CATS VISUAL RESPONSE TO CERTAIN GEOMETRIC ILLUSIONS

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SCOPE AND CONTENTS:

Two behavioral experiments were performed to determine whether cats perceive some geometric illusions. Cats were trained on a visual discrimination in a modified Yerkes-Watson box and tested on the illusion patterns. The two illusions used were the Hering illusion (preliminary experiment 1) and the Muller-Lyer illusion (primary experiment 2). The data of the primary experiment provided strong evidence that cats experience illusory percepts in a way similar to humans. This study supports a recent neurophysiological finding by Burns and Pritchard (1971) and suggests that some visual mechanisms of both human and cat are comparable.

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INTRODUCTION

Early psychologists (Hering, 1861, Helmholtz, 1910, Luckiesch, 1922, Sully, 1881, Titchner, 1901, Wundt, 1893) studied illusions in the hope that an understanding of the 'errors' of perception might lead to a subsequent understanding of the mechanisms of perception in general. The emphasis of the early experiments was to determine what caused illusory percepts and the conditions that maximized the illusory percepts. From these experiments some early theories of vision perception emerged. Wundt (Luckiesh, 1965) attributed illusory percepts to direct perception and not to errors of judgement, and he emphasised that laws of fixation and eye movements were critical determinants of the percept. Hering and Helmholtz both attributed a role to volition in respect to some illusory percepts. (Luckiesh, 1965)

For about the last decade a new approach has been increasingly employed to study the mechanisms of vision. These modern studies are concerned with the manner in which complex visual patterns are displayed within the brain: how does the nervous system analyse and transmit information derived from visual patterned stimulation? Sophisticated electrophysiological techniques are used to record single neuronal activity and patterns of excitation from the retina to the cortex. The ultimate aim is to correlate specific brain activity with visual perception. However, nearly all the neurophysiological data associated with visual systems have been from animals other than man, primarily cats. Cats have been the major subjects in electrophysiological studies for good reasons. They have good vision, are relatively inexpensive, and are easy to work with for their visual cortex is accessible without ancillary damage to other parts of the brain. However, cats are notably difficult to train and thus there is little behavioral information of how cats 'see' the world. It is a genuine concern whether the neurophysiological data of cats can be correlated with the behavioral or psychophysical data of humans. Since neurophysiological experiments may not be conducted with human subjects, the alternative approach must be taken, that is, to carry out psychophysical and behavioral studies with other animals.

Some studies report evidence that animals do perceive geometric illusions. The first two reports (Revesz, 1924, Warden and Baar, 1929) are studies with birds, hens and ringdoves. In Revesz's study, two hens were trained to approach and eat from the smaller of many pairs of shapes. During the test, the Jastrow illusion, an illusory percept of size to the human, was presented and both subjects responded more to the subjectively smaller figure in the illusion. However this study is susceptible to criticism. The experiment is subjectively run and reported: for example, to explain data on test days that is contrary to what was predicted by the experimenter, Revesz comments that " the bird is not always in a condition favorable to a difficult test which demands so much attention." (p 409). The second study, with ringdoves, investigated the Muller-Lyer illusion, an illusory percept of length to the human. Positive results are again reported but, as in the previous experiment, the experimental technique was suspect.

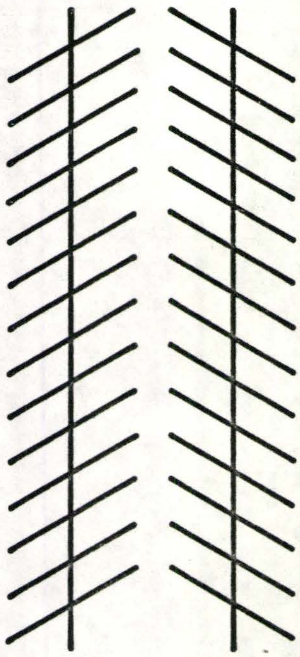
A more recent study (Ducharme, Delorme, and Boulard, 1967) eliminated the gross difficulties of the earlier experiments. White rats were trained on line length with various hatched and non-hatched horizontal line segments as targets. The illusion tested was the Oppel-Kundt illusion in which a hatched line, physically equal to a second non-hatched line, appears longer to the human. Ducharme, Delorme, and Boulard find all rats to be subject to the illusory percept, though some of the rats show a negative illusory effect. These rather confusing results are interpretable for young human children also experience a negative effect with this particular illusion.

Malott, Malott, and Pokrzywinski (1967) used pigeons in a study of the Muller-Lyer illusion. Pigeons were trained to peck a key containing a 0.7 centimetre horizontal line, with flat vertical arrowheads. Training was followed by a generalization test of line lengths with either flat or outward pointing arrowheads. Peak responding occurred to line lengths of 0.7 centimetres and 1.7 centimentres with the flat and outward pointing arrowheads respectively. This illustrates that pigeons do underestimate the length of a stimulus that also appears subjectively smaller to humans. However, for the pigeon there is no overestimation of the line with inward pointing arrowheads.

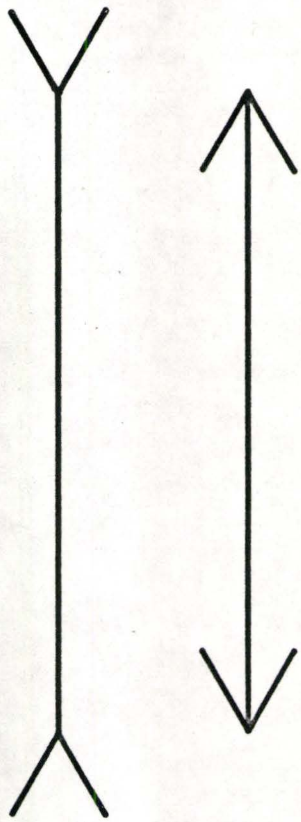
Even though the above studies may be sound and pigeons and white rats are influenced by illusory patterns, it does not necessarily follow that such behavior is a general phenomenon experienced by all visual animals. Large anatomical differences are observed in the visual systems between species, and there is much evidence that the processing of visual information occurs at different levels for different species (Thompson, 1967). Recent studies have provided evidence that considerable differences at the retinal level exist between cat and rabbit, two apparently quite similar animals (Barlow and Hill, 1963, Barlow, Hill and Levick 1964, Barlow and Levick 1965). Retinal ganglion cells that respond to the movement of an object in a particular direction have been found in rabbit but seem to be absent in cat.

Very much neurophysiological data have been gathered from the cat. However, because of the difficulty of extrapolating data from one animal to another, it is essential to investigate how cats 'see' before any serious correlation of this neurophysiological data can be made with human perceptual phenomena.

The present study is an attempt to verify behaviorally a recent finding concerning the activity of single neurons in the cat's primary visual cortex (Burns and Pritchard, 1971). They report that once the cortical receptive field and orientation specificity for a particular neurone have been determined for one line, the addition of a second line within the receptive field changes the response of the neurone so that it no longer responds to line one as though it was in the optimal position and orientation. In other words, the addition of the second line produced a 'neural distortion of the cortical image' which at least in humans could account for illusions of orientation. The present study is an attempt to determine whether cats perceive certain specific illusions. The illusion used in the preliminary experiment 1 is a geometric illusion (the Hering illusion) which occurs when two parallel lines appear non-parallel following the addition of small slanted lines to the parallels. (see Figure 1). The illusion used in the main experiment 2 is the Muller-Lyer illusion wherein one of two equal lines appear longer than the other when arrowheads are added (see Figure 1).



HERING



MULLER-LYER

FIGURE 1 THE HERING AND MULLER-LYER ILLUSIONS

METHOD

Subjects

Three cats were used in this preliminary part of the study; one female about three years old, and two males under a year old at the start of the experiment. The animals were maintained at ad lib weight but fed only during and immediately following the exeriment.

Apparatus

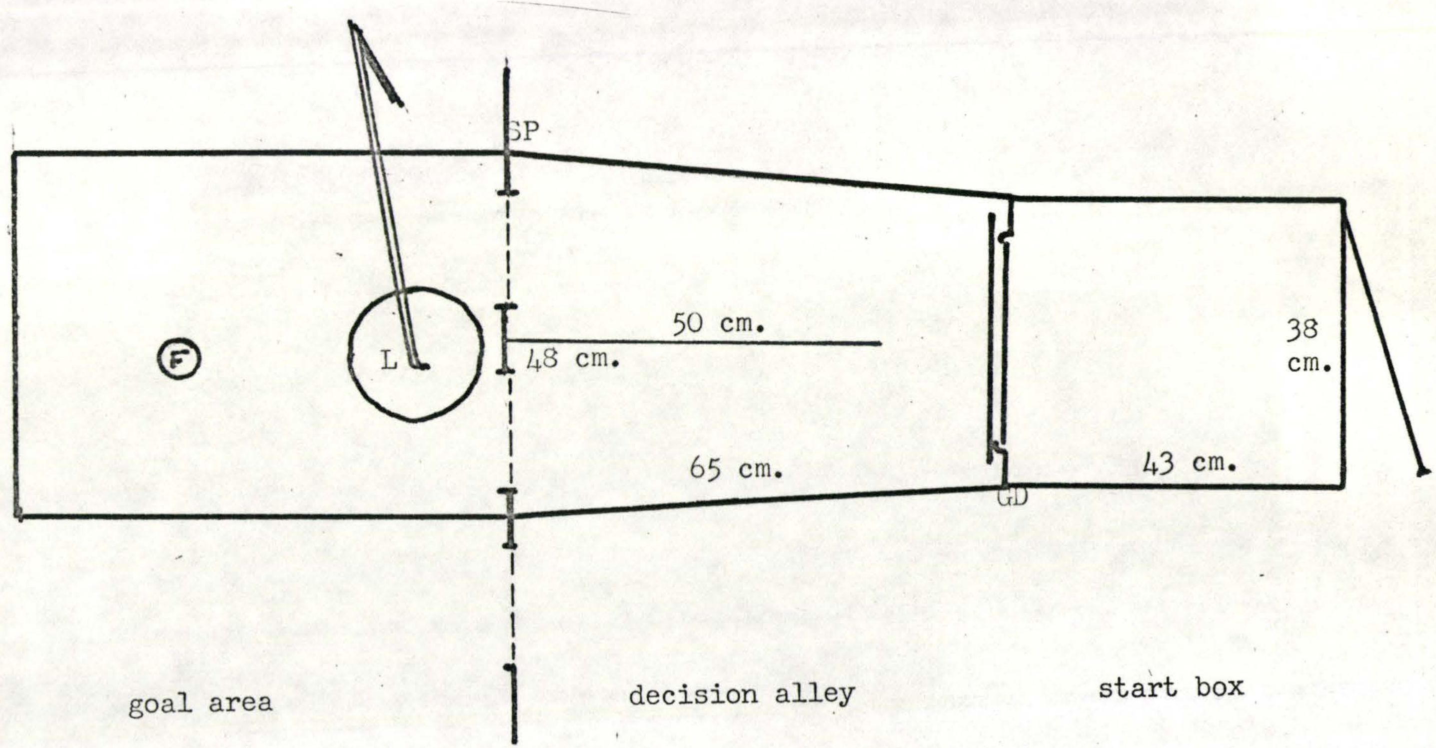
A modification of the Yerkes-Watson discrimination box was used. The apparatus consisted of a 43 by 38 centimetre (cm.) starting chambre, a 65 by approximately 48 cm. wide decision alley and finally an open goal area, where food was placed. The start box was the only entirely closed-in compartment and was totally dark before the start of any trial. Two doors, a black cardboard and a clear 0.3 cm Plexiglass guillotine door, both manually operated, separated the start box and alley way. Lifting the cardboard door gave a clear view of the decision alley and both stimulus doors. The decision alley was divided equally in two by a 50 cm. long partition that extended from the stimulus doors to within 15 cm. of the start box. This section of undivided alley facilitated a correction procedure. The decision alleys were covered by clear 0.6 cm. thick Plexiglass that allowed observation by the experimenter. Two 34 by 16.5 cm. top-hinged doors, made of translucent milky 0.15 cm. Plexiglass separated the decision alley and goal area. Each of the patterns to be discriminated were constructed from 0.6 cm. wide black tape, equated for area and displayed on the central part of one of the doors. The goal area could be entered only by pushing open the door with the correct stimulus pattern. All the doors could be locked.

Although only two doors could be seen from within the experimental chambre, three doors were used. The two outer doors dispalyed the same stimulus pattern, which differed from the middle door. By this arrangement, left-right positioning of the stimuli could be randomized. The panel of doors could be easily moved by the experimenter. The stimuli doors were equally illuminated from above and behind by a 25 Watt light bulb, the only light in the experimental room (see Figure 2). The luminance of the brightest parts of the stimuli was 10 foot Lamberts approximately.

Experimental Procedure

The cats were pretrained to push open the hinged doors in order to enter the goal box and obtain the reward of about two grams of beef kidney chunks. Following four days of pre-training they were presented with a light-dark discrimination to a criterion of 90 % correct for three consecutive days. This was followed with training on pattern stimuli. All stimuli used were 20 cm. in height (i.e. the stimuli maintained an approximate visual angle of 17 degrees from the initial viewing position) and were constructed of 0.6 cm. wide black tape. Two

FIGURE 2 TEST APPARATUS



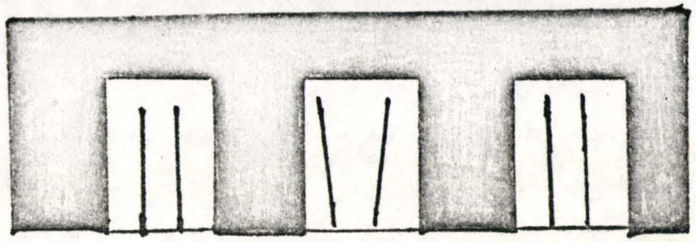
F: food dish

L: light source (40 cm. approx. above base)

SP: stimulus panel

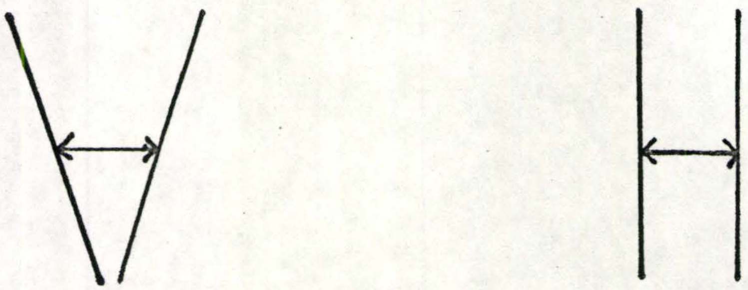
GD: plexiglass guillotine door

Stimulus Panel (SP)



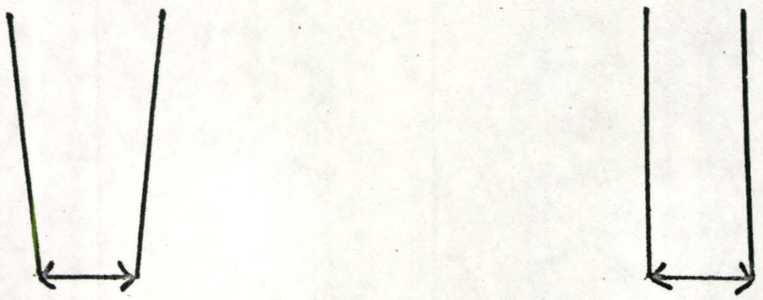
types of patterns were used. Stimuli 'a' consisted of two line that diverged upward and whose angle of divergence was changed for each phase of the experiment (Figure 3). Stimuli 'b' consisted of two parallel vertical lines which remained unchanged throughout the experiment. At the beginning of the experiment, stimulus 'a' had a bottom and top separation of approximately 1.5 cm. and 9.0 cm. respectively. The mid-point separation of the two lines of stimulus 'a' was equal to the separation between the lines of stimulus 'b' which was 5 cm. Once criterion was reached for the initial pair of stimuli 'a', b', training on the next pair of 'a, b', stimuli was started. The bottom separation of this stimulus 'a' was made the same as for stimulus 'b' and the top separation was decreased such that aach arm was at an angle of 10 degrees off the vertical. Following training to criterion for this pair of stimuli, a series of stimuli 'a' were used, each with a one-half degree decrease in the angle to the vertical. The final stimulus 'a' reached had a separation of 1.5 degrees to the vertical for each arm and appeared very similar to stimulus 'b'.

A trial consisted of placing the animal in the dark start box. After approximately 5 seconds the cardboard door was lifted and the cat was given a 5 second observation of the stimulus doors. The plexiglass door was then lifted and the animal was allowed to leave the start box and make his response. By pushing the door with the correct stimulus pattern he was allowed to enter the goal area and obtain food. Errors were scored when he hit the locked door displaying the incorrect stimulus. However, following an error, he was allowed to correct and obtain food



a) b)

Initial training stimuli



a) b)

Final training stimuli.

FIGURE 3

for a corrected response. No punishment was given at any time for an error. When the animal had finished eating, he was replaced in the start box for the next trial. The animals were given 30 trials a day for the light-dark discrimination, and 40 trials a day, 6 - 7 days a week for the pattern discrimination. Cat G was trained to stimulus 'b' (positive) and stimulus 'a' was non-rewarded. Cats C and W were rewarded to stimulus 'a' and non-rewarded to stimulus 'b'. The positioning of the correct door was alternated according to the Gellermann sequence (1933).

Testing Procedure

Following several days of overtraining to the final training stimuli, a test procedure was given. In an attempt to prevent the effects of extinction, test stimuli with no reinforcement were presented randomly interspersed with regular training trials. Sixteen test and 24 training trials were given daily.

Combinations of four test stimuli were used. All test stimuli were composed of stimulus type 'b' (two parallel vertical lines - see Figure 3) but with the addition of 4 cm. long and .15 cm. wide hash marks. For stimuli b_1, b_3 and b_4 the hash marks were at 30 degrees to the vertical, since there is evidence that at this angle the illusion is maximal (Fisher, 1969), whereas for stimulus b_2 the hash marks were at right angle to the verticals (Figure 4). With human subjects stimulus b_1 gives an illusory percept similar to the training stimulus 'a' (two lines converging upward). Stimuli b_2 and b_4 give no illusory percept but serve as controls for the area convered by the hash marks and for slanted lines respectively. The training trials during the test sessions

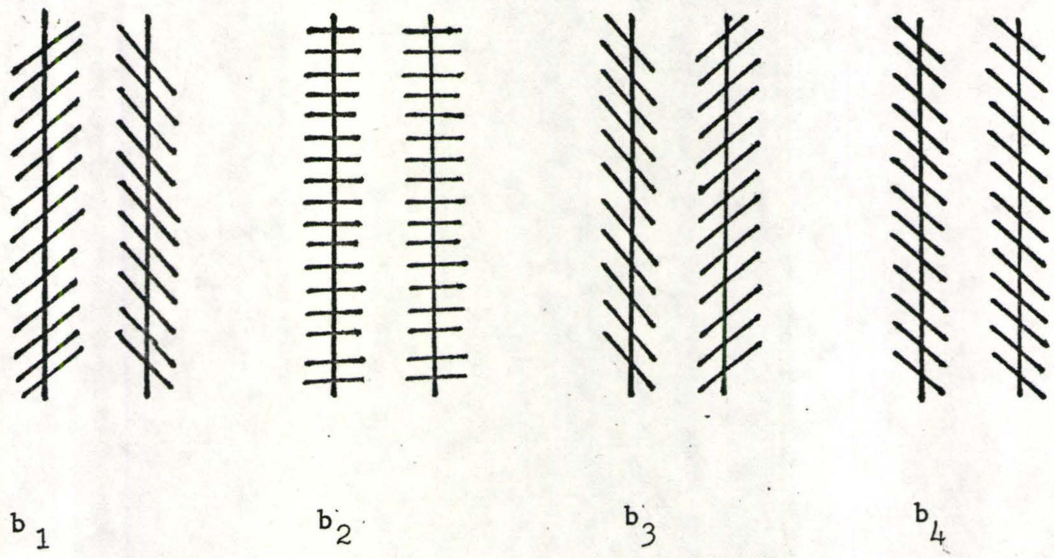


FIGURE 4 TEST STIMULI

served as a cue to the disruptive effects of testing. Testing was discontinued if subjects made errors on more than five consecutive training trials.

RESULTS

Considerable difficulty occurred during the training with the female cat G. Although given extra days of training, she never reached criterion for the final training stimulus. As a result, no data was reported for her.

For the two male cats, performance to stimuli 'a , b' reached criterion on day 15, and criterion to the final training stimulus was reached on day 31. Nine days of overtraining were given, then on day 40 the test procedure was started for the two cats. Three test days were given to cat W and two days for cat C before disruptions in behaviour made further testing impossible. Five days of retraining, then a retest was attempted but the retest failed to give any results.

The data of the test are presented in Table 1. For pairings of stimuli b_1 with b_2, W chose stimulus b_2 75 % of the time. Similarly when b_1 was presented with b_3 and b_4, b_3 was selected 80 % and b_4 was selected 63 % of the time. The results are similar for cat C. With b_1, b_2 pairings and b_1, b_4 pairings, C chose b_2 71 % and chose b_4 57 % of the time.

Stimulus 'a' had been positive for both cats and it was expected that if they could perceive illusions, they would choose stimulus b_1 in all test combinations since at least for humans, this is the test stimulus most similar to 'a'. Similarly stimulus b_2 gives no illusory percept in humans and is hence most similar to 'b', and should be avoided.

TABLE 1

Results of Experiment 1

	Pair of test stimuli	Preferred	Percentage preferred
Cat W	b_1, b_2	b_2	75 %
	b_1, b_3	b_3	80 %
	b_1, b_4	b_4	63 %
Cat C	b_1, b_2	b_2	71 %
	b_1, b_4	b_4	57 %

DISCUSSION

The results of the preliminary experiment 1 indicate that at least two of the cats learned a correct cue, i.e. line orientation, and generalized to this dimension during the test. However, the overall negative results obtained suggest that the stimuli provided an unknown and spurious cue which the cats consistently used. Possibly, the stimulus patterns were too large. Instead of attending to the whole test pattern the animals may have attended to and generalized to the small slanted hash marks during the test. This at least indicates the ability of cats to generalize a dimension, i.e. slope, to a much smaller stimuli. For example, the hash marks on stimulus b_3 were most similar to the line orientation of the positive training stimulus, and the hash marks of b_1 were opposite in orientation to the training stimulus. Considering orientation as the crucial dimension, then given a choice between b_1 and b_2 it is possible that what the animal actually did was not respond to b_2, but to respond away from b_1. Further evidence that the animals did avoid b_1 is that both animals preferred test stimulus b_4 when paired with b_1, though b_4 was entirely novel and could not be fitted along a dimension.

Further, the addition of the very complicated test stimuli proved to be a disturbing factor for the cats. Long before an association of non-reinforcement could have been formed with the test stimuli, i.e. on early test trials, the animals were more hesitant about leaving the start box, vocalized a great deal and in general seemed very aware that the stimulus pattern had changed.

The test stimuli are so extremely complicated it would have been fortuitous and surprising for the cats to respond to the illusion effect. It would have indicated an ability to perceive an illusion under adverse conditions. The addition of the hash marks on the test stimuli drastically changed the overall brightness of the stimulus array, and brightness is a strong cue for the cat. Also, the cats learned to respond to one pair of lines during training. During the test, they were confronted with thirteen pairs of lines. Although the two parallel lines on the test stimuli were thicker, more of the total area of the stimulus was composed of the small hash marks. Further, the cats used in this experiment were standard laboratory cats with unquestionably deprived backgrounds, and it is known that cats reared in restricted environments are unusually susceptible to the impact of novel stimuli (Konrad and Bagshaw, 1970). Considering all these factors, it is understandable that behaviour was so disrupted during the tests.

The question of whether or not cats see certain illusory percepts is still unanswered. What has been learned however, is a method of training cats to perform very fine discriminations. This is important since for many illusory patterns the illusory effect is small. However, to answer the proposed question two modifications are required. The first is simply to use much smaller targets. Secondly, what is needed is an illusion that gives a reasonably strong effect and does so without disruptive additions.

What is needed is an illusion that could be trained and tested on stimuli which are identical with respect to brightness, the number of lines and line orientation. One possible illusion that satisfies these requirements is the Muller-Lyer illusion wherein one of two equal lines appears longer than the other when arrowheads are added. However, there are many possible problems with this illusion. For example, cats could be taught to respond to the longer of two lines during training. During the test, the illusion is presented and the cat is expected to respond to the line with the inward facing arrows if he sees the illusion. However, if he does respond this way, is he doing so because the straight line appears longer or because he is using the overall length of the stimulus, including the arrows. If all combinations of arrowheads were repeatedly presented during training with the arrowheads having no scheduled consequence, then responding to the arrowheads alone should extinguish and the undesired effect should not occur. A second problem might occur from the difference in overall brightness between the two training stimuli since one would be longer. Cats are sensitive to brightness cues but given that the stimuli are small relative to the field, a discrimination by brightness alone would be difficult. Although unlikely, the cat could learn something about absolute line length. This could be discouraged by using several lines of different lengths for each condition.

Although the Muller-Lyer illusion has some possible problems of training and testing, it was believed that these problems are less severe than those experienced with the Hering illusion and could be managed.

The preliminary experiment 1 was repeated in the primary experiment 2, with the Muller-Lyer illusion substituted for the Hering pattern.

PRIMARY EXPERIMENT 2 WITH THE MULLER-LYER ILLUSION

METHOD

Subjects

Five cats were used in this primary part of the study: three males, W and C (who were also used in Experiment 1) and LC (ten months old at the start of this experiment); two females, M (about five years old and pregnant near the end of the experiment); and D (seven months old at the start of the experiment). The cats, except for M when pregnant, were maintained at about 90-95% of their ad lib weight. They were fed during and just after each experimental session.

Apparatus

The apparatus used in Experiment 2 was a slightly modified version of that used in Experiment 1. In the decision chambre the partition forming the two alleyways was decreased from 50 cm to 25 cm and removed during the test procedure. This was done to encourage comparison between the two stimuli. The second alteration involved fixing the panel on which the stimulus doors were hinged so that only two doors were used. Each door was constructed of translucent milky 0.15 cm Plexiglass and all but a section 7.5 cm long was covered by black cardboard. Two 1 cm wide strips of Plexiglass were fused along both edges for the total length of the door. A thin groove 7.5 cm long was drilled between the door and the strip, 10 cm from the bottom of the door on each side. Stimulus cards of clear heavy plastic were slipped through the slits and held on the decision chambre side of the door. Stimuli constructed of black tape were displayed on these 22 X 7 cm plastic stimulus cards. For cat D, the smallest subject in this experiment, the stimulus cards were displayed lower on the doors than for the other cats, approximately at her eye level.

Experimental Procedure

The initial pretraining involved training the cats to enter the goal box by pushing open the stimulus door, followed by training of a light-dark discrimination to a criterion of 90% correct for three consecutive days.

Training of a length discrimination with vertical targets was carried out in a series of 13 steps. The original stimuli to be discriminated were 5cm and 1cm in length and 0.6cm wide. Arrowheads 0.5cm long and constructed of 0.1cm wide tape were set at 30 degrees to the vertical line. For all animals, the longer stimulus was rewarded and a correction procedure was used.

In each step, four stimuli were used: the longer with outward facing arrowheads, reinforced; the longer with inward facing arrowheads, reinforced; the shorter with outward facing arrowheads, non-reinforced; the shorter with inward facing arrowheads, non-reinforced. (See Figure 5a.) All four combinations of these stimuli were used equally and in a random order throughout the session of 40 trials. (See Figure 5b.) Right - left positioning was alternated by the Gellerman series.

The difference in length between positive and negative stimuli was decreased gradually. The width of both stimuli was also decreased gradually so that the final stimuli were 0.15cm wide. The complete series of training stimuli used are shown in Figure 6.

Testing Procedure

When a cat's response to the final stimuli had stabilized above a

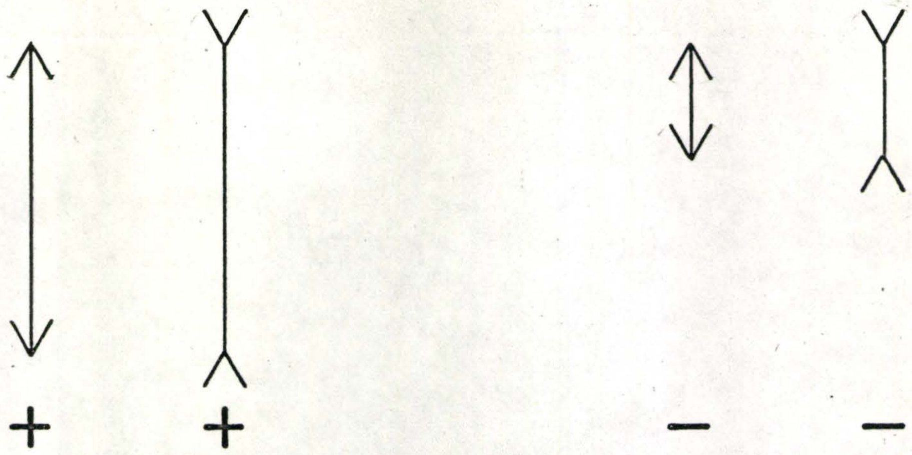


Fig. 5a Example of training stimuli used in Experiment 2.

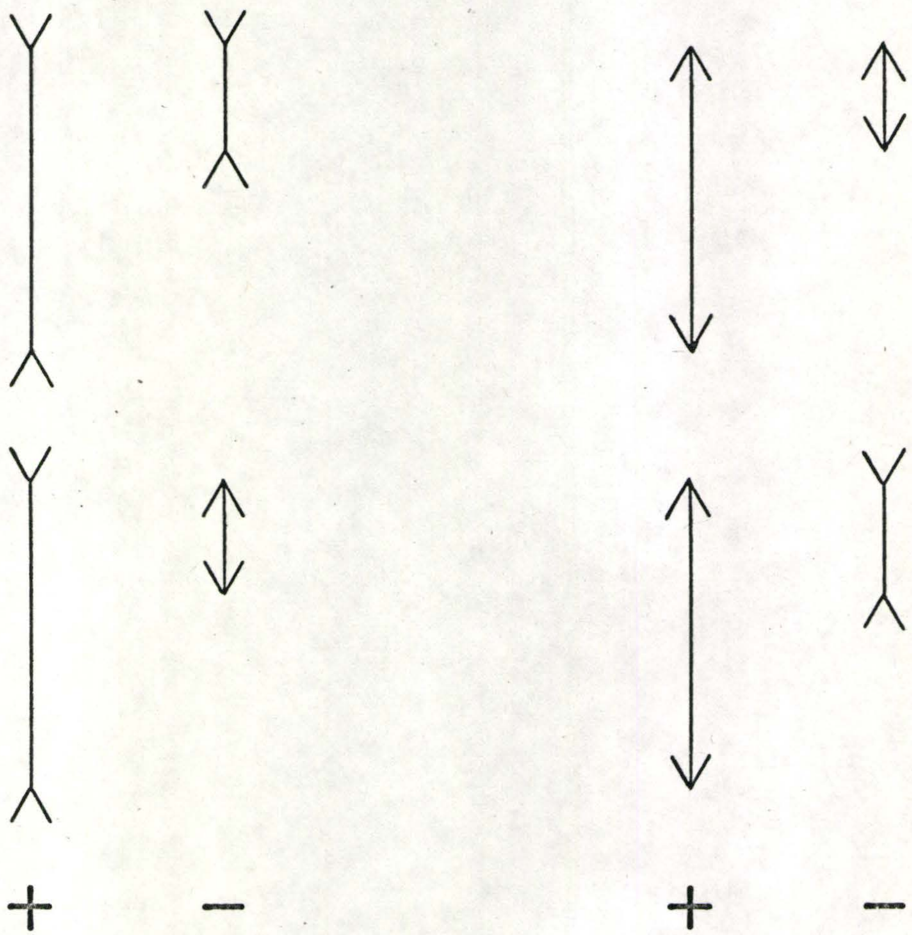


Fig. 5b Combination of training stimuli used in Experiment 2.

FIGURE 5

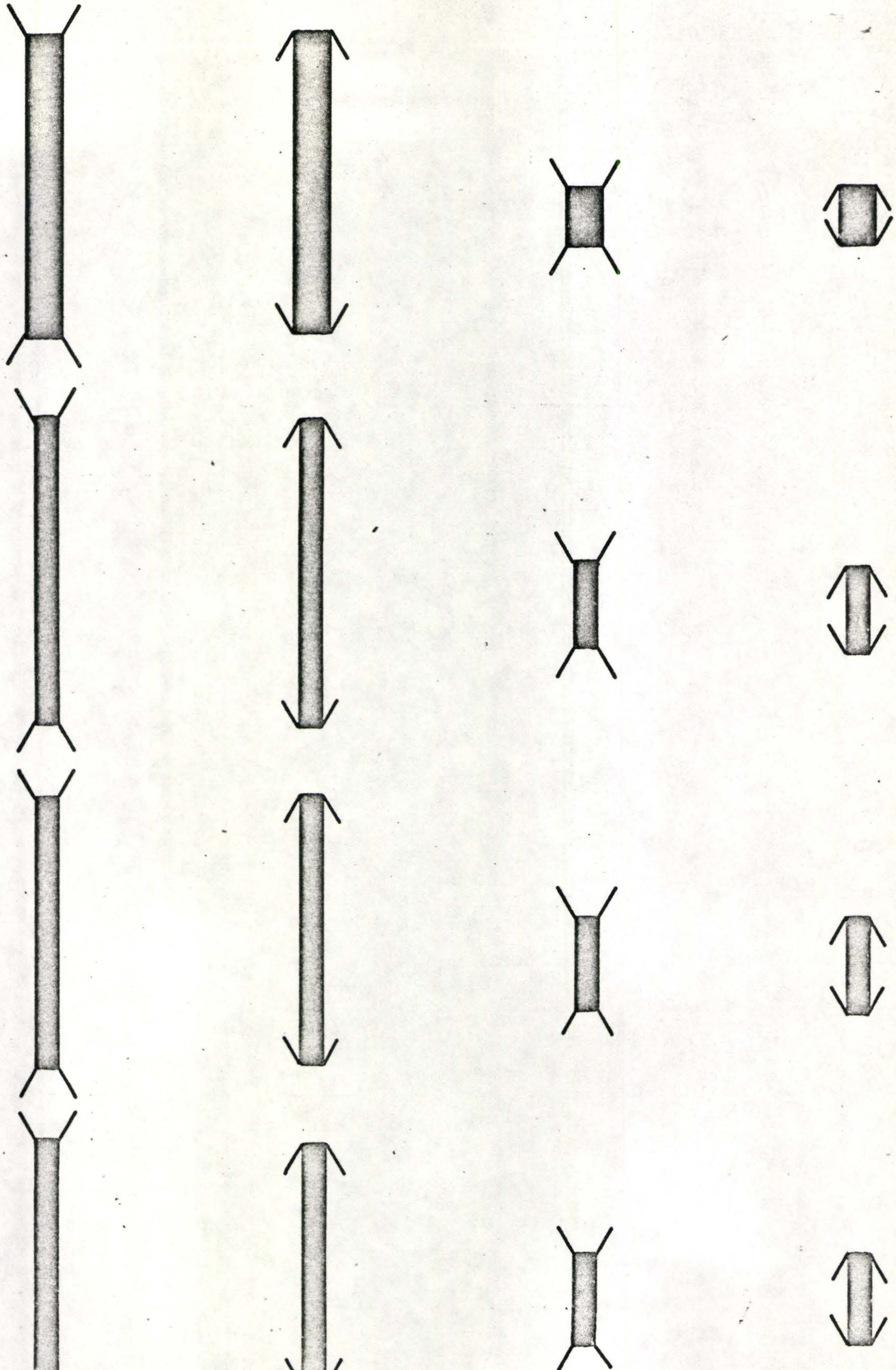


FIGURE 6 i Series of training stimuli to scale used in Experiment 2.

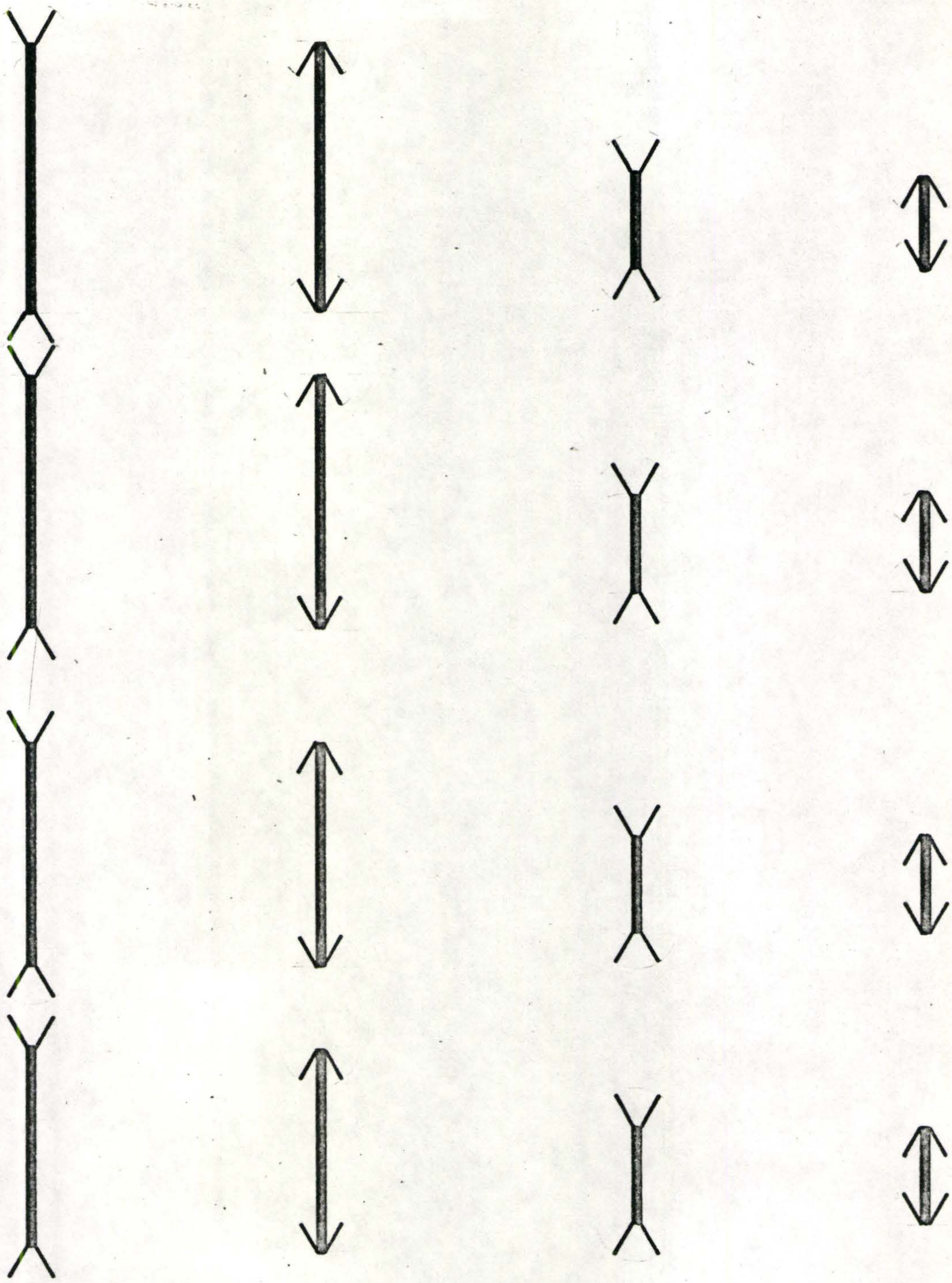


FIGURE 6 ii Series of training stimuli to scale used in Experiment 2.

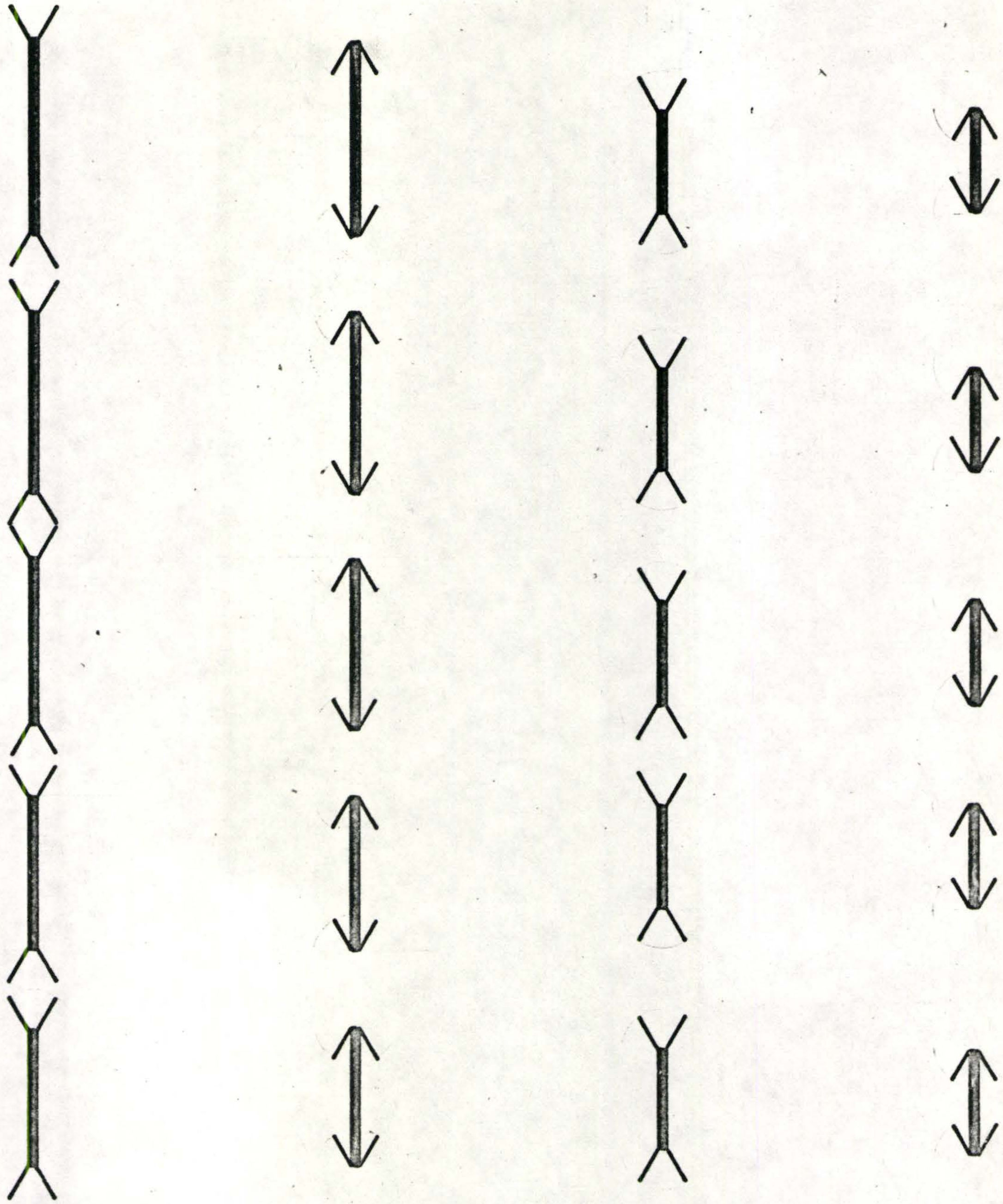


FIGURE 6 iii   Series of training stimuli to scale used in Experiment 2.

criterion of 80% correct for five consecutive days, the testing procedure was begun. A one day pretest was given two days before the test. The pretest was to determine the part of the stimuli that the cat was using for the length estimate. Stimuli 1.45 cm and 2.4 cm in length with 0.8 cm arrowheads set at 30 degrees to the vertical line were given. All four combinations of the stimuli were used as during training but reward was available for both alternatives. If at least 75% of the pretest stimuli were responded to correctly, retraining was given for one day followed by test 1.

Test 1 was conducted for five sessions. In each session 20 test trials and 20 training trials were presented in a random order. The test stimuli were of equal length, 1.75 cm long but one had an inward facing arrowhead whereas the other had outward facing arrowheads. The 20 training trials were composed of 2 trial types, both with the same direction arrowhead - the positive stimuli were 2.0 cm in length while the negative stimuli were 1.5 cm long. The series of stimuli presented during the pretest and test are shown in Figures 7 and 8 respectively.

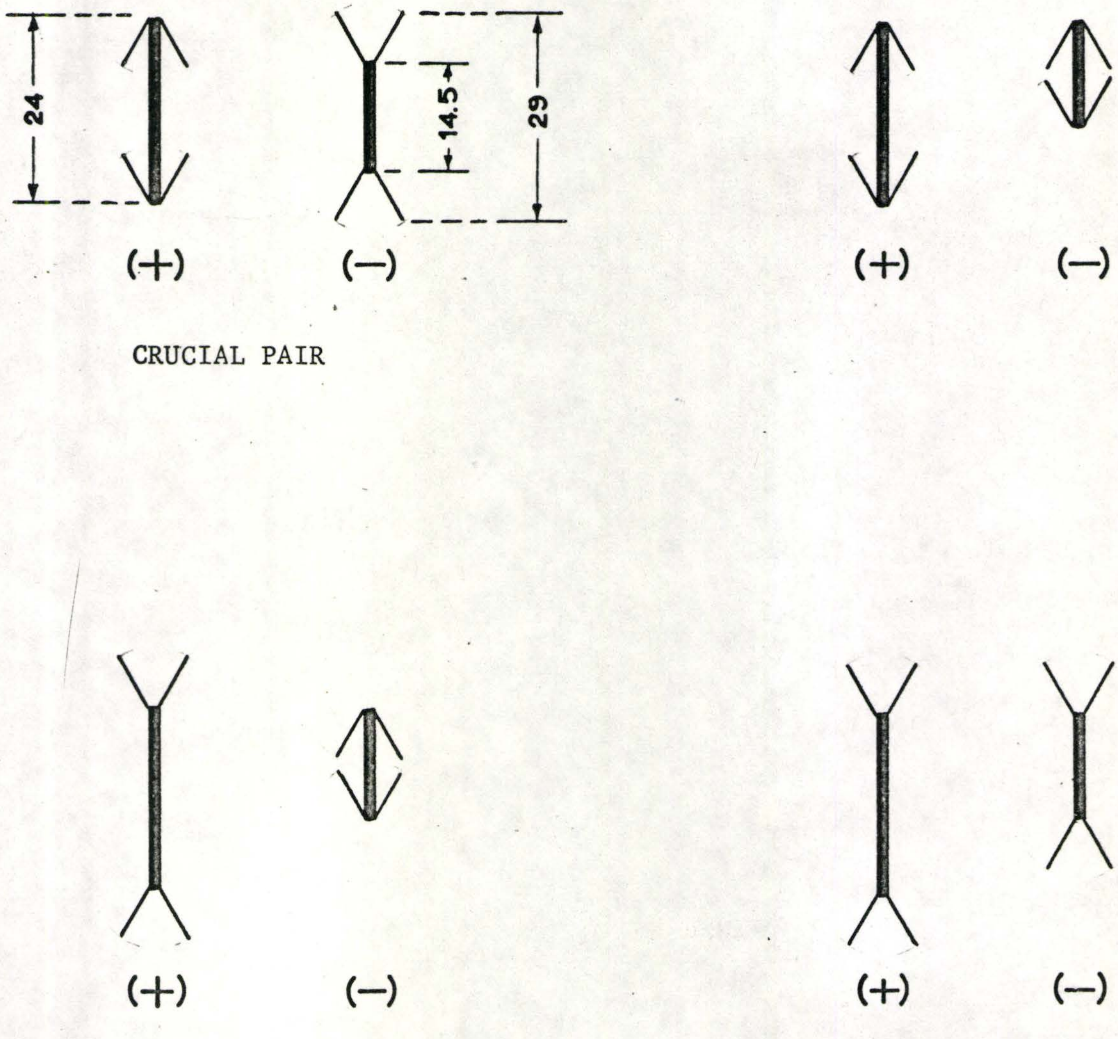


FIGURE 7 PRETEST STIMULI

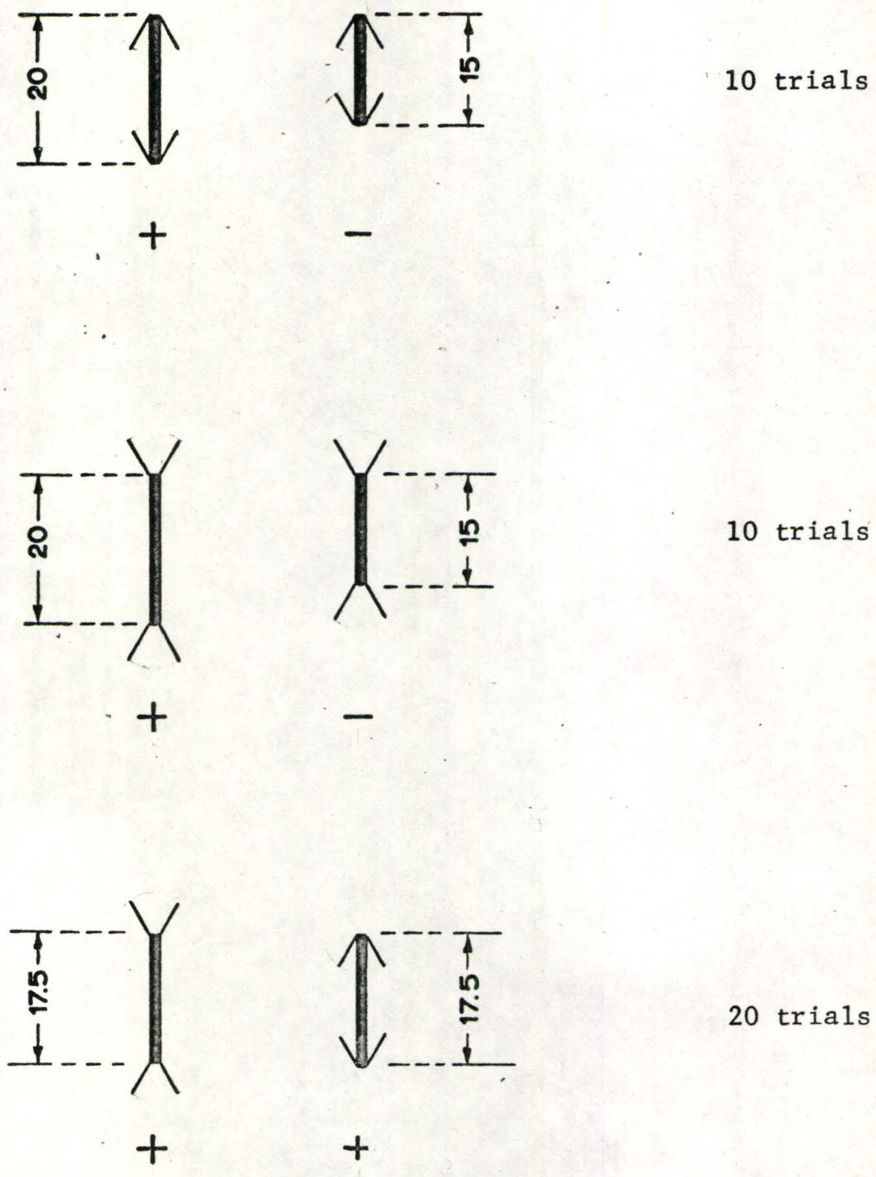


FIGURE 8 TEST STIMULI

RESULTS

Initial training using horizontal representations of the Muller-Lyer illusion was discontinued following 30 days of no learning. Using vertical targets, a criterion of 75% correct responses to stimulus 1 was obtained on day 8, cat M; day 12, cat W; day 13, cats C, LC AND D.

Table 2 presents a summary of the number of days, 40 trials a day, that each cat required to reach a criterion of 75% correct responses to the stimuli in each phase of Experiment 2. The total number of days to obtain 80% correct responding to the final training stimuli was day 33, cat M, day 40, cat D, day 41 cat LC and day 42, cats C and W.

The pretest data is presented in Table 3. All cats preferred the correct rather than the overall longer stimulus in the 'crucial pair' (see Figure 7). Cats W, C, D and LC chose the overall longer stimulus only twice in ten trials and cat M chose it 3 times. Although the performance was generally poorer during the pretest, there was no marked change in the cats behaviour.

The results of five days of testing are shown in Table 4. All animals showed a preference for the subjectively longer stimulus; cat W, 83%; cat C, 75%; cat M, 70.7%; cat LC, 70% and cat D, 68%. Only 82 test trials were given to cat M for although she appeared very hungry, she refused to leave the goal box after about 30 trials. A sixth day of testing was cancelled due to the birth of her kittens.

TABLE 2

Number of Days of 40 Trials in Each Phase of Experiment 2

Stage Cat	W	C	L.C.	M	D
1	12	13	13	8	13
2	2	2	2	2	5
3	1	1	2	1	3
4	2	2	1	2	2
5	3	3	3	1	1
6	1	1	1	1	1
7	4	1	2	2	1
8	2	3	3	1	2
9	3	3	1	2	3
10	1	1	2	1	1
11	1	3	2	3	2
12	3	3	4	3	1
13	7	6	5	6	5
TOTALS	42	42	41	33	40

TABLE 3

PRETEST DATA

CAT	W	C	D	LC	M
Percent of Errors During Pretest (N=40)	22.5	12.5	22.5	25.0	25.0
Percent of Errors to Crutial Pair (N=10)	20.0	20.0	20.0	20.0	30.0

TABLE 4

TEST DATA

CAT	TEST DAY	Proportion of Errors In Training Trials	Proportion of Positive Responses to Illusion	
W	1	7/20	17/20	
	2	5/20	17/20	
	3	2/20	17/20	
	4	2/20	15/20	
	5	1/20	17/20	
	TOTAL	17%	83%	N= 100
C	1	5/20	15/20	
	2	3/20	14/20	
	3	2/20	16/20	
	4	6/20	15/20	
	5	2/20	15/20	
	TOTAL	18%	75%	N= 100
D	1	3/20	14/20	
	2	3/20	14/20	
	3	2/20	11/20	
	4	2/20	14/20	
	5	3/20	15/20	
	TOTAL	13%	68%	N= 100
LC	1	5/20	13/20	
	2	6/20	14/20	
	3	4/20	14/20	
	4	4/20	16/20	
	5	3/20	13/20	
	TOTAL	22%	70%	N= 100
M	1	1/14	12/18	
	2	1/16	12/16	
	3	1/14	12/16	
	4	2/14	11/16	
	5	1/14	11/16	
	TOTAL	8.3%	70.7%	N= 82

Two animals C and LC appeared to be upset by the removal of the divider during the test. Both animals showed a position preference at the start of test day 1. A series of trials in which the preferred side was made negative were given. After five and seven trials for C and LC respectively the regular session was begun again.

There was no evidence of any disruptive effect of the test stimuli themselves. Errors to the 2 sets of training patterns were low, cat W, 17%; cat C, 18%, cat D, 13%; cat LC, 22% and cat M, 8.3%. Also, there was generally a high consistency of responding during each test day.

DISCUSSION

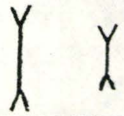
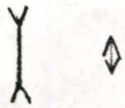
The data strongly suggests that cats do perceive the Muller-Lyer illusion. All cats in this experiment chose the subjectively longer target in the test more than the subjectively shorter target and two of the cats chose it significantly more ($p = 0.05$ with X_2 test with 4df). The behaviour during the test (the speed of responding, the number of alterations, hesitancy, vocalizations) did not differ noticably from the behaviour during training.

There is evidence that the direction of the arrowheads played some role during training. See Table 5. Table 5 presents the total and mean number of errors per session to each pair of stimuli during training. Four cats, W, C, D and LC made fewer errors to the two pairs of stimuli in which the negative member of the pair contained outward facing arrowheads, and appeared subjectively smaller than the other negative target. One cat, M, made fewer errors to the pairs in which the positive member had inward facing arrowheads, and was subjectively larger. Thus it appears that four of the cats more easily recognized and avoided the subjectively shorter negative stimulus than the subjectively longer negative stimulus. The fifth cat made more correct responses to the subjectively longer positive stimulus than the subjectively shorter positive stimulus.

Although the cats were influenced by the arrowheads, there is reason to believe that they used only the vertical shaft of the target for the length estimate and not the overall length. In the

TABLE 5.

Errors made in each pair of stimuli during training

CAT				
W				
TOTAL ERRORS	128	120	120	135
Mean Number of Errors Per Session	3.0	2.9	2.9	3.2
C				
TOTAL ERRORS	103	88	83	102
Mean Number of Errors Per Session	2.5	2.1	2.0	2.5
D				
TOTAL ERRORS	126	123	115	126
Mean Number of Errors Per Session	3.2	3.1	2.9	3.2
LC				
TOTAL ERRORS	98	89	92	106
Mean Number of Errors Per Session	2.4	2.2	2.2	2.6
M				
TOTAL ERRORS	54	64	56	76
Mean Number of Errors Per Session	1.7	1.9	1.7	2.3

Muller-Lyer illusion, the subjectively longer target is, in fact, longer than the subjectively shorter target when the overall length, including arrowheads is considered. The pretest was given to determine what part of the stimulus the cats were using for their length estimate. In the pretest ten 'crucial pairings' were given to each animal. See Figure 7. Animals responding to the overall length of the stimulus would have selected the stimulus with inward facing arrowheads, with an overall length of 2.9 cm. compared with 2.4 cm. for the stimulus with outward facing arrowheads. Animals using such a criterion were forced to discriminate a difference of 0.5 cm. If, however, the cats were using the shaft alone for their estimate of length, then the longer of the 'crucial pairing' should be easily discriminated. The shaft differences between positive and negative stimuli was 0.95 cm. This would have been a comparatively easy discrimination for these animals and rapid responding would have been expected. As reported above, few errors did occur to this pair but responding was slow and involved many alterations before the final response was made. However, it was observed that there was a greater degree of uncertainty shown during the pretest as a whole then at any other stage in the experiment. The greatest hesitancy seemed to occur with pairs containing the negative member with outward facing arrowheads. In Figure 7 such a stimulus appears most unlike the preceeding negative stimuli of the training pattern, at least to the human eye. It is believed that all cats were using the shaft portion of the stimuli for their length estimate and that the uncertainty shown was due to the slight differences in the stimulus patterns.

During the preliminary experiment 1 large disruptions in behaviour were observed when novel stimuli were presented. Throughout the primary experiment 2, the cats were given a progressive series of training stimuli in an attempt to minimize adverse effects of novel stimuli. However, the pretest stimuli produced some uneasiness in the subjects.

The finding that cats perceive the Muller-Lyer illusion as do humans suggests that some visual mechanisms of both humans and cat are comparable. Further it suggests that many of the neurophysiological recording studies with cats may have produced information relevant to visual studies with humans. Human visual perception may now be discussed with greater confidence in terms of known neurophysiological data.

More specifically the present data support the study by Burns and Pritchard which was based upon the assumption that cats experienced illusory percepts in a way similar to human observers. They found that some cortical cells produced displaced 'cortical images' with the addition of a second line in the cell's cortical receptive field. Hence, they proposed a possible mechanism to explain the perceptual distortion caused by illusory patterns.

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