degree of success of a treatment technique, again by monitoring the change in visual acuity. This can be done in place of, or in addition to, electrophysiological studies of brain activity. The behavioral assessment technique allows non-invasive, yet specific measurement of a subject's visual functioning.

APPENDIX 1

Start training at eight weeks of age.

Train with .5 and 2 cpd alternating grating sizes and sides randomly with no more then two consecutive grating presentations per side. The total number of presentations per side should be equal.

Reinforce correct responses on a random schedule.

Follow each step until kitten is performing the task with confidence.

Step 1: Place train grating on locked side, open door on other side.

Step 2: Close unlocked door, no stimulus on this side.

Step 3: Grating on locked side, grey photograph on unlocked side.

Step 4: Testing sequence.

Both sides are locked during presentation of a test grating.

During presentation of a train grating, the side with the grey photograph is left unlocked.

There is no reinforcement during test presentation.

Testing form:

Train gratings are interspersed between test gratings so the kitten will remain familiar with the procedure.

No more than two consecutive grating presentations (test or train) should be placed on the same side.

The total number of presentations per side should be equal. Each test grating should appear on right and left sides an equal number of times overall.

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BIO-PAGE

Patricia M. Feiten came to Pacific University from Colby, Wisconsin. She attended the University of Wisconsin-Oshkosh, before graduating in May of 1984 from Pacific University with a Bachelor of Science degree in Visual Science. She will receive her Doctor of Optometry degree in May of 1987.

Shari L. Mace is a Colorado resident who attended Colorado State University for undergraduate studies. Her Bachelor of Science degree in Visual Science was awarded at Pacific University in May, 1984. She will receive her Doctor of Optometry degree from Pacific University College of Optometry in 1987. A move back to Colorado and a practice there are her future plans.

SIGNATURE PAGE

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