TWO STUDIES OF THE M-L ILLUSION :

PROCEDURE AND PRETRAINING

DESTRUCTION OF THE MÜLLER-LYER ILLUSION AS A FUNCTION OF PROCEDURE AND PRETRAINING

By

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SCOPE AND CONTENTS:

Two experiments were performed to investigate conditions affecting the Müller-Lyer illusion and its decrement with practice.

The first experiment was a methodological study concerned with the setting of the variable before adjustment by the subject. The results indicated that the method employed may determine whether a decrement occurs with repeated trials. The evidence suggested the most suitable method to employ in the succeeding experiment.

The second experiment was performed to investigate the effect of practice with another illusion figure on the magnitude of illusion on the Müller-Lyer figure. The practice figure was the same as the Müller-Lyer illusion figure except that circles replaced the obliques. It was found that the magnitude of the initial illusion is a decreasing monotonic function of the amount of preliminary training. This finding is interpreted as meaning that in pretraining subjects are practised in disregarding the context (circles) of the horizontal lines of the figure and this transfers positively to the Müller-Lyer task.

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CHAPTER 1

Introduction

Two experiments concerned with the Müller-Lyer illusion are reported on in this thesis. This illusion, and particularly its destruction over trials, has become the object of considerable experimental and theoretical interest since the publication of two articles by Köhler and Fishback (1950) relating its destruction to the general theory of "satiation". The present studies are also concerned with the decrement in the illusion with repeated exposures.

The first experiment is a methodological study concerned with decrement in the illusion as a function of procedure. Some experiments reviewed in the next section suggest that the method used in setting the variable stimulus before adjustment by the subject, may determine whether or not a decrement occurs. Four variations in the basic procedure are introduced and the effect of these conditions on the trend over trials is observed.

The second experiment, which forms the main part of this thesis, is an investigation of the effect of pre-training on the magnitude of initial illusion and its subsequent decrement. Pre-training with a stimulus figure in which circles replace the obliques of the Müller-Lyer figure is given. If this is as effective in producing a decrement in the illusion as practice on the illusion figure itself, it would seem to offer some evidence for a learning interpretation of the decrement rather than Köhler's explanation in terms of satiation.

In order to establish the background for these two experiments, the history of the Müller-Lyer illusion is reviewed, with particular emphasis on the investigations having to do with destruction of the illusion. The theoretical interpretations of the decrement are considered and an alternative to the satiation hypothesis, in terms of perceptual learning, is offered. This survey should clarify the considerations which led to the experiments carried out in this study.

Finally, the method used and the results obtained in each experiment are presented and the significance of these results is discussed.

CHAPTER 2

History

Although specifically this investigation deals with the Müller-Lyer illusion, the more general concern is with the effects of learning on perception, especially changes in perception as a function of controlled training. We will, therefore, before proceeding to a discussion of the Müller-Lyer illusion itself, discuss briefly the problem of perceptual learning. This will be followed by a review of the empirical data on the Müller-Lyer illusion, and then a consideration of the theoretical interpretations of the illusion and its destruction.

Perceptual Learning

A survey of the relevant literature indicates that the term "perceptual learning" is used to refer to two different approaches to the study of perception. On the one hand, there is the problem of the influence of past experience or learning on perceptual development. The question here is "Do we learn to perceive?" or how much of perception is attributable to learning. On the other hand there is the somewhat more limited use of the term to refer to changes in perception which occur as a function of repeated trials within a limited time space. The problem in this case is whether such practice can bring about an improvement in perceptual discrimination.

The first question - in what sense do we learn to perceive - can be traced back to, or beyond, the 19th century controversy between nativism and empiricism which it appears unnecessary to discuss in detail here. The modern counterpart can be exemplified by the opposing approaches of Gestalt psychology and behaviorism or neo-empiricism. The Gestalt approach attributes complex perception, such as the perception of objects, to field-like properties of the central nervous system. Perception is considered to be an inherent process and is said to be isomorphic to the physiological process going on in the brain. The empiricist approach, in simplified form, holds that the perception of objects and events is the result of learning and comes from past experience. Most psychologists would now agree that there must be some respects in which perception develops spontaneously and other respects in which it depends upon experience. The problem, then, is how much is contributed by each. This has resulted in studies of perception from the developmental point of view, such as investigations of the nature of perception when the subject has been deprived of certain experiences, or provided with extra stimulation, during infancy. The object of these studies has been to determine what part of perception is innate and what is acquired through learning. The study of age changes in perception, such as those reviewed by Wohlwill (1960), can also be included here, as presumably some of the changes in perception which occur with age are due to learning as well as maturation.

In the other area also designated by the term perceptual learning, experiments are concerned with the problem of whether discrimination is rendered more acute by practice or training. In the experimental situation, practice, involving repeated presentation of the stimulus, is manipulated. This area would include the type of experimental investigations reviewed by Gibson (1953).

The two approaches outlined are not distinct and it is presumed that the same principles may apply to both. It would appear, therefore, that any investigation which throws light on the one question would also help answer the other. The present study is concerned with changes in perception as a function of practice, in that it is an investigation of whether improvement in perception developed through practice in one situation can be transferred to another situation, rendering perception in the latter more acute. The specific details have already been pointed out in the introduction and in order to set the stage for a description of the experiments conducted in this study, we will now turn to a review of the history of the Müller-Lyer illusion and the theoretical interpretations of the destruction of the illusion.

Experimental Studies of the Müller-Lyer Illusion

The Müller-Lyer illusion consists of two lines of equal length, one of which is enclosed by arrow heads, while the other has the tails of the arrow extended away from itself (see Figure 1). It is the best known of the geometric or optical illusions, which are illusions in the sense that what is perceived does not correspond with the physical or metric properties of the stimulus. Thus the two horizontal lines of Figure 1 are physically equal but the one enclosed by the arrow heads that form acute angles with the line, usually appears shorter than the line with the tails that form obtuse angles.

Attention was first drawn to this illusion by Müller-Lyer in 1889 (Boring, 1942) and a variety of theories were advanced to account for it. These theories stimulated a number of experimental investigations, one of

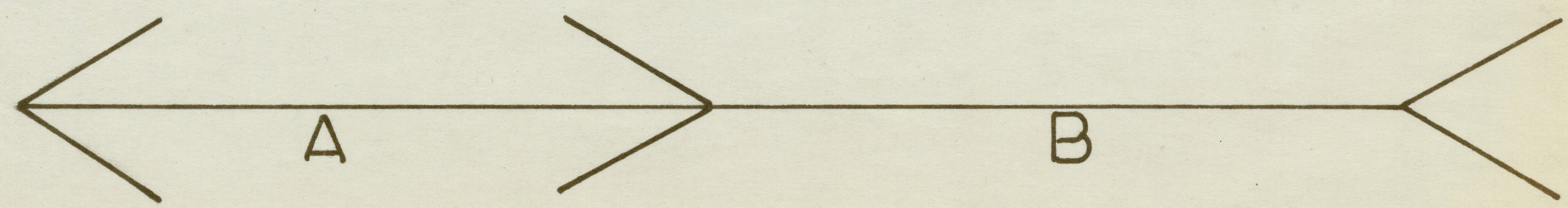

Figure 1. The Müller-Lyer illusion. Line A, with the acute angles, appears shorter than line B with the obtuse angles. The two lines are physically equal in length.

the earliest of which was that of Heymans (1896) who reported on some of the variables affecting the strength of the illusion. He found that varying the lengths of the obliques and the size of the angles both affected the average magnitude of illusion. The maximum effect, an average of 25%, was obtained when the obliques were about a quarter of the length of the horizontal lines and when the angles were about 30°, although considerable variation occurred with different individuals. Heymans also observed that after the figure had been shown over and over again to the same subject, a considerable decrease of illusion size was noticeable. Further, when the illusion had been reduced to some extent by this method, rotation of the figure 180° restored the illusion to its original size and intensity.

Several studies of the effect produced by repeated presentations of the illusion, followed Heymans' reference to this phenomenon. Judd (1902), using two subjects, determined the amount of illusion before practice by averaging the first 25 measurements, and then a series of approximately 1000 measures were taken. Judd's findings conformed to those of Heymans as he noted that each period of practice resulted in some improvement, with the final result being the disappearance of the illusion. He also found that when the figure was rotated so that the variable was on the other side, the illusion recurred in almost the same strength as in the original determination. It then, however, decreased very rapidly, indicating transfer of the effects of practice before rotation of the figure. In this experiment, Judd remarked on the sudden improvement shown by one subject after a pause of two days between practice sessions. The beneficial effects of rest were again noted in his monograph (Judd, 1905).

In this investigation, rather than confining practice to a few days of concentrated effort, considerable intervals were inserted between the practice periods. The practice effect was again obtained and Judd also reported that, in some cases, a negative illusion developed, that is, the line which had originally appeared shorter now was perceived as the longer of the two.

Results conflicting with these reports of a practice effect then began to appear. Smith (1906) reported that he was unable to obtain the practice effect. Rather, he found that practice in the form of repeated adjustments failed to decrease the amount of illusion. Seashore, Carter, Farnum, and Sies (1908) maintained that different subjects showed different effects from practice and thought this was dependent on the knowledge, or lack of it, which the subject had of the illusion. With subjects who began the experiment without knowledge of the illusion, the force of the illusion remained unchanged through long continued practice. However, of the four subjects in Seashore's experiment only one was completely naive in regard to the illusion and Seashore's thesis is thus based on the results from one subject. The other three did show the practice effect, two of them to the point of developing a negative illusion.

On the other hand, Lewis (1908) in investigating the effects of momentary and prolonged exposure of the figure, confirmed the earlier findings that the illusion decreased with practice. In the series with prolonged exposure the influence of practice was quite definite, with the illusion diminishing in each session and ultimately disappearing. With only a momentary exposure, however, the results were more ambiguous as one subject showed no change and two showed a tendency to increase while the other four showed a tendency to decrease. Lewis did not find that knowledge of the illusion increased the probability of obtaining a decrement. In agreement with Judd, he did find that a day's rest pause accelerated the rate of decrease.

The findings of this period of investigation, although not altogether consistent, may be summarized as follows:

1) Some (Heymans, 1896; Judd, 1902, 1905; Lewis, 1908) found that the illusion decreased and in some cases disappeared after repeated presentations. Others (Smith, 1906; Seashore, 1908) did not obtain this effect and in some subjects found an increase.

2) Where the practice effect did occur, it was observed that in some cases over-correction or a negative illusion developed (Judd, 1905).

3) Other effects which were reported concerned the effect on the decrement of rotating the figure and the effect of massed trials. With rotation, the illusion recurred in its original intensity (Judd, 1902). Massed trials were not as efficient in reducing the illusion as spaced trials (Judd, 1902, 1905; Lewis, 1908).

4) It was noted that factors such as the construction of the figure (Heymans, 1896) may influence the magnitude of the illusion. Thus, the length of the obliques and the size of the angles influenced the average magnitude of illusion.

Before proceeding to a description of the more recent experimental studies of the effect of repeated exposures of the illusion figure, a brief summary will next be given of some of the experimental work conducted on the Müller-Lyer illusion during the intervening period. These studies were more concerned with individual differences in the amount of illusion attributable to such factors as age, intelligence, and so on, than with the practice effect.

Pintner and Anderson (1916) studied the relationship between age and magnitude of illusion, finding that the amount decreases with increasing age up to age eleven after which fluctuations occur. This was corraborated by Walters (1942) and in a more recent study by Wapner and Werner (1957). These results indicate that the effect of assimilation to contextual stimuli decreases with age.

Other studies of individual differences in susceptibility to the illusion were those of Crosland, Taylor and Newsom (1927, 1929) on the relation between intelligence and the illusion. These studies do not appear to be critical to this thesis, but it may be noted that in both, the practice effect was again obtained. Their studies also lead to the conclusion that there was no significant correlation between intellectual rating and susceptibility to the illusion or amount of decrement resulting from practice.

Except for these isolated experiments, there was relatively little concern with the Müller-Lyer illusion until the attempt by Köhler and Fishback (1950a) to relate the decrement in magnitude of the illusion to satiation theory. This resulted in renewed interest in the phenomenon. The theory itself will be reviewed later when discussing the theoretical interpretations of the destruction of the illusion by repeated exposures, but we will first complete our review of the experimental investigations of this effect. Most of these studies were designed to test predictions arising from satiation theory.

Köhler and Fishback (1950a, 1950b) themselves obtained the practice effect, and also found that some subjects developed negative illusions in the course of repeated adjustments of the figure. In their experiments, a fixation point was used and they argued that this not only increased the size of the initial illusion but also hastened its destruction. Azuma (1952) obtained a significant decrement in magnitude of illusion when the subject was allowed to inspect the figure carefully in place of making repeated adjustments. He also found that drawing figures similar to the stimulus figure was effective in reducing the illusion. Selkin and Wertheimer (1957) also reported a decrement over trials and could find no difference in this process attributable to variations in the use of fixation point or adjustment.

In a paper concerned with methodology, Brown (1953) reported that changes in the apparent size relation between opposite halves of the visual field sometimes take place with repeated testing even when straight line stimuli are used. Brown draws attention to the necessity of taking half-meridional differences into consideration when planning experiments on the Müller-Lyer illusion and suggests some means of controlling for this factor, one being the use of the average of a number of measurements for each point on the curve, with half the measurements at each point made with the figure in one orientation and the other half with the figure rotated 180°. This would not only control for any differences in the halves of the visual field but should also provide a test of the satiation hypothesis since symmetrical satiation would thus be produced. Just such a procedure was used by Moed (1959) who found that rotation of the figure 180° failed to slow down the process of decrease. This finding of course conflicts with the earlier results obtained by Heymans (1896) and Judd

(1902). Moed (1959) also tested a prediction from satiation theory that a large number of brief exposures should be as effective in reducing the illusion as a smaller number of long exposures. This hypothesis was confirmed.

Spitz and Blackman (1958) in a study of the Müller-Lyer illusion in retardates and normals report confirmation of the hypothesis that capacity to "satiate" as inferred by a visual figural after effects test is predictive of the ability to perceive the illusion, whereas intelligence as measured by an IQ score is not.

Mountjoy conducted a series of experiments (1958a, 1958b, 1958c, 1960a, 1960b, 1961) designed to test Köhler's satiation hypothesis and his own interpretation of the reported decrement in the magnitude of the illusion. His principal findings were that decrement did occur, that this decrement was greater with massed rather than spaced trials, and that spontaneous recovery of the illusion took place during a 24-hour period between experimental sessions. He also reported (1960b) that the presence of a fixation point did not produce greater decrement and that the naiveté or sophistication of subjects concerning the illusion figure was not related to the occurrence of decrement.

Predicting from satiation theory that there would be an absolute difference in the amount of illusion as well as differences in the rate of decrease for different brightness intensities, L. E. Kamin (1959) did find a significant difference in the amount of illusion but not in the rate of decrease. The partial confirmation of her hypothesis provided some support for satiation theory.

The next two studies to be reported are of particular interest in that they failed to obtain the practice effect. Eysenck and Slater (1958) reported that with a group of 50 subjects practice produced scarcely any effect on the group as a whole. Rather, the effect of repeated trials varied greatly among subjects. Some did show a decrease, in others the trend was toward greater error, while still others showed no change. A similar failure to obtain the practice effect is also reported by Day (1960) who found in a series of three experiments that there was no decrement in the magnitude of the illusion. He then conducted three additional experiments designed to isolate the conditions under which a progressive decrease in error does occur and in these, and a seventh derived from the satiation hypothesis, he did obtain the desired effect. A methodological problem in regard to the setting of the standard arises with both Eysenck's study and those reported by Day. This may have been one of the factors responsible for their failure to obtain the practice effect and thereforetheir procedure will merit further consideration when the procedural study conducted as part of this thesis is introduced.

The principal findings from the recent spate of experiments on the Müller-Lyer illusion, and the few preceding these, can be summarized as follows:

1) The magnitude of illusion was found to decrease with increasing age (Pintner and Anderson, 1916; Walters, 1942; Wapner and Werner, 1957).

2) Most (Kohler and Fishback, 1950a, 1950b; Azuma, 1952; Selkin and Wertheimer, 1957; Moed, 1959; Mountjoy, 1958a, 1958b, 1960a, 1960b, 1961) found a decrement in the illusion over trials confirming the earlier reports of this effect. Several (Eysenck, 1958; Day, 1960) failed to obtain a decrease in the illusion in a group of subjects and reported marked

individual variations.

3) The development of negative illusions in some subjects after a series of trials was again reported (Köhler and Fishback, 1950a; Eysenck, 1958; Mountjoy, 1958a).

4) It was found that free inspection of the figure was just as effective in reducing the illusion as the use of a fixation point (Azuma, 1952; Selkin and Wertheimer, 1957; Mountjoy, 1960b).

5) Mountjoy (1958a, 1961) found that massed trials are more effective in reducing the illusion than spaced trials. This is contrary to the conclusion of Köhler and Fishback (1950b) as well as earlier investigators (Judd, 1902, 1905; Lewis, 1908) that spaced trials are more efficient. Mountjoy also reported spontaneous recovery of the illusion after a rest period.

6) Moed found that rotation of the illusion figure on each trial did not impede the process of destruction (1959).

Despite inconsistencies in the reported experimental findings, it may be said, in regard to both the early investigations and the more recent work, that it seems clear that decrement in the illusion has been amply demonstrated. The problem of interpretation of this phenomenon still remains.

Theoretical Explanations of the Destruction of the Müller-Lyer Illusion

While theory at one time attempted to account for the occurrence of the illusion, the main theoretical concern now seems to be centred in the destruction of the illusion. In this section we will first discuss a recent interpretation of the illusion as a constancy effect, and then consider four interpretations of its destruction. Considerable attention will be given to Köhler's "satiation" hypothesis while Eysenck's interpretation in terms of "habit formation" and Mountjoy's "habituation" hypothesis will also be considered. Finally an interpretation in terms of perceptual learning will be suggested.

The Müller-Lyer Illusion as a Constancy Effect:

As has been mentioned, a variety of theories purporting to account for the occurrence of the Müller-Lyer illusion were advanced during the latter part of the 19th century. Walker (1960) has reviewed these early theories quite intensively and since a complete account can be obtained from his work, they will be omitted here.

A more recent interpretation of the perceptual illusions is in terms of the "constancies" (Teuber, 1960). This is similar to the perspective theory (Boring, 1942; Woodworth and Schlosberg, 1956) which suggests that the figure is seen in the third dimension causing one line to appear farther away and therefore longer. The psychological phenomenon of constancy (which takes many forms - colour, brightness, shape, etc.) has been known to psychologists for generations. As with the illusions, various explanations have been given but the prevailing approach now is based on the belief that nearly all perception is perception of objects. Osgood (1953) maintains that when the observer shows nearly perfect constancy, he is perceiving in terms of how the object would appear in its normal mode of presentation. Supporting this view is the fact that conditions that destroy the object as something known, also destroy constancy, while a set of cues that indicate the actual nature of the object causes the organism to perceive it as it is known to him. This view is essentially that presented by Teuber (1960) who maintains that both constancies and the illusions can be approached on the same level. Teuber states that since perception in general lacks a simple one to one correspondence with physical stimuli, illusions should not be regarded as exceptions or special cases, but can instead be looked upon as misapplied constancy effects. According to this view most, or all, of the geometrical-optical illusions are tendencies toward size and shape constancy that persist as they function in everyday life, even with relatively isolated lines and angles drawn on paper. An attempt will be made here to illustrate this interpretation with the Müller-Lyer illusion. In the ordinary view of a table the far edge is enlarged "by the mind" in order to maintain constancy of shape. Applying this to the Müller-Lyer, if the figure with the acute angles is seen as a saw-horse with its legs away from the observer and the back near, while the obtuse angled figure is seen as a saw-horse with its legs toward the observer and the "belly" far away (Boring, 1942) the latter line will be enlarged, as is the far edge of a table, while the line in the acute angled figure will be seen as relatively small. This viewing of the figure as an object or "whole" results in the illusory effect. The presence of the obliques provides the essential context for perceiving the figure in this manner and it is only when they can be disregarded that the horizontal lines are seen as equal.

We will return to this interpretation of the illusion as a constancy effect, in discussing the derivation of the present experiment. It may be mentioned here that interpretation of the illusion in terms of the perceptual constancies may appear to be at variance with the data on decrease of the illusion with age, since there is substantial evidence that the constancies increase with age (Wohlwill, 1960; Teuber, 1960). However, these apparently contradictory findings may be reconciled since in both cases ability to attend to and discriminate cues appears to be the essential variable. Attending to cues which indicate the object quality of the stimulus in the constancies, and attending to cues which make possible finer discrimination and thus less illusory effect, would account for the increase in constancy and decrease in the illusion in the adult.

Interpretations of the Decrement:

When the progressive decrement in magnitude of the illusion over trials was first noted, the interpretation was generally in terms of learning. Although the explanation varied somewhat, the general idea seemed to be that the illusion effect was due to errors in judgement which the subject gradually learned to avoid with repeated trials, and thus the magnitude of illusion decreased. Judd's (1905) explanation of the practice effect appears to be an exception as he maintained that the change in illusion over trials was not a judgemental process but was due to a change in the perceptual process.

Opposed to the learning interpretation is the more recent attempt by Köhler and Fishback (1950a) to relate the destruction of the illusion to "satiation" theory. It was the appearance of their articles which focused attention on accounting for the decrease with practice rather than on explaining the initial illusion.

Satiation theory was developed following the reports on figural after-effects by Gibson in the 1930's (Osgood, 1953). Kamin (1959) presents a thorough review of the interpretation of figural after effects in terms of satiation theory. Here an attempt will be made to state briefly what is meant by satiation and how it is employed to explain the change in the Müller-Lyer illusion.

Satiation theory is based on brain field theory and involves the postulation of non-neural electrical forces in the brain. The term itself refers to the changed condition of the neural tissue following a perceptual process occurring in a particular area for some time; that is, satiation is built up following repeated stimulation of a region. Apparently, figure currents are set up in the neural medium and flow without regard to neural pathways. These currents are presumed to follow paths of least resistance and, as they flow, due to polarization of the tissue, set up resistance to further flow. Thus an area of increased resistance is built up around the cortical representation of a figure which is inspected for any length of time. This satiation affects the perception of a stimulus figure in that any percept occupying a satiated area of the brain tends to recede from that area.

Köhler and Fishback (1950a) interpreted the destruction of the Müller-Lyer illusion in terms of satiation as follows. Satiation is always stronger in enclosed areas and since the two parts of the Müller-Lyer figure differ with respect to this feature, they must be subjected to different degrees of satiation. The areas enclosed by the angles will, with repeated viewing of the figure, become more satiated than other regions, especially those regions toward which the angles point. Under these circumstances the angles will be displaced into the less satiated areas, that is, in the direction of their apexes, and thus the amount of illusion will gradually be reduced by the process of satiation. Figure 2 illustrates the points at which satiation occurs most strongly resulting in the obliques being displaced away from the satiated areas. Thus point A in Figure 2 would be pushed to the left and point B to the right extending the distance between them, while point C would be pushed to the left by satiation reducing the distance between it and B. In this manner the horizontal distance which had formerly appeared longer would be reduced while the opposite would be occurring in the other half of the figure.

Köhler and Fishback (1950a, 1950b) maintained that explanation of the destruction of the illusion in terms of learning was unsatisfactory and proposed instead that it could be accounted for by satiation theory. These points of view were supported with empirical evidence from their own and preceding investigations (Judd, 1902, 1905; Lewis, 1907; Seashore, et al, 1908).

First, they point out that the illusion can be destroyed when subjects do not know they are dealing with an illusion, or to what extent or in what direction their judgements are incorrect. It is difficult, according to Köhler and Fishback, to explain the change as learning when subjects do not have this knowledge.

Second, the illusion can be destroyed when, after the initial determination of the magnitude of the illusion, adjustment of the figure is replaced by inspection periods approximately equalling in length the average time spent by other subjects on adjusting the figure. The subject fixates or inspects only part of the figure so that he is unable to make comparisons between the two sections. The authors argue that since no

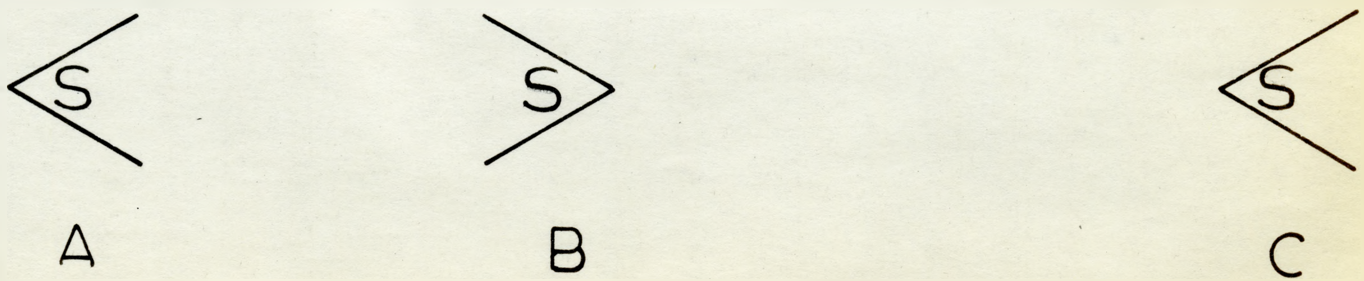

Figure 2. Diagram of the proposed interpretation in terms of satiation of the decrement in the Müller-Lyer illusion. Satiation occurs most strongly in the areas marked by an 'S'. This pushes point A to the left and point B to the right, increasing the distance between them, while point C is pushed to the left reducing the distance between it and B.

direct comparison can be made, it is hard to understand how the subject eliminates errors of judgement, while, on the other hand, satiation could still be built up using this procedure.

The fact that negative illusions may be established is also used as an argument for satiation. They state that the learning interpretation has difficulty accounting for negative illusions since, rather than eliminating errors, the subject begins making them in the opposite direction, whereas one would expect the process to come to an end when comparisons can no longer be improved. On the other hand, satiation could presumably continue beyond this point, thus accounting for the appearance of negative illusions.

Evidence that the illusion cannot be completely destroyed in all subjects is attributed by Köhler and Fishback to individual differences in ability to satiate. They tested one subject who had failed to show a decrease after repeated trials, with figural after effects and found that with most combinations of inspection and test patterns, this subject saw no figural after effects. This correlation, they maintain, is further evidence that the illusion is destroyed by satiation. They suggest that if a large group of subjects were tested and the speed with which the Müller-Lyer illusion was destroyed was compared with the size of the subject's figural after effects, a reliable correlation would be found between the two measures.

A fifth argument is concerned with the effect of change in position. When the illusion has been destroyed in one position, it returns, or is still present, when the pattern is placed in a new position, for example, when rotated 180° (Judd, 1905). This would be predicted from satiation theory but, Köhler maintains, is difficult to account for if the destruction of the illusion is interpreted as learning.

Further support for the satiation hypothesis is seen in the observed effects on a test pattern placed in the area formerly occupied by the illusion. When, after destruction of the illusion, a test pattern from which the main characteristics of the illusion are absent is presented in this area, the test pattern exhibits the after effects which would be expected if satiation had occurred with the illusion figure. Thus it was found that when three parallel vertical lines were presented in the positions previously occupied by the apexes in the Müller-Lyer illusion, the distance between the middle line and the other two did not appear equal to a satiated subject, although objectively they were equal.

Köhler and Fishback (1950a) used a fixation point in their experiment. They also obtained a more rapid decrement of the illusion than had been reported by earlier investigators. This they advance as indirect evidence for their interpretation, as satiation should build up more rapidly with fixation than with free inspection of the figure, although in the latter case there should still be a less rapid development of satiation, thus accounting for the decrease in the illusion when free inspection is allowed.

Finally, the observation that the illusion cannot be destroyed in tachistoscopic presentations is said to follow from satiation theory.

In their second publication, Köhler and Fishback (1950b) report the finding, supporting the observations of Judd (1902, 1905) and Lewis (1908), that spacing of trials produced greater decrement than massed trials. They then extend the theory of satiation to account for this. In the case of massed trials, they state, satiation (which also builds up on the outside of the arrows as well as in the enclosed areas) does not have time to dissipate from areas toward which the apexes point and therefore destruction of the illusion cannot proceed. When trials are not massed the satiation in the outside areas, being less intense than in the enclosed areas, dissipates more quickly and thus the destruction of the illusion takes place more effectively.

Needless to say, Köhler and Fishback's articles have provoked considerable debate regarding the interpretation of the practice effect as well as proving to be the stimulus for a number of experimental investigations.

It is argued, for example, that there is no evidence to support the claim that learning cannot take place without knowledge of results. In fact, in the area of perceptual learning, there is evidence (Gibson, 1953) to show that perceptual judgements do improve without the subject being given any information. Eysenck (1958) argues that learning in the sense of habit formation may occur without information as long as reinforcement is given, while Woodworth and Schlosberg (1956) reply to this particular objection to explanation in terms of learning, with the suggestion that the subject, seeing that his task of equating the main lines is difficult because of the complexity of the whole figure, examines the figure in detail and gradually attacks it in a different way, probably more analytically. In addition, Woodworth and Schlosberg suggest that the results of learning disappear when the figure is rotated, because after long practice the subject's procedure becomes habituated to one arrangement of the figure and breaks down temporarily when the sides are reversed.

As a possible explanation for the development of negative illusions, they argue that the subject's judgements will vary somewhat from trial to trial and when his average error has been reduced to zero, it is sure to be negative on some trials. Another argument (Eysenck and Slater, 1958) against the satiation interpretation, is that the modification of the original hypothesis to account for the results of spaced practice is debatable since it disagrees with the findings that satiation effects disappear relatively fast. The extension of satiation theory to account for the effects of spaced trials does seem questionable, since it leaves the impression that if massed practice had been more efficient in destroying the illusion, satiation theory could have accommodated this result as well, and perhaps more logically since with massed trials one might expect a more rapid build up of satiation within the enclosed areas.

These points could no doubt be debated endlessly so that it would appear more productive to turn to the experimental evidence which has been forthcoming since the controversy regarding the destruction of the illusion started. Since these studies have already been reviewed we will merely draw attention to the results which are relevant to the present discussion. Frequently these results have failed to confirm predictions made on the basis of the satiation interpretation of the decrement. Azuma's (1952) experiment cannot be interpreted as supporting Köhler's hypothesis, since, although the subject inspected the figure rather than making adjustments, a fixation point was not used. However, since satiation supposedly develops, although less rapidly, even when free inspection is allowed, Azuma's study does not directly contradict an interpretation in terms of satiation. Stronger evidence against such an explanation is obtained in the studies (Selkin and Wertheimer, 1957; Mountjoy, 1960) which found that use of a fixation point did not produce statistically greater decrement. In addition, since it would appear that asymmetrical satiation is a necessary condition for the reduction of the illusion, Moed's (1959) findings also are contrary to what would be expected if the satiation interpretation is the correct one. On the other hand, some support for satiation theory is found in Kamin's (1959) study and that of Spitz and Blackman (1958).

In addition to the negative findings from investigations of the Müller-Lyer illusion itself, further evidence against the satiation hypothesis is available from work in other areas. Experiments by Lashley, Chow and Semmes (1951) and Sperry and Miner (1955a, 1955b) provide evidence against Köhler's electrical field theory on which the satiation hypothesis is based. Thus, in view of the lack of empirical support for satiation theory, an alternative explanation of the destruction of the Müller-Lyer illusion appears necessary.

Attempts to provide such an alternative have been made by Eysenck and Slater (1958) and by Mountjoy (1958a).

Eysenck and Slater do not feel that their results can be suitably accounted for by either satiation theory or the learning interpretation, and suggest that the changes which occur with repeated adjustments be described as "habit formation". As previously noted, Eysenck argues that one of Köhler's major objections to regarding the effect as a learning phenomenon, namely, that when subjects are unable to compare their results with the objective situation they cannot learn, is untenable, since learning in the sense of habit formation may take place without the subject's awareness as long as reinforcement is provided. Reinforcement for a change in a particular direction is provided by the subject's discontentment with the setting he has chosen and thus on the next trial a habitual trend of change is started. The trend of change could be in any direction and this would account for individual differences in the effects of repeated trials. Eysenck withdraws the term "learning" because of the implication that performance at the end of a series of trials must, in some way, be improved, while his results indicated that change could be in any direction. Eysenck's theory would predict a course of development in the illusion which, once started, should continue unchanged (Eysenck and Slater, 1958), but changes do occur; for example, some subjects show an increase in the illusion and then, without a rest pause, a decrease. Further, the theory is based mainly on the results of Eysenck and Slater's own experiment. These results may be a function of the method they used, and, in addition, are at variance with those of the numerous investigators who have reported a decrement in the illusion.

Mountjoy (1958a) proposes that destruction of the illusion be regarded as "habituation", the decrement in magnitude of response which occurs as a function of trials. There is no explanation of just what response is being habituated, or of how this interpretation takes care of the experimental data on the Müller-Lyer, but Mountjoy develops certain predictions regarding the destruction of the illusion, from what has been established regarding habituatory decrement in learning experiments. Some of his hypotheses were only partially supported; for example, his prediction that decrement of the illusion would be greatest under massed trials, since differences were not statistically significant although they were in the predicted direction. It will be noted that this finding is contradictory to those of Köhler and Fishback (1950) and others (Judd, 1902, 1905; Lewis, 1908) who reported that spacing of trials produced more rapid decrement of the illusion. Another prediction which received only partial support stated that greater decrement of the illusion would occur when there was no inter-trial task. Thus, although some of his results, such as those having to do with spontaneous recovery and the use of a fixation point, provided additional evidence that an alternative to satiation is required to explain the decrement, other results he obtained did not provide conclusive support for either satiation or the habituation hypothesis (Mountjoy, 1958). Therefore, although the previous discussion of the experimental evidence indicates that some other explanation of the destruction of the illusion rather than satiation is required, the explanations offered by Eysenck and Slater (1958) and Mountjoy (1958) do not appear to be quite adequate as alternatives. On the other hand, much of the data supports an interpretation in terms of perceptual learning. It will be recalled that, in the introduction, it was pointed out that the term 'perceptual learning' may be used to refer to improvement in perception as a function of trials over a limited time span. Also, attention has already been drawn to the fact that Gibson (1953) has collected considerable data indicating that controlled practice or training can effect improvement in perception, where improvement is defined as a closer approximation of the subject's judgement to the physical standards of a stimulus. This appears to be the process which occurs with practice on the Müller-Lyer figure, and it is proposed that the destruction of the illusion could be explained in terms of the theory of perceptual learning which is offered by the Gibsons (1950, 1955a, 1955b).

According to the Gibsons' formulation of perceptual learning, perception is progressively in greater correspondence with stimulation as learning proceeds. This occurs through a process of differentiation rather than enrichment of sensation[1]. In order to visualize how this takes place, stimulation must be thought of as the total range of physical stimulation impinging on the receptors. This array of energy is very rich in complex variables which, with learning, are capable of becoming cues and providing the observer with additional information about his environment. Qualities of stimulation previously not responded to, now are, and the observer is thus able to make finer sensory discriminations. Thus, if perceptual learning is successful, perception corresponds more and more to physical properties of the environment. Support offered for this theory of perceptual learning comes from their own studies of perception (Gibson and Gibson, 1955a), the data from psychophysical experiments showing progressive improvement in accuracy of perceptual judgements (Gibson, 1953) and the study of discrimination of cues in verbal learning by E. J. Gibson (1940).

To return to the Müller-Lyer illusion, its destruction with re-

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1. The Gibsons present two opposing interpretations of perceptual learning, their own and what they describe as enrichment theory. Perceptual learning, according to the latter, is a matter of enriching sensations by past experience and there is an increasing discrepancy between the sensory input and the finished percept.

peated exposures could well be regarded as an instance of perception becoming more veridical with repeated practice. If the initial illusion is interpreted as a misapplied constancy effect, with the illusory quality being attributed to the tendency of the observer to regard the figure as a whole with an "object" quality, then the decrement in the illusion may be due to the development of improved discrimination wherein relevant information as to the actual nature of the figure is utilized. Thus, as the subject becomes more analytical in his judgements, he is able to concentrate on essential cues, disregarding the obliques, and as repeated exposure of the illusion provides the subject with the opportunity for progressively finer differentiations, the perception of the horizontal lines becomes gradually more veridical.

This interpretation of the decrement suggests that practice with other stimulus figures containing the essential elements, that is, the horizontal lines, should be as effective in improving discrimination and thus reducing the illusion, as is practice on the Müller-Lyer figure. There is some evidence to indicate transfer of perceptual learning (Gibson, 1953) and Gibson states that this suggests that a process of abstraction may go on along with differentiation. This implies that the improved discrimination resulting from practice on the first task should transfer to the second if the subject is able to abstract the common qualities of the two and utilize this information. There is already some evidence for transfer with the Müller-Lyer illusion (Judd, 1902; Lewis, 1908) and the present study is designed to investigate more intensively the effect of pre-training on the magnitude of illusion. The type of pre-training to be given has already been outlined in the introduction. It was expected that the following effects would be obtained:

1) That relevant pre-training would result in positive transfer to the Müller-Lyer figure, resulting in a decrease in magnitude of the initial illusion.

2) That transfer would increase with an increased number of pre-training trials.

These predictions are tested in the second experiment described below. Before turning to the experiments, however, a specific review is given of the background to Experiment I.

Methodology and Decrement in the Illusion

It is necessary, in order to indicate the reasoning which prompted the other experiment which forms part of this thesis, to refer again to some of the studies previously reviewed. As indicated by the preceding summary of the empirical investigations of the Müller-Lyer illusion, the results are sometimes ambiguous and in certain instances quite contradictory. In fact, despite the ample evidence for the occurrence of the practice effect, it is not universally accepted that this can be obtained (Eysenck, 1958). The reported failures to obtain such an effect have already been noted (Smith, 1906; Seashore, et al, 1908; Eysenck, 1958; Day, 1960). Of these the earlier studies could be criticized on the basis of the limited number of subjects used, but the same could be said of the early studies, excepting Heymans', which reported a decrement (Judd, 1902, 1905; Lewis, 1908). There are, however, even in the recent literature, studies showing the decrement in error occurred in only a small proportion of the subjects used. Eysenck (1958) using fifty subjects reported that on the group as a whole, practice produced scarcely any effect. Day

(1960) reported three experiments wherein the effect was not obtained, with only 13 out of the 46 subjects used in the three studies showing a progressive decrease in the magnitude of error. It was felt that perhaps these results might be due to the particular psychophysical methods employed, and the first experiment in this study was designed to determine whether this could be one of the conditions affecting the magnitude of the illusion and its ultimate destruction.

The majority of recent experiments on the Müller-Lyer used the Method of Average Error, in which the figure is presented to the subject with the variable portion set at a point where there is a gross difference between it and the fixed or standard portion. The subject is then asked to adjust the variable until the two portions appear to be equal. In some cases the experimenter varies the adjustable portion of the illusion and the subject signals when it is apparently equal to the standard. With either method, however, the generally accepted practice is to use settings of the variable on both sides of physical equality, that is, longer or shorter, in a random series.

Examination of the two recent studies mentioned (Eysenck and Slater, 1958; Day, 1960), in which the practice effect was not obtained, reveals, however, that this usual procedure was not used. In the experiment by Eysenck and Slater the illusion was presented with the subjectively shorter distance kept constant while the subjectively longer distance could be varied by pulling out the Perspex on which it was drawn and pushing it back again. "The experimenter pulled the adjustable part of the apparatus out to a point where preliminary experiments had shown there would be no chance at all of any subject regarding the distance as equal. He then pushed it slowly back until the subject said 'Halt!'" (Eysenck and Slater, 1958, p. 250). After recording the amount of error, the experimenter removed again the adjustable part to an extreme position. Thus, in this experiment the variable portion of the illusion was always set longer before adjustment, rather than being set on both sides of physical equality. In his studies, Day employed the method of adjustment with a rather peculiar modification - "before the subject made each adjustment, the variable distance was adjusted by the experimenter so that it was physically equal to the standard." (Day, 1960, p. 11). Since the variable is the line that normally appears longer Day's procedure was essentially the same as Eysenck et al.

These two investigations can be contrasted to that of Köhler and Fishback (1950) where the method of setting the variable stimulus conformed more to recognized procedure. They alternated trials in which the variable distance was first too long with trials in which it was originally set too short. With this procedure, the illusion disappeared for five subjects, it decreased for four others and in only one subject did repeated trials fail to affect illusion size.

Consideration of these experiments suggests that perhaps failure to obtain a decrement in the illusion over trials might be at least partially attributable to the unique methods employed by Day, and by Eysenck and Slater. It has long been recognized that errors in measurement may occur if the variable stimulus changes consistently in one direction (Osgood, 1953). For example, it is possible that the subject may anticipate and report equality before the variable actually appears equal to the standard. This would lead to an underestimation of the size of the

the illusion if the variable is always set longer, and overestimation if the variable is always set shorter. In addition, it is difficult to understand with Day's procedure how the subjects could be expected to approach physical equality in a series of adjustments, when the variable was originally set at that point. It seems probable that subjects would continue to show some magnitude of illusion although it might decrease a certain amount. In addition to these considerations, it is difficult to compare results from experiments each of which employs a different method of presenting the variable.

This study, then, was designed to investigate the effect on the magnitude of illusion and on the decrement over trials of varying the method of presentation of the variable stimulus. The procedure used for one group of subjects was similar to Eysenck's method in that the variable was always set longer than the standard part of the illusion figure, while Day's procedure of setting the variable at physical equality was used with another group. A third group of subjects had the variable always set shorter while with the fourth group the standard procedure of randomly varying the settings on both sides of physical equality was used.

CHAPTER 3

Experiments

As this study involved two separate experiments, the method and results of Experiment I will be described and a brief discussion of the results given. This will be followed by a description of the method and results of Experiment II and a discussion of those results.

Experiment I

Method

<u>Subjects</u>: <u>S</u>s were 40 students from the Brampton Training School for Boys. The average age of these subjects was 19.3 years. <u>S</u>s were randomly assigned to four groups.

<u>Apparatus</u>: The apparatus consisted of a rectangular stand (48" x 25" x $3\frac{1}{2}$") placed on supports $1\frac{1}{2}$" high and 16" long, and enclosing a frame of plywood with a 31" x 10" opening in the centre. The stand and frame were painted flat white forming a white surround for the illusion figure.

The stimulus figure was drawn in India ink on two rectangular pieces of white cardboard and mounted on two movable panels which slid into grooves in the stand at the back of the frame. The standard portion of the stimulus, consisting of the acute angled part of the illusion figure, remained stationary in the foremost groove while the obtuse angled figure, the variable section of the stimulus, moved in the groove behind it. The panels were interchangeable, thus the variable could be placed on either the S's left or right. Attachment to a small electric motor provided for movement of the panels. The connection was adjustable so that whichever panel supported the standard could be disengaged while the other panel moved. A motor controller with remote control switch and automatic switch permitted control of the adjustable panel by either S or E (experimenter). By means of a reversing switch the panel could be reset after each adjustment as the switch provided movement of the panels in either direction. The speed at which the panels moved could be altered but the control was adjusted to the same speed for all Ss and was set so that the panel moved at the rate of 1 cm. per 1.5 seconds.

The motor and control box were at the back of the apparatus out of view of the S. This entire set up - frame, motor and control box - was placed on a desk at the end of an eight foot table, the frame providing the screen behind which E was seated. Attached to the back of each panel was a centimetre scale and pointers on the frame indicated S's setting. Errors could be measured to the nearest millimetre.

The S, seated at the other end of the table, could move the panel by pressing a key, thus adjusting the length of the variable.

The dimensions of the stimulus figure used in Experiment I were as follows: the length of the horizontal line between the apexes of the acute angled figure, that is, the standard section, was 28 cm.; the horizontal line of the variable measured 33 cm.; the obliques were a quarter the length of the standard, that is, 7 cm.; the angles formed by the obliques with the horizontal line were 45°.

When the variable was placed on the right, it could be shortened to an extent which would constitute 14 cm. of positive illusion or lengthened to a position representing 5 cm. of negative illusion. With the variable on the left, construction of the apparatus changed the extent of movement slightly and the variable could be moved to 14 cm. of positive illusion and to 4 cm. of negative illusion. From this range, eight settings, four shorter and four longer than objective equality, were selected to be used in setting the variable before adjustment by S. These settings were so extreme that there was little chance that any S would perceive them as being equal. The shorter settings were 9, 10, 11 and 12 cm. from physical equality, while the longer settings were 1, 2, 3 and 4 cm. from physical equality. The manner in which these settings were used for each group is discussed in the procedure.

Procedure: The window shades were drawn and the room was illuminated by ordinary room lighting so that the degree of illumination was the same for all Ss.

S was seated eight feet from the apparatus. Although open viewing of the figure was permitted, a chin rest was used to control movement of the head and restrict the range of vision for each S to the same area.

The adjustable line was set at an extreme position and the following instructions were given to each S along with the necessary demonstration of how the variable could be adjusted.

"Please look at the figure before you on the panels. You can see that the horizontal lines are unequal. When you press this key beside you it will cause the panel to your right (left) to move and you can thus adjust the length of the line on it. I will set this line either longer or shorter than the other one and when I give you a signal to start, I want you to adjust the line, by pressing the key, until it appears equal to the other line. When you have reached the point at which the lines appear equal, will you please indicate that you are satisfied with your setting by saying 'O.K..' The panel will move in only one direction at any one time so that you will be unable to move it back if you go too far. Try to keep looking at the figure and remember you are to set one line to appear equal to the other."

Ss were then asked if there were any questions and if there were these were answered from the instruction sheet. The experimental session then proceeded. Each subject had one session which lasted from three-quarters to one hour. This varied with Ss as each S was permitted to make an adjustment at his own rate and the time taken varied slightly.

The method of adjustment was used with E setting the variable at a predetermined point and S then adjusting it to apparent equality with the standard. After each adjustment by S, the experimenter recorded the amount of error (the distance of S's setting from physical equality) and reset the variable. Each adjustment by S constituted a trial and S had 11 blocks of eight trials. For those Ss who adjusted the variable from points on both sides of objective equality, the eight settings of the variable mentioned previously were randomized within blocks of eight trials with the restriction that these were four shorter and four longer settings. For those who made their adjustment with the variable always shorter, the four settings on that side were used twice within a block and the same procedure was followed for the Ss who adjusted the variable from positions always longer than physical equality. In all cases, the order in which the settings occurred within a block was randomly predetermined. The remaining Ss adjusted the variable from the point of physical equality.

Measure of the illusion: This was the amount of error as shown by the distance of the S's setting of the variable from the point of physical equality with the standard.

Design: There were four groups of ten subjects. The conditions for each group differed only with respect to the method of setting the variable stimulus before adjustment by the subject. The conditions for each group can be summarized as follows. Group 1: variable always set longer than the standard; Group 2: variable always set at physical equality with the standard; Group 3: variable set shorter and longer than the standard; Group 4: variable always set shorter than the standard. The condition for Group 1 is similar to the method used by Eysenck and Slater (1958) while that for Group 2 simulates the procedure followed by Day (1960). Approaching the point of objective quality from both sides is the usual procedure followed and is that employed by Köhler and Fishback (1950).

Half the subjects in each experimental group were tested with the

Table I

Mean Magnitude of Illusion in Per Cent on each Block of Eight Trials for each Group

Blocks of Trials

	1	2	3	4	5	6	7	8	9	10	11	Group Mean
Group 1 Variable Longer	13.67	15.37	15.33	15.37	14.89	15.97	16.10	15.91	15.95	15.68	14.89	14.89
Group 2 Physical Equality	15.02	16.16	16.30	17.62	18.04	18.18	17.88	17.36	17.10	17.51	17.24	17.14
Group 3 Longer and Shorter	18.13	18.02	17.67	17.07	16.76	17.46	17.11	17.75	17.19	16.29	16.28	17.25
Group 4 Variable Shorter	24.52	22.14	21.28	20.60	19.89	18.88	18.11	18.42	17.23	16.37	16.80	19.46

variable stimulus on the right while the other half were tested with the variable on the left.

The main effects to be considered in the analysis of the data are conditions (setting of the variable) and the effect of trials.

Results

Table I presents the average magnitude of the illusion in successive blocks of eight trials for each of the four groups and the over-all mean illusion for each. The amount of illusion is the mean error expressed as a percentage of the standard. These data are shown graphically in Figure 3. For convenience in discussing the data, the groups are referred to by number, as assigned in Table I.

These data were subjected to an analysis of variance, a summary of which is presented in Table II. The analysis is a Type I design

Table II

Analysis of Variance of the Error Data for the Four Experimental Conditions

Source	df	S.S.	M.S.	F.	P.
Between Ss	39	969.72			
Setting	3	73.02	24.34	<1	-
Error (b)	36	896.70	24.91		
Within Ss	400	171.53			
Trials	10	9.20	.92	3.07	<.01
Trials x Setting	30	53.88	1.80	6.00	<.01
Error (w)	360	108.45	.30		
Total	439	1,141.25			

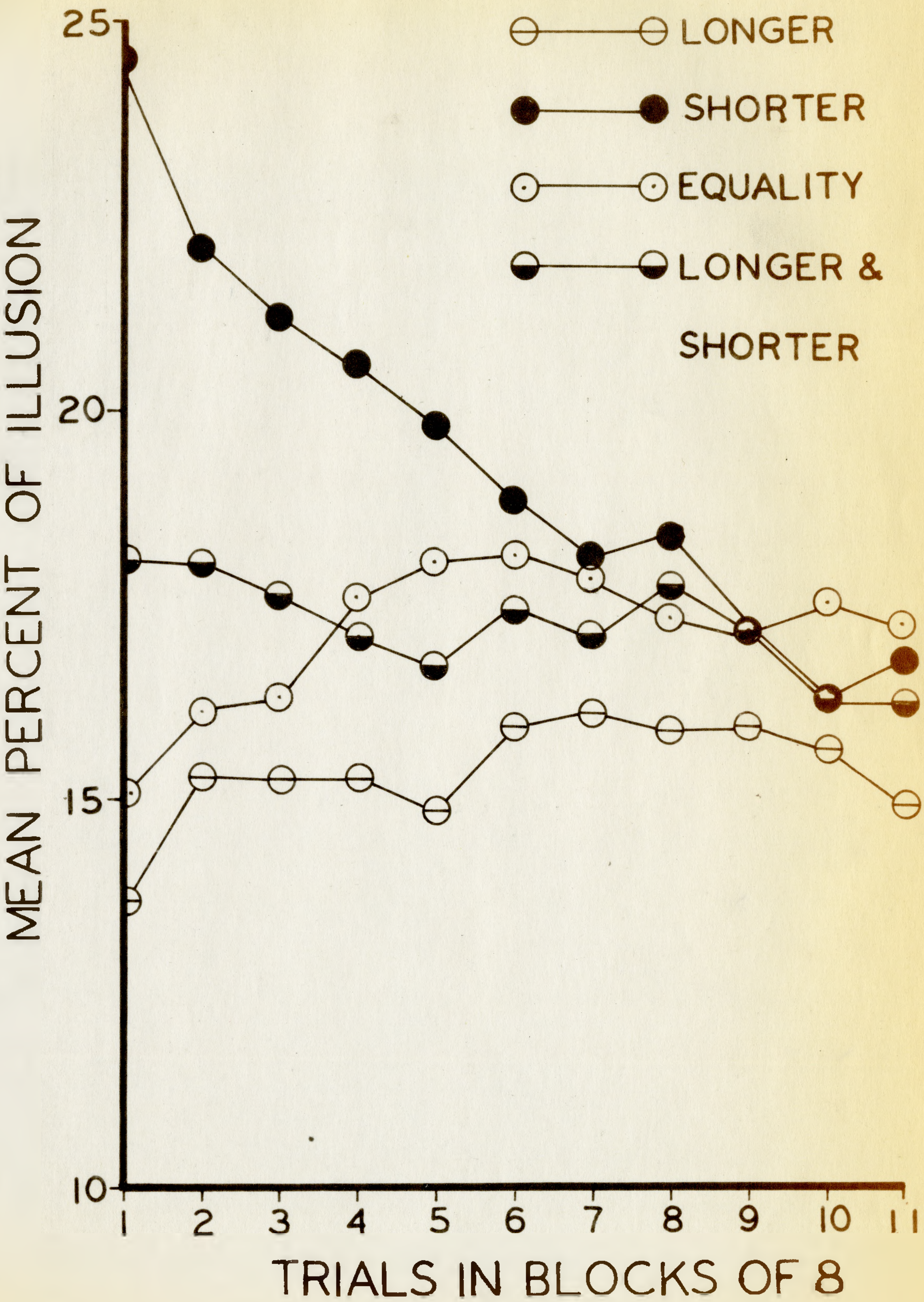

Figure 3. Mean per cent of illusion as a function of trials for Groups 1, 2, 3 and 4

(Lindquist, 1953).

The main effect of setting is not significant but the main effect of trials and the interaction between settings and trials is significant. Since this experiment was designed to determine whether there would be differences in the trends of the trial means under the different experimental conditions, the significant interaction indicates that these trends are not parallel (Lindquist, 1953) and it can therefore be concluded that the effect of trials differs with the various methods of setting the variable.

Inspection of Table I shows that with the variable always set shorter (Group 4) there was a much larger initial illusion (24.52%) than was obtained under any of the other three conditions. The illusion decreases rapidly and continued practice brings about additional decrement until the last block of trials, when there is a very slight increase over the preceding block. The magnitude of initial illusion with the variable always set longer (Group 1) or with it set at physical equality (Group 2) is considerably less, being 13.67% for Group 1 and 15.02% for Group 2. Both these groups show a slight increase in magnitude of the illusion over trials. When the setting of the variable was on both sides of physical equality (Group 3) the mean initial illusion was slightly higher than for Groups 1 and 2 but less than that for Group 4. The illusion in the first block of trials for Group 3 was 18.13% and over trials this was reduced slightly to 16.28%.

In order to determine whether the initial magnitude of illusion in the four groups differed significantly, an analysis of variance on the first block of eight trials for each group was performed. This analysis presented in Table III, shows that there is a highly significant difference between the groups in the magnitude of initial illusion.

Table III

Analysis of Variance of the Error Data on the First Block of Trials for each Group

Source	df	S.S.	M.S.	F.	P.
Between	3	54.91	18.30	8.55	<.01
Within	35	74.92	2.14		

An analysis of the data from the first and last block of trials for each of the four groups was also carried out (see Table IV).

Table IV

Analysis of Variance of the Error Data on the First and Last Block of Trials for each of the Four Groups

Source	df	S.S.	M.S.	F.	P.
Group 1					
Between	1	.59	.59	<1	-
Within	18	64.78	3.60		
Group 2					
Between	1	2.68	2.68	<1	-
Within	18	66.85	3.71		
Group 3					
Between	1	1.34	1.34	1.13	N.S.
Within	18	21.44	1.19		
Group 4					
Between	1	23.39	23.39	16.59	<.01
Within	18	25.40	1.41		

This analysis shows that the increase in magnitude of illusion between the first and last block of trials in Groups 1 and 2 is not significant. The decrement in Group 4, however, is highly significant while the reduction in amount of illusion in Group 3 is not statistically significant.

Discussion

Despite the fact that the over-all mean magnitude of illusion does not differ for the four groups, the results which have been described provide evidence that one of the conditions affecting both the size of the initial illusion and the presence or absence of the practice effect is the procedure used in setting the variable part of the stimulus.

Examination of the data (Table I) for the two contrasting conditions where the variable was always set shorter and always longer illustrates most effectively that the procedure employed may be a critical determinant of whether there is a progressive reduction in illusion. Using the first condition the initial magnitude of the illusion was 24.52%, while with the latter an initial illusion of 13.67% occurred. In addition, when the variable was always set longer, there was a slight, but not significant, increase in the illusion, to 14.89% rather than a decrement over trials. On the other hand, with the variable always set shorter there was a decrement of 7.72% over trials, which was significant. It appears, therefore, that to demonstrate effectively that there is a practice effect, the ideal procedure would be always to set the variable shorter than the standard.

Day (1960) has attempted to isolate the conditions under which a consistent decrement in error occurs. The results of the two conditions which, as pointed out in the introduction, are essentially similar to the procedures he and Eysenck (1958) used in setting the variable, indicate that the procedure used may be another factor responsible for failure to obtain a decrement in the illusion.

It should be pointed out that the results obtained when the variable was randomly set on both sides of physical equality were not exactly what had been anticipated. Although there was a decrement, the amount was not significant and the group failed to approach the point of complete destruction of the illusion. There are several possible explanations for the failure to obtain this destruction. First, the number of trials may not have been sufficient. This would not, however, appear to be a very satisfactory explanation since 88 trials is a fairly substantial number, and more than the number required in several investigations by Mountjoy (1958) to obtain a substantially larger decrement. The average number of trials reported by Köhler and Fishback (1950) to obtain complete destruction of the illusion was 103. However, since conditions of these experiments, other than the setting of the variable, differed, there is still the possibility that a large number of trials for the group would have been effective in destroying the illusion. Judd (1902, 1905) reported that 600 to 1,000 trials were necessary to destroy the illusion, while Seashore et al (1908) administered 1,000 trials.

The failure to obtain destruction of the illusion could also be attributed to the massing of trials in this experiment but the conflicting reports (Köhler and Fishback, 1950; Mountjoy, 1958a, 1961) regarding the relative effectiveness of massed and spaced trials eliminates this as a clear explanation. In addition, the investigations showing that free inspection of the figure is as effective in obtaining a decrement as fixation, indicate that permitting free inspection was not the responsible factor. In fact, Day (1960) has shown that free inspection of a large figure is more effective in producing a decrement than is fixation and the figure used in this experiment was quite large. We are, therefore, unable to state what factor or factors were responsible for the failure to obtain a significant decrease in error in this particular group.

The significant effect on the trends of the means for the different treatments, as well as the significant difference in the magnitude of initial illusion in the groups, indicates that in planning experiments of this type careful consideration should be given to the method to be used in setting the variable. In planning Experiment II, it was decided that, despite the failure to obtain a significant decrement in the illusion using the procedure of setting the variable on both sides of physical equality, use of this method was justified in view of the fact that the decrement has typically been obtained in studies (Walters, 1942; Köhler & Fishback, 1950a; Spitz & Blackman, 1958; Mountjoy, 1960a) using this procedure. In addition, random mixture of both longer and shorter settings conforms to accepted psychophysical procedure (Guilford, 1954).

Some further observations made during this experiment concerned the size of the illusion figure. Assuming that decrement in the illusion is an instance of perceptual learning, it would appear that with a large figure such as used in this experiment, the opportunity to compare the variable with the standard would be enhanced, and thus the decrement in error should be greater. However, with the apparatus used in this experiment, it increased the tendency of some subjects to pay attention to irrelevant clues. This resulted in attempts to equate the lines by setting the variable at a distance from the edge of the frame equal to the distance of the standard from the frame on the other side, rather than where it appeared equal. Such attempts were quite apparent as they resulted in a marked reduction of the variability of the subjects' adjustments, although not necessarily a reduction in illusion[2]. Because of this observation it was decided that the dimensions of the illusion figure should be changed in Experiment II and they were reduced to almost half the size, the standard being 16 cm. as compared to the 28 cm. standard used in this experiment.

Experiment II

Method

<u>Subjects</u>: <u>S</u>s were 50 first year university students between the ages of 18 and 27 years. The mean age was 19.1 years.

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2. The results of four subjects were discarded for this reason. It became apparent that they were setting the variable at almost precisely the same point on each trial. Questioning of these subjects after completion of the trials elicited the information that they were setting the variable a certain distance from the frame on that side, which they estimated would equal the distance between the standard and the frame on the other side. Since the standard and variable did not appear equal to them when set in this way, it was felt that as they were not following the instructions, the results could legitimately be discarded.

Apparatus: The apparatus was identical to that used in Experiment I but changes were made in the dimensions of the illusion pattern. In this experiment the horizontal line of the standard portion of the figure was 16 cm., the obliques measured 4 cm. and the angles formed by the obliques with the horizontal line was 30°. When placed on the S's right, the variable could be shortened to a point representing 10 cm. of illusion or extended to a position constituting a negative illusion of 10 cm. When the variable was placed on the S's left, due to construction of the apparatus these amounts were 9 and 10 cm. respectively. Eight extreme settings, on each side of physical equality, were again selected to be used as settings for the variable, from which points Ss would make their adjustments.

The settings chosen were as follows. With the variable on the S's right the longer settings were 6, 7, 8 and 9 cm. from physical equality, while the shorter settingss were 7, 8, 9 and 10 cm. from physical equality. With the variable on the S's left, both longer and shorter settings were 6, 7, 8, and 9 cm. from physical equality.

The manner in which these settings were distributed over trials is described in the procedure.

An additional stimulus figure for those Ss receiving pretraining was required for this experiment. The pattern used was another illusion figure in which circles replaced the obliques. This is illustrated in Figure 4. The horizontal line which extends through the circles on the left (see Figure 4) is physically equal to the linewwhich extends between the inner circle and the circle on the extreme right, but it appears shorter.

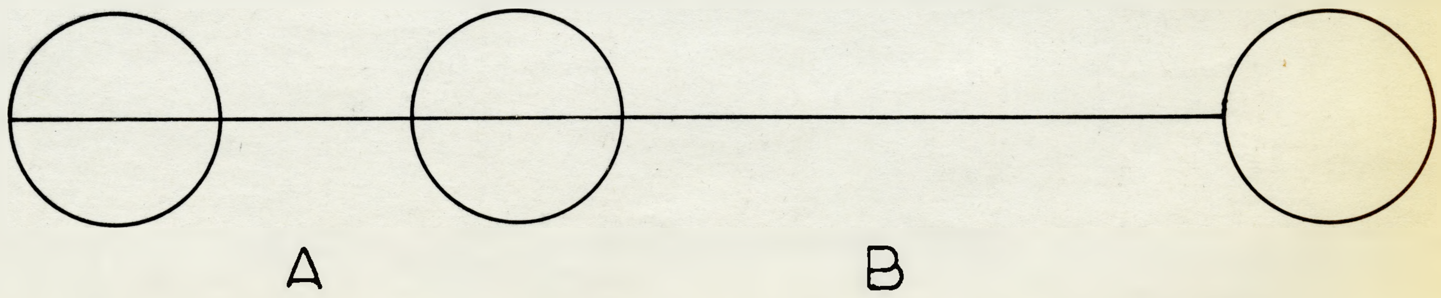

Figure 4. Circle illusion figure used as pretraining stimulus in Experiment II. Line A, extending through the circles on the left is physically equal to line B, extending between the circles on the right, but it appears shorter.

As with the Müller-Lyer illusion, the line which appears shorter and the circles through which it extends constituted the standard section of the figure while the horizontal line meeting the edge of the circle was the variable. The dimensions of this figure were the same as those of the Müller-Lyer, the horizontal lines being the same length while the diameter of the circles was 4 cm. It was thought that this similarity in the two stimulus figures would be conducive to obtaining positive transfer. Additional equipment which was required in this experiment was a buzzer and two sheets of plain white cardboard the same as those on which the stimulus figures were drawn. These items were used for two control groups in a warm-up task.

Procedure: The seating arrangement for this experiment differed slightly from that in Experiment I as Ss were seated six feet from the front of the apparatus.

The pretraining task consisted of setting the variable line of the circle illusion figure to apparent equality with the standard on each trial. Two groups of ten subjects each received 8 or 40 trials on the circle illusion figure before practice on the Müller-Lyer illusion.

The warm-up task was designed to give Ss in two control groups experience in the experimental situation, and with the apparatus, equivalent in amount to that received by the Ss receiving pretraining. Thune (1950) demonstrated that preliminary "warm-up" activity enabled Ss to begin the learning of a task at a higher level than Ss who did not have this experience. This is apparently due to postural and attentive adjustments which are necessary for optimal performance, as well as adaptation to the experimental situation and apparatus. In transfer experiments, improved performance on a second task may be due to these non-specific transfer effects rather than to the pretraining given. In order to determine whether transfer, if obtained, is specific to the pretraining activity, it has become customary in transfer experiments to use control subjects who are given some warming-up task. Any superiority in performance on the part of the experimental subjects over these control subjects is then attributable to the pretraining they received on the relevant task. In this experiment, the two "warm-up" control groups were given eight and 40 trials with the apparatus under the guise of a reaction time test. The panels on the apparatus were covered with plain white cardboard during this part of the procedure. Ss were seated in the usual position at the apparatus. E set the panel at one of the predetermined settings, indicated to the S that he should press the key, and, after the panel had been moved varying distances, which were selected to approximate as closely as possible the amount of movement which would obtain in the pretraining task, sounded the buzzer which was the signal for S to stop. This procedure ensured that S would receive a similar amount of practice in running the apparatus before practice on the Müller-Lyer figure as those Ss in the experimental groups. It also provided these Ss with the same opportunity to adjust to the experimental situation. At the same time, it was expected that this task would produce minimum amounts of negative transfer since it involved only the running of the apparatus and attending to the buzzer.

A third control group received no pretraining and had no warming-up activity, but proceeded directly to the practice trials on the Müller-Lyer illusion.

Assignment of $\underline{S}$s to groups was random and the instructions they received depended upon whether they were assigned to one of the two experimental groups or the three control groups.

Instructions for the experimental subjects were as follows. For the pretraining task:

> "Please look at the figure before you on the panels. As you can see, the horizontal line which extends between the circles (indicate) is longer than the one which extends through the circles.
>
> You can move the panel on your right (or left) by pressing this key and can thus adjust the length of the line (demonstrate). When the key is released, the panel will stop moving. I will set the adjustable line either longer or shorter than the other one and your task will be to adjust it until the two lines appear equal to you.
>
> When you have completed each adjustment, would you please indicate that you are finished. The panel will move in only one direction at any one time so that you will be unable to move it back. You will be given a number of trials with this figure on each of which you are to adjust the movable line until it appears equal to the other one. Following completion of these, you will have further trials with a different pattern.
>
> Try to keep looking at the figure and remember you are to set the line which extends between the circles to where it appears equal to the line which extends through the circles."

For the Müller-Lyer figure:

"Your task in this part of the experiment is similar to what you have just done. Looking at this figure you see that the line between the arrow feathers is longer than the line between the arrow heads. On each trial you are to adjust the variable line until the two lines appear equal to you. The adjustable line will again be set longer or shorter each time, you will be given a signal to start, and will again adjust it by pressing the key. As before, please indicate each time when you have completed your setting. Keep looking at the figure and adjust it to where the two lines appear equal to you."

Those subjects receiving no pretraining received similar instructions regarding the Müller-Lyer task except where slight changes had to be made because they had not received the instructions regarding the circle illusion figure:

" "Please look at the figure before you on the panels. You can see that the line between the arrow feathers is longer than the line between the arrow heads. You can move the panel on your right (or left) by pressing this key and can thus adjust the length of the line (demonstrate). When the key is released, the panel will stop moving. I will set the adjustable line either longer or shorter than the other one, and your task will be to adjust it until the two lines appear equal to you.

When you have completed each adjustment, would you please indicate that you are finished. The panel will move in only one direction at any one time so that you will be unable to move it back. You will be given a number of trials on each of of which you are to adjust the variable line until it appears equal to the other one. Keep looking at the figure and remember you are to adjust it to where the two lines appear equal to you."

The instructions for the subjects who received the warm-up task were:

"The experiment in which you have been asked to participate consists of two parts, the first of which will be a test of your reaction time. By pressing this key you can move the right left panel on the apparatus before you. This panel will be set at a certain point on each trial and when I tell you to begin, you are to press the key so that the panel moves. You are to continue moving it until you hear a buzzer sound when you are to release the key as quickly as possible.

"You will be given a number of trials on each of which you will release the key as soon as the buzzer sounds. After this part of the experiment is completed, you will be given further instructions for the next part."

After the warm-up task had been completed, the control group Ss were given the same instructions for the Müller-Lyer practice as the no pretraining group had received.

Following these instructions, the control group with no pretraining proceeded directly to the Müller-Lyer task while Ss in the experimental groups received eight or 40 pretraining trails depending on the group to which they were assigned. Ss in the two groups which constituted the controls for warm-up received eight or 40 trials on the warm-up task.

All Ss underwent one experimental session the length of which varied with the procedure. As in the first experiment, there was no set time for the S to make each adjustment but the speed at which the panel moved was kept constant between Ss. All Ss were given identical treatment on the Müller-Lyer task.

On both the pretraining and Müller-Lyer tasks the method of adjustment was used. E set the variable, using predetermined settings, and S then adjusted it to apparent equality with the standard. After each adjustment, E recorded the amount of error and then reset the variable. Each adjustment constituted a trial, and, with the Müller-Lyer illusion, each S had 12 blocks of four trials. The eight settings which had been selected were distributed in random order over the entire 48 trials, with each setting being used six times. The same settings were used in the pretraining task, each setting being used once for the eight trial group and five times for the 40 trial group.

The measure of the illusion was the same as in Experiment I, that is, the distance of S's setting of the variable from the point of physical equality with the standard. The measure of the initial illusion on the Müller-Lyer was the mean of the first block of four trials.

Design: There were ten subjects in each of the five groups used in this experiment. Two groups received either eight or 40 pretraining trials in which they received practice in adjusting the variable of the circle illusion figure to apparent equality with the standard. Two groups were given corresponding amounts of practice with the apparatus. One group had no pretraining or warm-up. All Ss were then given 48 trials on the Müller-Lyer illusion, the experimental task.

The design may be summarized as follows:

Group	N	Treatment	Amount	Transfer Task
Exp'l Group 1	10	Relevant Pretraining	8 trials	Müller-Lyer
Exp'l Group 2	10	Relevant Pretraining	40 trials	"
Control Group 1	10	No Pretraining	0 trials	"
Control Group 2	10	Warm-up Task	8 trials	"
Control Group 3	10	Warm-up task	40 trials	"

Half of the subjects in each group were tested on the Müller-Lyer with the variable on the right and half with the variable on the left. With the experimental groups, the same procedure was followed and the variable was on the same side in both pretraining and transfer task.

The variables to be considered in the statistical analysis of the data are: 1) the type of pretraining (relevant or warm-up); 2) the amount of pretraining (number of trials); 3) trials (on the transfer task).

Stated in terms of the above design, the expected results were:
1) That relevant pretraining would transfer positively to the Müller-Lyer task, resulting in decreased magnitude of the initial illusion for both groups receiving pretraining as compared with the control groups.
2) If the condition imposed on the experimental groups is conducive to obtaining positive transfer, this should increase with an increase in pretraining so that the Ss receiving 40 pretraining trials would be expected to show a smaller initial illusion than the group receiving eight pretraining trials.
3) In addition to these expected results, we may add that in many cases of positive transfer, Ss with pretraining begin the test activity at a higher level of performance than the control Ss and this advantage continues for some time. In other cases, only the initial trials show a significant transfer effect and the difference diminishes soon after

the initial trials (McGeoch and Irion, 1952). In this experiment, if the pretraining did reduce the magnitude of the initial illusion significantly, there is no basis for predicting whether the experimental groups would maintain this advantage over the total number of trials on the Müller-Lyer or whether by the end of practice, or before, the practice effect would have reduced the magnitude of the illusion in the control groups to that of the experimental groups.

4) Since habituation to the experimental situation and warming-up activity has been shown to produce non-specific transfer effects, the performance of the two warm-up control groups might be expected to be somewhat superior to the no pretraining group in terms of a smaller magnitude of illusion.

Results

Illusion over trials: Table V presents a summary of the average magnitude of illusion on the Müller-Lyer figure for each block of four trials for all groups. The magnitude of illusion is the mean error expressed as a percentage of the standard. The mean over-all illusion is also included in this table. These data are represented graphically in Figure 5.

It will be noted in Figure 5 that both experimental groups begin practice on the Müller-Lyer figure with a smaller initial illusion than any of the control groups and that they maintain this trend throughout the series of trials. Both the experimental groups and the control groups appear to show a decrement in the magnitude of the illusion over trials, but in none of the groups is the illusion completely destroyed.

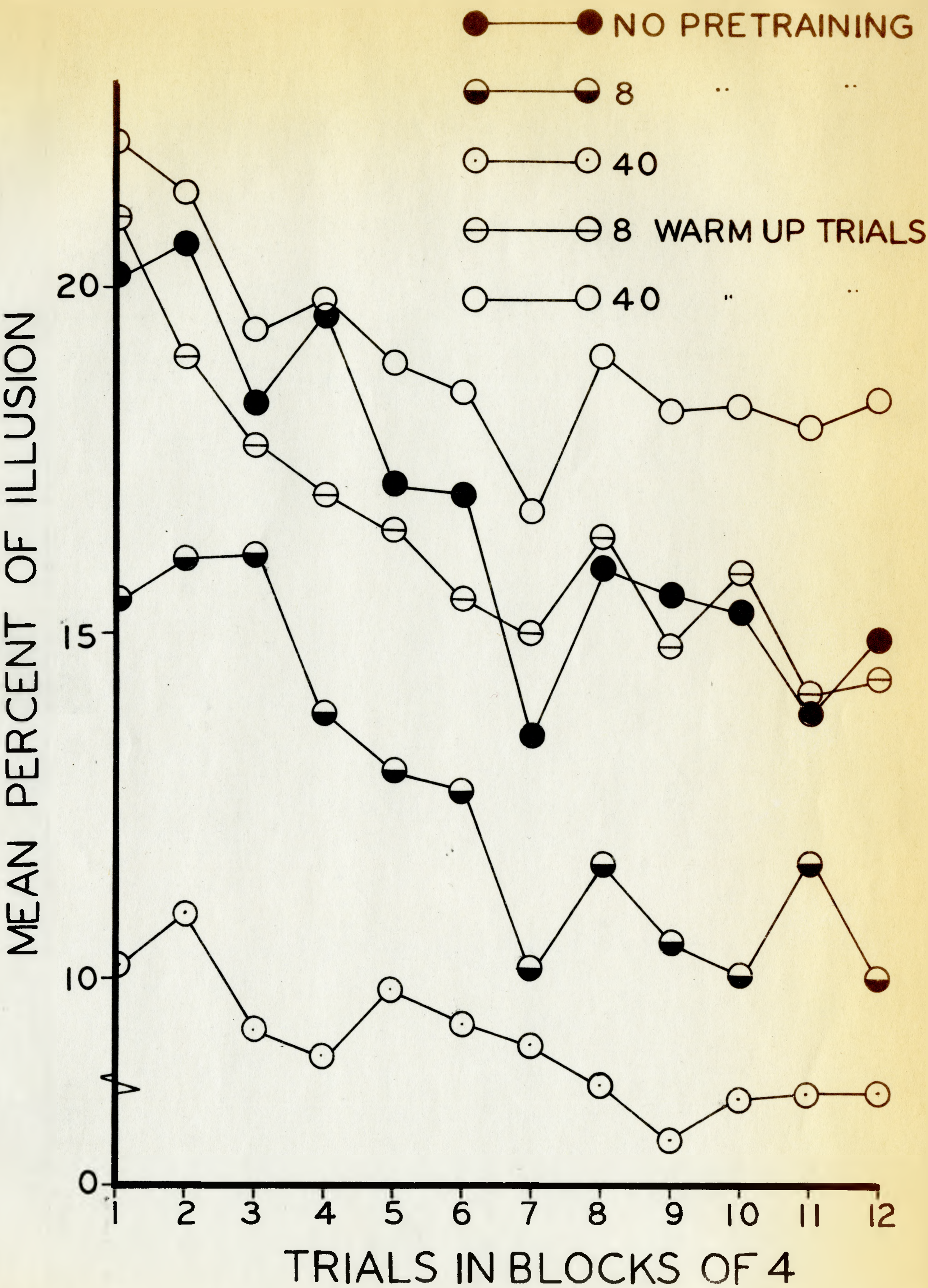

Figure 5. Average per cent of illusion as a function of trials for both experimental and control groups.

Table V

Mean Magnitude of Illusion in Per Cent on each Block of Four Trials for the Two Pretraining and Three Control Groups

	Blocks of Trials												
	1	2	3	4	5	6	7	8	9	10	11	12	Group Mean
Experimental Groups													
8	15.44	16.06	16.13	13.81	13.00	12.75	10.13	11.69	10.50	10.06	11.69	10.00	12.63
40	10.19	10.94	9.25	8.88	9.81	9.31	9.06	8.44	7.69	8.25	8.31	8.38	9.06
Control Groups													
0	20.13	20.63	18.31	19.63	17.19	17.06	13.50	15.94	15.56	15.31	13.81	14.94	16.81
8	21.00	19.06	17.75	17.06	16.56	15.50	15.00	16.44	14.88	15.94	14.13	14.38	16.44
40	22.13	21.44	19.44	19.81	18.94	18.56	16.75	19.00	18.25	18.38	18.00	18.44	19.13

These data were subjected to statistical analysis as follows: 1) The error data for the 48 trials on the Müller-Lyer were analysed for the two experimental groups and the two warm-up control groups according to Lindquist's Type 3 design, the variables being type of pretraining, amount of pretraining and trials. This analysis is summarized in Table VI. There was a significant effect for the type of pretraining.

Table VI

Summary of Analysis of Variance of the Data from the Two Experimental Groups and the Two Warm-up Control Groups

Source	df	S.S.	M.S.	F.	P.
Between Ss	39	570.29			
Amount	1	.68	.68	.062	N.S.
Type	1	148.93	148.93	13.70	<.01
Amount x Type	1	29.62	29.62	2.73	N.S.
Error (b)	36	391.06	10.86		
Within Ss	440	157.36			
Trials	11	27.78	2.52	8.13	<.01
Trials x Amount	11	3.48	.316	1.02	N.S.
Trials x Type	11	2.26	.205	.66	N.S.
Trials x Amount x Type	11	1.69	.154	.50	N.S.
Error (w)	396	122.15	.31		
Total	479	727.65			

No significant difference was found for amount of pretraining, while the effect of trials was significant. None of the interactions were significant indicating that the trend over the 48 trials did not differ significantly from parallelism.

2) In order to compare the performance of the no pretraining group with the experimental groups and the two warm-up groups, two further analyses were performed. A Lindquist (1953) Type I analysis showed that there was no significant difference between the three control groups (see Table VII).

Table VII

Analysis of Variance Applied to the Data from the Three Control Groups

Source	df	S.S.	M.S.	F.	P.
Between Ss	29	310.18	10.70		
Amount	2	12.52	6.26	.57	N.S.
Error (b)	27	297.66	11.02		
Within Ss	330	142.81			
Trials	11	30.70	2.79	7.47	<.01
Trials x Amount	22	3.46	.16	.44	N.S.
Error	297	108.65	.36		
Total	359	452.99			

The same type of analysis performed on the data from the experimental groups and the no pretraining group showed that when the warm-up groups were not included in the analysis, the effect of the amount of pretraining was significant. (See Table VIII). Although the amount of pretraining was not significant in the analysis shown in Table VI, this is understandable in view of the fact that the warm-up activity which did not produce any significant effect as compared to the no pretraining group is included in that analysis.

Table VIII

Analysis of Variance Applied to the Data from the Two Experimental Groups and the No Pretraining Group

Source	df	S.S.	M.S.	F.	P.
Between Ss	29	358.85			
Amount	2	93.55	46.77	4.76	<.025
Error (b)	27	265.30	9.83		
Within Ss	330	151.54			
Trials	11	26.97	2.45	6.81	<.01
Trials x Amount	22	7.21	.33	.92	N.S.
Error (w)	297	117.36	.36		
Total	359	510.39			

Duncan's Multiple Range test showed that the mean of the group receiving 40 pretraining trials differed significantly from the mean of the no pretraining group while the mean of the group receiving eight pretraining trials did not. The mean of the group receiving eight pretraining trials did not differ significantly from the group receiving 40 pretraining trials, (p .01).

Initial illusion: The mean of the first block of four trials was taken as the initial size of the illusion. As Table V has already shown, both the experimental groups began the Müller-Lyer task with a markedly reduced magnitude of illusion as compared with the three control groups. This initial illusion as a function of amount of pretraining is represented in Figure 6. The magnitude of the illusion is

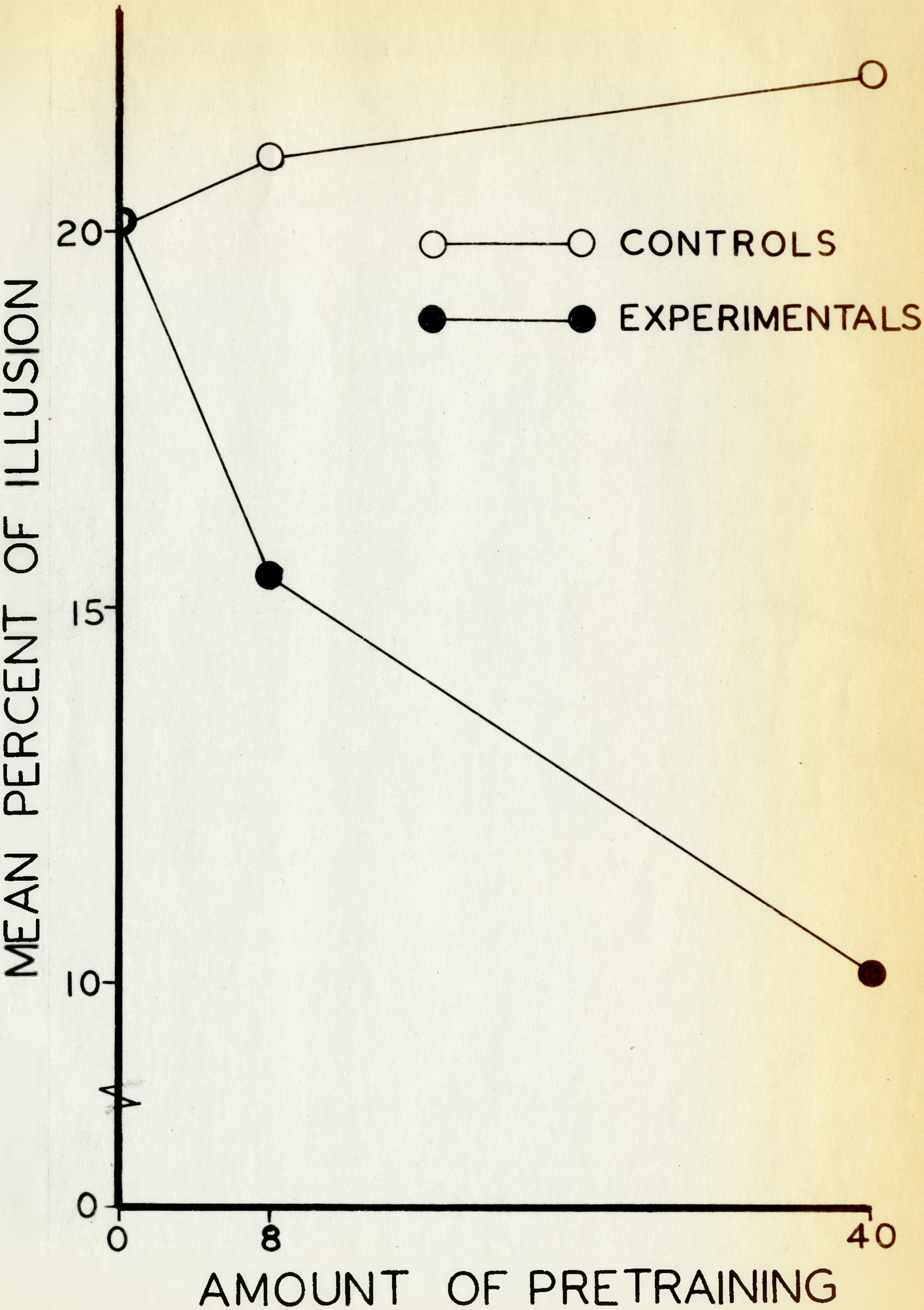

Figure 6. Mean per cent of illusion on the first block of four trials as a function of amount of pretraining.

a decreasing monotonic function of the amount of pretraining. Köhler and Fishback, as mentioned in a preceding section, obtained an initial illusion of 27%. In this study, the no pretraining group, which of all the groups would be most comparable to Köhler and Fishback's group, have a mean initial illusion of 20.13%. The initial illusion for the eight and 40 pretraining groups is 15.44% and 10.19% respectively. A simple analysis of variance comparing the no pretraining group with the experimental groups reveals that the difference is significant ($p < .01$). Duncan's Multiple Range test showed that the 40 pretraining groups differed significantly in magnitude of initial illusion from the no pretraining group while the eight pretraining group did not. A similar analysis showed no significant difference in the mean initial illusion for the three control groups, (p .01).

Pretraining data: Both groups showed a small decrease in the amount of error over the number of trials given each on the circle illusion. The decrease was not significant. The average magnitude of illusion was less than for the Müller-Lyer but there was greater variability among individual subjects.

Discussion

The results of this experiment show that preliminary practice on an illusion figure in which circles replaced the obliques resulted in a decreased magnitude of illusion on the Müller-Lyer figure. The reduction of the illusion did not reach a significant level following eight pretraining trials on the circle illusion but was found to be significant following 40 preliminary practice trials. Thus when pretraining was given in large enough amounts there was a significant amount of positive transfer of the learning which occurred on the first task.

The effects of transfer are most apparent on the initial illusion but, since the initial advantage of the experimental groups over the controls continues for the whole series of trials, despite a decrement in the control groups due to the "practice effect", it can be assumed that the preliminary training is still having an effect. Although the trends are parallel examination of Figure 5 indicates that the difference between the experimental and control groups is diminishing slightly so there is the possibility that eventually it would disappear. In any case, the reduced decrement of the illusion on the initial trials represents significant positive transfer. Whether there is savings over the whole learning curve could only be determined by setting some criterion and determining the number of trials necessary for each group to reach this point. Perhaps trials could be continued until the illusion is destroyed.

The results from the control groups show that under the conditions of this experiment general habituation to the experimental setting and practice on the apparatus itself was not responsible for the transfer effects. Further, the fact that the two control groups for warm-up did not differ significantly from the group which had no pretraining, indicates that there was no transfer of non-specific factors in this situation. Had there been, presumably the warming-up activity should have resulted in some reduction in error for the warm-up control groups as compared to the no pretraining group.

In contrast to the results reported by Eysenck and Slater (1958) and by Day (1960) there was a significant decrement in the illusion over trials for all groups. Since this decrement occurred in the control groups as well as the experimental groups, it cannot be entirely attributed to the effects of pretraining. This provides supportive data for the numerous experiments which have reported a practice effect. Within the number of trials administered in this experiment, however, the illusion was never completely destroyed in any group. A possible explanation for this lies in the number of trials. Early investigators (Judd, 1902, 1905; Seashore, et al, 1908) reported a much larger number of trials before the illusion was destroyed, while Köhler and Fishback (1950) reported that for five subjects who reached a point where the illusion disappeared, the number of trials required varied from 20 to 200, the average being 103 trials.

It will be noted that in the control groups, as in Group 3 of Experiment I, the magnitude of illusion is less than that reported by Köhler and Fishback (1950). Köhler discusses three possible explanations for obtaining a larger initial illusion than that reported by other investigators. He states that the illusion tends to be greater when, as in his study, the apexes of the angles are not joined by lines. Secondly, he states that the use of a fixation point may have increased the initial size, and, finally, because in earlier investigations the size of the initial illusion had been based on a great many measurements, the satiation developed would have reduced the size. This last argument could not apply in the present experiment, since the estimate of the initial illusion had been based on the same number of trials as Köhler and Fishback based their estimate. It could very possibly have been due to the use of connecting horizontal lines, as these lines, even in the initial judgements of the subject, should provide cues lacking when the area between the apexes is empty. No fixation point was used here but the results of other experiments (Mountjoy, 1960; Day, 1960) do not demonstrate any difference in size of initial illusion due to the use of a fixation point.

The principal findings of this experiment can be summarized as follows.

1) A significant decrement in the magnitude of the illusion occurred over trials.

2) Pretraining resulted in positive transfer which, when pretraining was given in a large enough amount, produced a significant decrease in the magnitude of the initial illusion.

3) Since the control groups never reached the level of the experimental groups, even though they showed a significant decrement due to practice on the Müller-Lyer, it can be assumed that the beneficial effects of transfer were not limited to the initial trials.

Chapter 4

Discussion

The results of these experiments, particularly Experiment II, provide clear evidence that at least under some procedural conditions a decrement in the magnitude of the illusion occurs with practice on the Müller-Lyer illusion figure. Although the results from the critical group in Experiment I, that is, the group which had the variable set on both sides of physical equality, would not, if taken by themselves, provide sufficient evidence for this statement, the results from Experiment II in which this procedure was used for all groups, leaves no doubt that the "practice effect" does occur. In addition, the results from Experiment I indicate that when such an effect is not obtained, one of the possible factors responsible may be the procedure employed.

Although the decrement in the illusion has been demonstrated, the question of interpreting this phenomenon still remains, and it appears that the data obtained in this investigation do offer support for an interpretation in terms of perceptual learning. The crucial evidence in this regard comes from Experiment II. The fact that the transfer of the preliminary training did occur is in itself suggestive of an explanation in terms of learning. Further support for such an interpretation comes from the fact that, over a series of 48 trials on the Müller-Lyer itself, the control groups never reach the level at which the experimental group with 40 pretraining trials began practice on the Müller-Lyer illusion. In other words, the magnitude of illusion in each of the control groups, even with the decrement due to practice, is still greater than the initial magnitude of the illusion in the experimental group after 40 pretraining trials. This evidence, that 40 trials of pretraining were equivalent to, or more effective than, 48 trials on the Müller-Lyer, strongly suggests that the decrement in the illusion over trials should be interpreted in terms of learning.

In addition, the conditions of this experiment favour such an interpretation. The comparatively unrestricted inspection of the figure, as well as the use of connecting horizontal lines in between the obliques, would provide the subject with more favourable conditions for making comparisons between the two halves of the figure. On the other hand, the same free inspection of the figures as well as the massing of trials, which was another condition of this experiment, are supposedly not conducive to the occurrence of satiation.

Thus it is felt that Experiment II adds to the evidence already accumulated which supports a learning interpretation of the decrement, rather than the satiation hypothesis. More specifically, it is suggested that the "practice effect" is a case of perceptual learning which, as was pointed out in the introduction, has been widely demonstrated in other areas of perception (Gibson, 1953). It was proposed there that the decrement could be explained in terms of the Gibsons' theory of perceptual learning, that is, that the judgements of the horizontal lines become more veridical as the subject becomes more sensitive to the relevant cues. The data on transfer obtained in this study can also be accounted for by this theory. As pointed out in the discussion following Experiment II, the transfer obtained cannot reasonably be attributed to habituation to experimental conditions or to warm-up effects. It is suggested, therefore, that in pretraining differentiation of the parts of the stimulus figure occurs. When practice on the Müller-Lyer begins, these effects of pretraining transfer to the second task resulting in a reduced magnitude of initial illusion. This interpretation is particularly appropriate if the Müller-Lyer illusion is regarded as a constancy effect, as the obliques, which induce the three dimensional aspect of the figure causing the line with the obtuse angle to be seen as further away, and therefore longer than the acute angled line, would, after pretraining, to some extent be disregarded and the magnitude of the illusory effect thus reduced. Theoretically it should be possible with sufficient pretraining to destroy the illusory effect of the Müller-Lyer altogether. We do not feel that omitting the horizontal lines, as has been done in some experiments on the Müller-Lyer, nullifies the above explanation, since judgements of visual extent have also been shown to improve with practice (Gibson, 1953).

This investigation has demonstrated that transfer occurs and that it increases with increased amounts of pretraining. However, there are a number of questions regarding the transfer effect which cannot be answered by the present research. In view of the practical importance of whether perceptual learning will transfer to new situations, further study would appear worthwhile. One of the questions which cannot be answered by the present study is concerned with the relative permanency of the effects of pretraining. In Experiment II, the transfer task was given immediately after the pretraining task. Whether the effects of pretraining are fairly long lasting could be determined by varying the interval between the two tasks. That the effects of such training may be relatively permanent is indicated by the evidence regarding constancy effects on artists discussed by Osgood (1953). He discusses Thouless' finding that artists show reduced constancy effects, although they can never completely eliminate the tendency toward constancy. It is assumed that this is the result of training in observation of sensory data. This certainly indicates that effects of such training can be permanent. It would be interesting to ascertain whether artists or a professional group such as surveyors would, as a group, show less magnitude of illusion on the Müller-Lyer, thus demonstrating transfer of extensive training to the experimental situation.

In addition to the above suggestion, since one of the variables affecting transfer is the degree of similarity between the two tasks, it might be possible to vary the degree of similarity between the pretraining pattern and the Müller-Lyer illusion to determine how transfer is affected in such a situation.

There is also the problem, previously referred to, of whether the transfer which occurs affects the entire learning curve. It was suggested then, that if practice on the Müller-Lyer was continued until all groups reached a specified criterion, the savings in trials for subjects receiving pretraining would give some indication as to whether the initial advantage was only a transitory effect.

Summary

Two experiments were performed to investigate conditions affecting the magnitude of the Müller-Lyer illusion and the decrement in magnitude which occurs with practice.

The first experiment was a methodological study concerned with the method of setting the variable part of the illusion figure before adjustment by the subject. Forty subjects were randomly assigned to four groups of ten subjects each. Each group received 88 trials on the Müller-Lyer illusion. The conditions which were varied for the groups concerned the setting of the variable stimulus in relation to the point of physical equality. The variable was set at physical equality on each trial for one group, always longer for another, always shorter for a third, and on both sides of physical equality for a fourth group. The results indicated that the method employed in setting the variable may determine both the initial magnitude of the illusion and the trend in the treatment means over trials.

The second experiment was performed to investigate the effect of pretraining on the magnitude of illusion with the Müller-Lyer figure. Two groups of ten subjects received either eight or 40 practice trials on another illusion figure previous to practice on the Müller-Lyer figure. The practice figure was the same as the Müller-Lyer figure except that circles replaced the obliques. Two other groups of ten sub-

jects were given corresponding amounts of practice in running the apparatus, while a fifth group had no pretraining. All subjects were given 48 trials on the Müller-Lyer illusion. Positive transfer to the Müller-Lyer task was demonstrated as the magnitude of the initial illusion on the Müller-Lyer was found to be a decreasing monotonic function of the amount of relevant pretraining. The experimental groups as compared to the control groups continued to show a smaller magnitude of illusion over the series of trials on the transfer task, although the control groups also showed a significant decrement in the illusion.

These findings are interpreted as meaning that in pretraining subjects receive practice in disregarding the context of the horizontal lines of the circle illusion figure, and this transfers positively to the Müller-Lyer task. It is suggested that the evidence supports an interpretation of the decrement in terms of perceptual learning. Suggestions for further investigations of the transfer effect are offered.

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APPENDIX A

RAW DATA FOR EXPERIMENT I

Experiment I

Group 1 - Variable always set longer than the standard

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
1	.5	3.4	5.9	3.2	3.7	3.7	3.9	3.5	5.6	7.5
2	1.1	2.5	3.2	2.0	2.2	3.3	3.1	4.4	6.6	6.5
3	.5	2.7	3.0	3.3	2.4	3.3	3.7	4.1	7.0	8.3
4	1.9	2.4	1.6	1.9	3.3	3.5	4.5	5.1	6.3	7.4
5	.7	2.0	2.3	3.6	3.7	2.4	5.5	5.9	7.0	6.0
6	1.3	2.4	1.4	3.9	3.8	4.2	4.5	6.7	7.6	6.2
7	1.2	1.9	2.1	2.4	3.1	2.9	4.3	5.2	6.4	6.6
8	1.4	1.2	3.1	2.5	3.2	3.2	4.7	5.5	6.6	5.9
9	2.5	2.0	1.0	2.5	4.5	4.0	5.7	6.1	6.4	6.6
10	2.0	2.9	3.4	1.7	4.3	3.7	6.0	5.8	6.2	6.7
11	1.9	1.3	3.6	1.8	3.1	4.1	6.0	5.6	6.2	6.5
12	2.1	2.4	2.4	4.1	4.3	5.1	6.4	5.3	6.1	7.0
13	1.9	4.0	2.1	3.2	4.1	5.1	5.3	6.2	6.7	6.2
14	1.3	2.2	3.2	2.8	3.7	4.3	6.8	4.3	5.8	6.6
15	1.2	3.0	3.3	3.5	5.4	4.5	6.5	5.5	6.5	7.2
16	1.8	2.0	3.0	2.8	3.4	4.3	5.8	6.8	7.4	5.7
17	.5	1.6	2.2	1.7	5.1	5.4	5.0	6.8	6.3	5.8
18	1.0	3.0	1.7	1.6	4.3	4.3	5.3	5.1	5.8	6.0
19	.9	3.6	2.7	2.7	2.6	4.8	5.0	6.4	6.5	5.6
20	1.4	4.3	4.8	3.3	4.1	4.1	5.8	6.1	7.0	6.0
21	.9	4.1	4.6	3.5	3.6	3.9	6.3	5.0	6.9	5.4
22	1.0	3.8	3.7	2.0	3.1	5.8	5.8	7.0	7.3	5.6
23	2.2	3.7	3.8	3.2	5.5	4.7	5.2	5.5	6.5	6.0
24	1.6	4.3	3.1	3.3	3.3	1.9	5.8	6.1	7.2	5.4
25	.5	4.8	4.6	4.2	4.4	3.9	6.1	6.0	7.1	6.2
26	1.4	3.7	2.9	3.7	3.8	2.1	4.7	8.1	7.3	6.0
27	.6	3.1	2.8	3.4	4.9	3.8	6.1	6.6	7.2	5.7
28	1.5	3.5	3.1	3.2	5.0	3.0	4.7	5.8	7.2	5.5
29	1.4	3.2	4.1	3.4	4.2	4.3	5.1	5.9	7.0	5.4
30	.8	3.0	2.8	2.7	3.1	4.7	5.4	5.0	7.3	5.8
31	.8	3.4	2.2	2.9	3.5	3.9	4.7	6.4	6.7	5.2
32	1.4	4.0	2.1	3.3	1.5	5.4	4.2	6.2	7.0	5.1
33	1.8	2.8	2.9	3.4	4.1	4.7	5.0	5.7	7.7	6.1
34	2.1	2.2	2.1	4.0	4.6	4.9	5.1	5.9	7.3	5.5
35	.5	3.0	2.6	4.2	4.2	3.7	5.4	6.3	7.0	6.4
36	.3	2.2	1.6	4.9	5.0	2.8	4.6	3.5	7.6	5.5
37	1.4	3.8	2.2	4.6	4.1	3.1	5.7	2.6	7.8	5.2
38	.8	5.2	3.0	4.4	3.7	3.5	5.1	4.0	7.8	5.9
39	1.0	1.9	3.0	4.2	3.0	4.0	5.1	3.4	6.7	5.7
40	1.4	4.0	2.2	3.6	5.5	3.9	5.8	3.1	7.6	5.7
41	1.4	3.0	3.0	4.6	3.3	4.2	5.1	2.3	7.7	6.2
42	2.1	3.9	3.3	5.7	5.9	4.2	4.6	3.0	7.8	5.5
43	1.1	5.3	1.8	5.0	4.3	3.9	5.1	4.7	7.4	5.7
44	2.1	3.0	1.8	4.9	6.1	3.4	5.7	4.5	7.1	5.8

Experiment I

Group 1 (Cont.)

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
45	1.4	3.9	1.8	5.7	6.7	4.2	4.6	3.9	7.5	5.7
46	1.4	4.0	2.2	4.6	6.7	2.2	4.7	4.9	7.4	5.5
47	1.4	4.7	2.5	4.2	6.9	4.1	4.3	4.1	7.7	6.0
48	2.7	3.4	2.2	5.1	6.2	5.2	5.1	4.4	7.6	5.8
49	2.2	4.1	2.3	3.7	6.9	3.7	5.0	5.2	6.9	5.2
50	2.3	2.7	4.0	5.1	6.7	2.8	4.1	5.7	7.3	5.5
51	.7	2.5	3.6	5.3	7.1	3.4	5.8	4.8	7.6	6.0
52	2.1	3.6	2.3	4.8	5.9	3.4	5.2	5.5	7.2	5.1
53	1.0	3.2	3.4	4.3	5.8	3.1	4.4	5.2	7.1	5.0
54	1.4	.9	1.3	4.4	6.7	3.1	5.6	5.7	6.8	4.7
55	1.0	3.3	2.3	4.9	7.5	3.9	5.2	5.7	7.4	5.8
56	1.6	4.0	1.8	5.3	6.2	4.1	5.5	6.9	7.1	5.2
57	2.6	5.5	4.0	4.5	6.8	2.8	5.7	5.0	7.2	5.5
58	1.4	5.0	1.7	4.4	4.4	2.3	3.7	6.1	7.6	5.7
59	1.3	3.4	1.3	4.8	4.8	2.0	5.2	6.0	7.2	5.8
60	.4	3.6	2.5	5.1	5.3	3.1	5.1	6.1	7.8	5.7
61	1.0	3.2	3.0	5.7	5.2	3.4	3.9	7.1	7.8	4.8
62	1.8	4.1	4.1	5.1	6.2	3.7	5.7	7.4	7.4	5.6
63	1.4	2.9	2.1	4.1	5.5	4.3	4.0	6.8	7.4	5.7
64	1.0	1.6	2.6	4.9	6.0	2.5	2.3	5.5	6.9	4.7
65	1.0	2.9	1.8	4.6	5.4	2.9	4.6	4.8	7.1	5.3
66	1.8	4.2	2.5	4.9	5.3	4.3	4.2	4.2	7.6	5.2
67	1.6	3.6	2.8	4.5	5.3	3.8	4.4	7.2	7.3	5.4
68	2.7	2.7	1.7	5.1	5.6	3.7	3.5	5.8	7.8	5.2
69	1.0	3.9	2.1	4.4	5.4	4.2	5.2	6.3	8.4	6.1
70	1.4	4.3	2.1	4.7	5.4	4.1	5.0	5.2	7.9	5.7
71	1.4	2.8	3.9	4.3	5.9	5.1	3.4	4.7	7.6	6.0
72	1.8	4.0	2.8	5.0	6.0	3.8	4.7	4.9	7.6	5.3
73	.2	3.8	2.1	4.8	5.0	3.9	4.4	5.0	7.7	5.9
74	1.6	3.6	2.9	4.8	6.3	4.3	4.8	4.0	7.8	5.5
75	2.2	5.1	2.5	4.3	6.1	2.9	5.7	3.0	7.7	5.7
76	1.1	3.1	3.1	4.7	6.4	3.5	4.6	5.7	7.9	4.7
77	1.0	3.6	3.6	3.8	6.8	3.2	4.0	5.6	5.6	5.5
78	.5	2.7	1.4	4.2	7.1	3.7	6.1	5.7	7.5	5.7
79	1.5	4.8	1.4	3.2	6.9	4.1	5.9	4.1	8.1	5.0
80	.5	2.6	2.5	4.1	5.2	3.2	5.3	6.0	7.3	5.2
81	1.7	2.3	3.1	2.8	6.2	4.7	4.1	3.8	7.7	6.2
82	1.2	3.3	2.7	4.6	4.3	3.8	4.5	5.0	8.4	4.8
83	.4	3.4	1.8	3.6	5.6	3.9	5.6	5.4	7.1	4.5
84	.8	4.8	2.7	5.0	5.6	2.6	4.4	4.3	7.8	5.3
85	.4	3.3	2.9	4.1	6.6	3.5	3.8	4.9	7.4	6.3
86	.9	2.2	3.3	4.2	6.2	1.8	4.2	4.5	7.5	5.4
87	1.2	1.7	1.6	3.8	5.9	2.4	4.8	5.9	7.6	5.4
88	.9	2.8	1.9	3.9	6.1	2.7	4.4	5.3	7.6	4.9

Experiment I

Group 2 - Variable set at physical equality with the standard

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
1	2.3	2.7	3.5	2.7	4.2	4.6	4.3	4.4	7.2	5.0
2	2.8	2.8	1.0	3.3	4.4	4.8	5.4	4.6	6.5	5.9
3	2.5	3.0	2.0	3.3	3.8	3.1	5.5	5.3	7.0	7.9
4	1.8	2.6	2.0	3.3	3.2	3.2	4.7	5.3	6.1	8.0
5	1.3	3.1	2.5	3.0	2.9	1.9	4.9	5.6	6.8	7.6
6	2.6	3.3	3.5	2.9	2.0	2.9	4.9	5.0	7.0	9.1
7	2.1	2.8	5.1	3.1	2.5	4.0	4.2	4.8	7.1	8.3
8	1.5	2.3	5.2	3.6	2.5	3.5	5.3	4.4	8.1	7.6
9	2.3	2.3	6.1	4.0	2.1	3.1	6.2	4.8	8.5	7.1
10	2.5	2.4	5.3	3.5	2.7	5.0	5.3	4.8	6.7	6.9
11	1.7	2.3	6.4	3.1	2.6	3.4	5.3	4.9	7.4	6.6
12	2.5	2.1	5.2	3.6	2.3	3.4	4.3	5.1	6.9	7.8
13	3.1	2.0	5.7	4.3	2.1	4.0	4.8	4.1	7.5	7.9
14	2.7	2.2	4.8	4.2	2.2	3.8	4.6	4.1	7.8	8.1
15	2.7	2.3	5.9	5.0	2.7	4.2	4.8	4.4	6.9	8.2
16	2.7	2.6	5.5	4.7	2.8	4.3	4.4	4.6	6.3	8.3
17	2.1	2.6	5.8	3.8	2.4	4.1	4.8	4.1	7.0	8.1
18	2.2	2.7	4.8	3.1	2.8	4.0	4.8	4.4	7.0	8.7
19	2.7	2.3	5.0	4.2	3.0	3.9	4.6	4.7	7.3	9.0
20	2.0	2.8	5.9	2.8	2.8	3.5	5.0	5.2	7.2	8.9
21	1.5	2.2	5.4	4.0	2.7	3.3	4.7	4.8	6.9	7.7
22	2.9	2.7	5.5	3.9	2.9	3.4	5.0	4.8	7.7	8.7
23	3.2	2.8	4.2	3.7	3.3	4.0	5.1	5.9	6.6	8.6
24	2.3	2.9	4.4	4.2	2.8	4.1	5.0	5.6	6.7	8.4
25	2.5	3.3	5.1	3.9	2.9	3.9	5.1	5.7	6.6	9.3
26	3.0	2.8	5.3	3.3	2.7	3.7	5.4	5.7	6.2	9.1
27	3.2	3.7	5.2	2.9	3.0	4.1	4.9	5.5	6.5	9.9
28	3.0	3.4	5.2	3.5	2.7	4.5	5.6	5.7	6.7	9.1
29	2.8	3.2	5.2	3.5	3.0	3.7	5.3	6.2	7.2	9.2
30	3.0	3.2	5.8	3.9	3.0	3.8	5.1	5.8	7.2	9.1
31	2.6	3.5	6.0	4.2	2.7	4.0	5.2	6.5	7.0	8.3
32	3.5	3.0	5.0	4.8	2.8	4.6	5.9	6.1	7.3	8.8
33	2.8	2.9	6.8	4.5	2.1	4.3	4.7	5.4	6.7	7.4
34	2.8	3.3	4.7	4.6	2.6	4.3	5.6	7.2	6.5	8.0
35	3.1	3.7	5.1	4.1	2.9	4.7	5.1	6.4	7.3	8.0
36	3.8	3.4	6.0	4.7	2.4	4.8	5.0	7.0	7.2	8.5
37	3.0	2.8	5.6	4.4	2.7	4.5	5.4	5.7	7.7	8.4
38	4.0	3.3	6.4	4.9	2.5	4.5	5.3	6.0	9.1	8.5
39	2.4	3.4	5.7	4.7	3.0	4.4	4.2	5.6	6.8	8.8
40	3.0	3.4	5.9	4.7	3.0	4.9	4.9	5.8	5.8	9.0
41	2.9	3.8	5.0	5.1	3.2	4.3	5.2	6.3	6.9	9.2
42	4.3	3.6	6.3	5.2	3.1	3.4	4.6	6.3	6.9	8.7
43	3.1	3.5	6.5	4.1	3.2	4.1	5.7	4.7	7.2	8.6
44	2.7	3.3	6.0	4.3	3.1	4.2	6.3	6.9	7.5	8.9

Experiment I

Group 2 (Cont.)

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
45	3.0	4.0	6.5	4.0	3.0	3.9	5.2	5.5	6.6	9.1
46	2.6	3.7	5.3	4.0	2.6	4.2	4.9	6.0	7.5	9.3
47	2.7	3.5	5.0	4.4	1.5	4.4	5.3	5.3	7.6	9.8
48	2.6	3.3	5.5	4.2	2.4	4.3	5.3	5.9	6.6	8.9
49	2.2	3.5	5.5	4.4	2.8	4.4	6.0	5.2	6.5	9.4
50	2.8	3.4	5.3	4.8	3.2	4.0	5.2	4.9	7.3	8.6
51	3.3	3.7	5.5	4.3	2.6	4.6	5.4	5.8	7.8	8.8
52	2.8	3.5	5.6	4.5	2.5	4.6	5.7	4.7	7.4	8.3
53	3.5	3.8	5.5	4.4	2.7	4.2	5.6	5.9	7.6	9.1
54	3.0	3.9	5.8	4.6	2.8	4.2	5.6	6.3	6.6	8.8
55	2.9	3.5	5.9	4.5	2.2	4.3	4.9	7.3	5.7	8.3
56	2.5	3.4	5.8	4.2	2.5	4.2	5.2	4.5	5.6	8.7
57	2.6	3.1	5.4	4.4	3.0	5.1	4.7	5.9	5.2	8.5
58	3.0	3.5	5.1	4.4	3.1	4.3	4.9	5.4	6.2	8.8
59	2.0	3.6	5.8	4.8	1.7	4.4	4.8	6.0	6.8	8.5
60	2.1	4.0	5.0	4.7	2.6	4.5	5.3	6.1	6.0	8.8
61	2.0	3.7	5.5	4.6	4.0	4.3	5.0	5.6	5.8	8.6
62	2.2	3.4	5.2	4.8	3.0	4.8	5.3	6.1	6.0	9.3
63	2.0	2.8	5.5	4.7	2.4	4.4	5.1	6.6	4.9	8.5
64	2.8	3.6	4.9	4.5	2.6	4.5	5.0	6.2	6.2	8.8
65	3.0	3.8	5.2	4.4	2.8	4.2	5.3	5.9	7.4	9.2
66	2.4	3.3	5.4	4.8	2.0	4.5	4.9	5.9	5.5	9.0
67	2.5	3.3	5.0	4.6	2.3	4.6	5.3	5.6	5.8	5.8
68	3.3	1.5	4.7	5.1	1.5	4.5	4.9	6.7	6.2	8.7
69	2.7	2.7	5.5	4.7	1.6	4.7	4.7	7.3	5.8	8.5
70	2.4	2.4	5.6	4.5	2.0	4.7	5.5	6.7	5.5	8.3
71	2.3	2.3	4.7	4.7	2.3	4.8	4.8	6.1	5.8	7.9
72	2.5	2.6	5.0	4.9	2.1	4.6	5.4	5.7	6.4	9.0
73	2.7	2.9	5.6	5.0	2.8	4.5	5.2	5.9	5.5	9.2
74	3.2	2.6	5.3	4.9	3.2	4.6	4.9	6.6	5.7	9.1
75	3.1	2.7	5.2	5.0	2.6	4.6	4.7	7.1	4.7	9.1
76	2.8	2.8	3.9	5.0	3.1	4.9	4.5	6.8	5.4	9.0
77	2.7	2.4	4.8	5.2	2.9	4.3	4.9	6.1	5.4	8.9
78	3.2	2.8	4.8	5.2	3.3	4.5	5.0	7.1	5.7	9.3
79	3.0	2.5	5.2	4.8	2.2	4.2	6.0	6.7	5.9	8.8
80	2.3	2.8	4.6	4.7	2.3	4.4	5.2	6.5	5.9	9.7
81	2.1	3.0	4.9	5.3	2.4	4.5	4.3	6.7	5.4	9.2
82	3.0	2.6	5.1	5.2	2.5	4.7	4.7	6.0	6.1	9.9
83	3.7	2.7	4.9	5.3	1.9	4.2	5.3	5.2	6.4	8.7
84	3.1	2.9	5.1	4.8	1.8	4.6	4.9	6.7	5.9	8.9
85	3.3	2.8	5.1	5.1	1.6	4.0	5.5	7.2	4.9	9.5
86	2.1	2.9	4.7	4.9	1.5	4.7	4.5	6.1	5.0	9.1
87	2.3	2.9	4.2	5.2	2.2	4.5	5.2	5.9	6.7	9.2
88	2.9	3.1	4.4	5.0	2.2	4.1	5.0	7.6	5.9	8.9

Experiment II

Group 3 - Variable set shorter & longer than the standard

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
1	1.5	1.8	6.1	2.7	5.9	2.0	4.9	7.0	8.1	6.5
2	3.2	4.6	3.1	4.5	6.5	6.8	5.5	7.6	7.6	6.4
3	4.3	5.1	7.3	4.6	6.1	7.2	5.7	4.2	5.7	5.1
4	2.4	6.4	3.3	6.6	3.8	5.4	5.9	7.7	6.9	7.1
5	2.6	2.1	6.7	4.2	7.0	7.2	6.5	4.3	5.3	6.3
6	4.5	1.8	2.4	4.1	4.1	4.4	3.5	4.5	4.3	7.0
7	5.0	3.0	5.4	5.7	4.0	6.2	6.0	6.7	3.5	4.0
8	4.4	4.3	3.3	6.5	3.9	5.3	6.4	4.0	5.9	7.0
9	2.9	3.1	5.2	6.3	4.2	5.1	5.7	6.5	6.7	6.7
10	3.2	4.3	4.3	5.8	4.5	5.5	5.5	6.2	3.8	7.9
11	3.0	2.9	2.3	3.7	5.1	6.3	5.6	2.3	5.7	7.7
12	3.8	3.6	5.8	4.1	4.3	7.4	6.7	2.3	6.4	8.6
13	3.8	2.3	1.2	6.9	3.6	6.3	6.0	5.8	4.6	9.3
14	4.1	2.3	3.7	6.0	5.5	6.9	5.6	3.6	5.0	6.2
15	3.7	3.9	4.2	5.7	5.8	6.5	6.0	4.3	6.2	4.9
16	2.4	5.0	3.4	5.4	5.5	6.4	6.7	6.6	4.5	6.2
17	3.5	1.8	1.0	5.4	3.4	6.0	6.5	6.0	6.2	7.8
18	2.7	3.2	6.1	6.6	4.5	5.0	5.6	3.7	5.4	7.6
19	3.5	3.5	2.7	5.4	5.4	6.4	6.3	5.5	4.2	4.4
20	3.0	2.0	5.0	5.8	5.1	6.6	5.3	2.4	4.8	6.1
21	3.8	4.0	6.7	5.9	4.0	6.2	5.7	5.4	7.1	8.2
22	3.8	2.7	2.5	7.7	3.1	5.8	7.2	2.6	4.5	6.2
23	2.8	5.0	5.7	6.2	3.8	6.1	6.1	3.5	4.2	7.4
24	3.3	4.8	4.5	6.5	3.4	5.4	6.3	7.0	4.7	5.1
25	3.2	4.3	1.8	6.3	3.8	4.6	6.0	4.0	5.2	5.0
26	2.9	4.1	3.5	6.4	2.8	6.1	6.1	5.3	4.4	6.6
27	3.5	3.5	2.2	7.3	3.8	6.0	5.9	3.0	5.1	8.6
28	3.1	4.3	4.0	5.9	4.4	5.6	6.4	3.6	9.0	6.7
29	3.7	3.9	4.4	5.4	3.8	6.9	6.2	3.2	1.6	5.4
30	3.3	3.8	2.7	6.0	4.2	6.4	6.0	3.0	4.4	6.6
31	3.7	4.2	5.5	6.0	4.3	6.0	6.2	3.1	5.9	5.2
32	3.5	4.2	3.5	5.4	4.2	5.5	6.7	4.1	3.9	6.5
33	4.5	3.7	4.2	5.7	7.3	5.0	6.2	4.1	4.6	5.1
34	3.2	3.8	3.3	5.2	4.0	5.2	3.1	3.5	5.8	7.2
35	3.3	3.7	5.2	5.7	3.0	4.8	5.8	5.2	5.0	5.4
36	2.4	4.5	3.1	5.8	3.3	6.1	6.3	3.6	3.7	5.2
37	3.5	4.2	3.5	5.8	2.8	5.8	4.7	4.7	4.9	6.8
38	2.8	4.0	6.0	5.5	4.4	5.0	5.6	4.5	4.5	7.5
39	3.1	4.4	3.3	5.6	3.7	5.4	5.7	3.6	5.5	7.1
40	3.0	4.3	4.9	5.1	4.4	6.1	5.8	4.0	5.8	5.8
41	3.0	3.8	6.3	6.1	4.0	7.1	6.0	4.3	5.0	5.7
42	2.8	3.4	5.0	5.7	3.4	6.6	6.2	5.1	4.3	5.8
43	2.9	3.8	6.0	7.3	3.9	6.6	6.5	3.7	3.2	5.5
44	3.1	3.7	4.4	6.8	3.8	5.9	6.7	4.7	4.5	5.9

Experiment I

Group 3 (Cont.)

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
45	3.0	4.1	5.2	7.0	3.8	5.5	6.0	4.1	6.4	6.4
46	3.4	4.1	2.5	7.1	4.2	5.2	6.5	5.0	4.6	6.0
47	3.0	3.8	1.9	6.7	3.9	5.3	6.3	3.7	4.4	5.7
48	3.0	3.9	3.4	5.7	4.5	5.6	7.0	3.5	5.3	6.3
49	3.2	4.4	5.7	6.0	3.3	5.7	6.1	3.7	4.6	3.4
50	3.2	3.5	5.3	6.8	3.9	5.4	6.4	3.4	5.2	4.7
51	3.2	4.0	3.2	5.2	3.2	6.0	6.0	5.2	6.1	4.1
52	3.2	3.7	4.6	7.1	4.3	5.8	6.0	5.2	5.8	5.8
53	3.0	4.2	5.4	7.3	3.9	6.3	5.5	5.1	5.2	5.8
54	2.8	3.6	3.0	6.9	3.5	5.5	5.5	3.3	5.0	5.4
55	3.4	3.6	4.6	6.5	3.3	6.2	5.1	3.4	5.1	4.5
56	3.3	3.9	2.4	5.7	4.6	7.8	5.1	4.6	5.0	7.8
57	3.3	3.4	3.4	7.7	4.3	6.2	5.6	3.9	6.5	8.7
58	3.1	3.6	3.5	7.2	3.5	6.8	5.3	3.7	5.1	5.4
59	3.1	3.2	5.8	7.0	3.0	6.8	5.6	4.0	5.9	5.7
60	3.7	3.1	5.3	6.0	3.9	7.3	5.5	4.7	5.7	7.1
61	4.3	3.6	4.5	4.5	3.7	7.3	4.7	4.5	4.7	6.4
62	3.4	4.1	6.2	6.0	3.5	5.8	5.0	4.7	5.4	6.7
63	2.8	4.6	5.5	5.7	3.8	6.2	5.0	4.3	5.7	5.6
64	3.2	3.2	4.9	5.9	3.9	7.1	4.6	4.8	6.2	3.2
65	3.1	4.1	5.1	5.3	3.3	7.4	4.8	4.7	5.5	5.2
66	3.0	3.1	5.1	6.1	4.1	6.5	5.4	4.6	4.5	3.5
67	3.1	4.0	4.7	6.6	3.6	6.7	5.4	4.5	5.7	4.7
68	2.8	4.1	4.0	6.0	3.8	6.8	6.0	4.8	5.0	9.3
69	3.3	2.9	5.4	5.9	3.5	6.2	4.6	4.7	5.8	7.0
70	3.1	3.2	5.1	6.7	2.1	6.2	5.7	3.7	6.4	5.6
71	3.0	3.3	6.2	5.8	3.4	6.1	4.7	4.3	5.4	3.3
72	3.8	4.4	4.5	6.4	3.2	5.8	4.4	5.4	3.9	5.1
73	3.7	3.9	3.9	5.6	3.3	6.5	4.7	5.1	4.3	6.1
74	2.9	3.0	4.1	4.8	3.5	5.7	4.5	4.9	4.2	5.4
75	3.0	4.2	4.7	6.0	3.6	6.3	4.2	4.6	3.8	5.9
76	3.2	3.1	4.5	6.8	4.0	6.3	4.4	4.9	4.2	4.9
77	3.1	3.8	5.8	6.0	3.8	6.0	4.3	4.7	4.8	6.3
78	3.2	2.9	4.8	5.4	3.9	6.7	4.2	5.0	3.9	3.7
79	3.0	4.2	5.4	6.5	2.0	6.1	4.5	5.1	4.3	5.8
80	3.4	3.8	3.5	5.1	3.1	6.0	4.1	5.0	5.2	4.2
81	3.1	3.6	4.4	4.8	2.5	6.4	4.6	5.0	5.4	5.5
82	3.0	4.1	4.3	7.0	1.8	5.3	5.1	4.2	3.9	6.2
83	3.0	3.1	5.7	5.2	2.9	5.6	4.7	4.6	4.4	8.1
84	3.3	3.8	4.4	6.9	1.4	6.2	4.3	5.2	4.6	7.5
85	2.7	3.5	4.0	5.7	3.0	5.8	4.0	5.4	4.8	8.3
86	3.0	3.0	4.7	3.9	3.5	4.9	3.9	4.2	5.0	5.5
87	3.1	2.6	3.9	5.3	5.4	5.2	4.1	5.1	4.0	6.7
88	3.0	3.7	6.3	6.3	3.5	5.4	4.2	4.7	4.3	5.7

Experiment I

Group 4 - Variable always set shorter than the standard

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
1	5.9	7.9	6.0	6.9	6.7	7.6	7.4	7.1	8.2	7.7
2	7.5	6.7	6.5	8.2	8.4	7.6	8.3	8.3	7.1	7.6
3	4.9	5.9	6.6	6.5	7.2	7.4	5.6	7.5	8.0	9.1
4	5.4	6.5	6.1	6.7	6.3	7.0	8.1	7.2	8.5	7.5
5	5.4	4.7	6.7	6.7	6.1	6.5	8.7	7.0	7.1	7.7
6	4.0	6.0	6.4	6.1	6.8	7.2	5.3	7.6	8.8	8.3
7	4.9	4.7	6.6	6.3	6.0	7.0	6.1	7.1	8.8	8.8
8	4.6	5.5	5.9	5.3	5.9	6.4	8.6	7.5	6.6	8.5
9	4.6	5.6	5.7	4.9	5.3	6.5	5.7	7.5	8.5	8.3
10	4.3	7.1	5.5	5.6	5.8	7.5	5.5	7.8	8.9	6.7
11	5.0	6.4	6.1	5.3	5.2	7.7	7.8	7.4	7.9	7.1
12	4.5	6.9	6.6	5.5	5.2	7.0	5.4	7.2	6.7	7.8
13	4.1	6.1	6.7	6.6	5.5	7.1	5.0	6.9	7.6	6.8
14	4.8	3.8	6.3	5.4	6.1	7.0	4.8	6.4	6.3	6.6
15	4.9	4.5	7.6	4.4	6.0	6.7	5.1	7.4	6.7	6.9
16	4.3	4.2	7.2	5.8	5.8	7.0	5.6	6.8	7.1	6.5
17	4.4	5.0	6.7	4.8	5.7	7.8	6.4	5.8	6.3	6.7
18	3.9	5.1	6.6	6.1	5.7	6.9	6.4	7.1	8.0	6.5
19	4.2	4.6	5.9	5.0	6.1	5.7	6.6	5.9	7.2	6.9
20	4.3	5.0	5.7	4.2	5.8	6.6	5.4	7.0	7.4	6.2
21	4.0	5.8	6.4	4.8	5.7	7.4	5.3	7.2	6.8	6.7
22	4.0	5.5	7.8	4.7	5.3	7.5	5.8	7.2	7.7	6.7
23	4.5	4.8	7.2	3.2	4.8	6.7	5.5	7.4	7.5	6.1
24	4.1	5.4	7.0	3.8	6.2	7.5	5.6	6.3	6.9	6.8
25	4.8	4.7	6.1	3.3	5.8	6.6	6.4	7.3	6.6	7.2
26	5.1	6.3	5.8	3.0	5.9	5.9	5.9	6.9	7.1	6.2
27	3.7	6.8	6.0	4.5	5.3	6.4	5.0	7.1	7.2	6.2
28	4.0	5.2	5.7	3.3	5.6	6.8	5.9	7.2	6.8	6.5
29	4.3	5.7	6.1	3.2	5.9	5.9	5.8	6.9	6.6	6.4
30	3.9	5.6	6.2	3.5	5.2	6.7	6.2	7.2	6.5	6.5
31	4.1	6.0	5.3	2.1	5.1	7.5	6.2	7.3	7.1	6.2
32	4.0	5.9	6.2	2.7	5.5	6.2	6.2	6.7	6.8	7.2
33	3.6	6.3	6.7	2.3	5.1	6.4	6.0	6.9	7.0	6.4
34	4.0	6.6	5.9	1.7	4.3	7.5	6.4	7.2	7.0	6.7
35	4.1	5.2	5.4	2.5	5.6	6.8	6.0	6.8	6.7	7.4
36	2.8	4.8	5.3	3.4	5.3	5.7	5.9	7.2	7.3	6.8
37	3.1	5.3	6.3	2.1	5.5	7.0	7.0	6.0	7.1	7.3
38	3.7	2.8	6.1	2.8	5.0	6.7	5.8	7.8	8.0	7.1
39	4.4	3.6	5.9	2.8	4.8	5.9	5.4	8.5	7.3	6.7
40	3.9	3.6	5.3	3.6	5.1	6.6	5.8	7.2	6.8	6.3
41	2.9	3.2	5.6	2.4	5.5	6.6	6.2	6.7	6.5	7.5
42	4.3	4.4	4.6	3.1	4.3	7.2	5.9	7.4	6.7	6.9
43	4.2	5.1	5.0	2.0	4.6	6.9	5.4	7.2	6.8	6.5
44	3.7	3.3	5.4	2.3	5.4	7.2	5.6	7.6	6.2	7.5

Experiment I

Group 4 (Cont.)

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
45	2.8	3.2	5.1	2.1	5.7	5.5	6.9	7.3	7.7	6.8
46	4.1	2.7	4.5	1.4	4.8	5.9	6.6	7.5	6.7	6.6
47	3.2	3.7	5.0	1.8	5.6	7.1	6.4	7.3	5.7	7.4
48	4.0	4.0	4.2	1.7	6.0	5.4	6.2	7.3	4.7	6.9
49	3.6	3.9	4.7	2.8	5.4	6.1	5.9	7.1	3.9	6.0
50	2.9	2.7	4.8	2.5	5.1	6.2	5.5	6.8	4.3	6.7
51	3.2	3.7	4.4	3.3	5.7	5.9	6.1	7.1	5.2	6.5
52	3.0	2.7	4.3	2.3	5.1	6.9	6.4	7.7	5.2	7.1
53	3.6	3.9	4.8	2.8	4.8	6.5	5.8	7.3	5.6	6.5
54	3.4	3.1	5.0	3.0	5.2	6.8	5.9	7.3	3.7	6.1
55	3.3	4.2	4.5	2.5	6.3	6.9	7.1	7.1	4.5	7.5
56	2.8	4.2	4.2	2.4	5.4	6.8	6.5	7.8	4.8	7.3
57	2.2	4.3	4.8	1.9	5.6	6.8	6.0	6.7	4.5	7.3
58	2.1	4.6	4.5	3.4	6.1	6.7	6.1	7.4	5.1	6.1
59	3.3	3.6	4.5	2.7	6.6	6.4	5.3	6.8	4.9	6.6
60	3.2	4.3	4.7	2.0	5.6	7.5	5.6	7.5	5.0	6.4
61	3.0	4.9	4.5	3.3	4.6	6.4	5.5	7.7	5.9	6.8
62	4.3	4.2	4.2	2.5	5.6	7.5	5.5	7.7	5.1	7.0
63	3.3	4.0	4.0	3.1	5.2	5.9	5.6	7.6	4.5	6.1
64	3.3	5.6	4.7	2.8	6.3	6.3	6.4	6.6	3.8	7.1
65	3.4	5.3	3.9	2.0	4.8	6.1	6.4	6.4	5.4	7.0
66	2.3	3.0	4.1	1.9	4.6	5.4	6.4	6.1	4.7	5.7
67	3.2	4.1	4.3	3.2	4.6	5.8	6.2	7.0	5.1	4.8
68	2.4	2.3	4.4	1.2	5.4	6.0	6.6	6.3	5.6	6.5
69	2.3	2.8	4.3	2.6	5.2	5.7	6.5	6.7	6.1	6.0
70	2.6	3.4	4.5	2.8	5.0	6.7	5.9	6.4	5.8	6.4
71	2.8	3.9	4.0	2.9	4.7	5.7	6.5	7.2	5.5	5.9
72	3.3	2.8	4.1	3.4	4.5	6.3	6.8	6.8	5.7	6.0
73	2.7	4.2	3.9	2.0	4.5	5.5	7.0	6.9	4.9	5.5
74	2.4	4.9	4.0	1.7	4.4	5.1	4.9	6.3	4.8	6.2
75	2.6	4.9	4.7	.2	4.5	6.1	5.6	5.7	3.2	6.1
76	2.6	4.7	4.4	2.0	4.1	6.4	4.4	6.6	5.5	5.9
77	2.0	3.6	3.8	1.8	4.7	6.3	4.8	6.3	5.4	6.3
78	2.5	4.1	4.1	1.3	3.9	6.7	4.6	6.3	5.6	5.6
79	1.8	4.0	4.2	3.0	4.1	6.4	5.4	6.9	5.5	6.2
80	3.0	3.8	3.7	2.1	4.0	7.3	4.9	6.8	5.9	6.3
81	3.3	5.4	4.2	2.8	3.8	5.5	5.3	5.9	4.8	6.8
82	2.6	5.6	4.5	1.9	3.8	5.6	6.8	7.0	5.1	5.7
83	2.3	5.7	4.3	2.7	3.6	6.4	6.6	5.2	5.3	5.8
84	2.6	4.8	4.1	2.7	4.4	6.3	6.2	6.0	4.7	6.2
85	2.4	4.2	4.1	2.6	4.3	6.7	5.9	6.9	5.1	5.5
86	1.4	4.4	3.9	3.1	4.5	5.7	5.8	6.5	6.0	6.2
87	1.8	4.5	3.9	1.9	3.9	6.6	5.7	5.8	4.8	5.9
88	1.4	5.1	3.9	2.5	5.0	5.3	5.0	5.8	4.2	6.1

APPENDIX B

RAW DATA FOR EXPERIMENT II

Experiment II. Group with no pretraining trials

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
1	4.9	3.0	2.9	4.8	5.4	.3	4.5	3.2	4.0	1.4
2	4.0	2.9	2.0	2.4	3.7	3.2	2.9	5.2	4.3	1.5
3	4.3	2.1	3.7	4.1	5.2	.8	3.6	3.3	2.2	4.0
4	3.4	3.0	2.2	2.7	4.0	1.0	2.9	3.7	1.8	4.4
5	3.7	3.3	3.0	2.0	3.6	1.0	3.3	4.8	3.8	2.8
6	3.3	2.8	3.3	3.6	5.4	1.2	3.4	4.4	3.6	2.7
7	3.6	2.5	1.8	3.3	4.5	2.8	2.3	5.1	4.1	3.3
8	3.5	2.2	2.5	4.1	4.7	2.3	4.1	4.9	3.4	2.1
9	3.1	1.4	2.3	4.6	6.0	3.2	3.8	4.5	2.8	3.6
10	3.4	1.8	2.8	2.2	3.2	1.8	3.2	4.3	1.0	2.9
11	3.1	.6	2.4	2.3	2.8	1.4	3.5	4.5	2.5	3.2
12	2.0	3.3	2.4	1.8	3.8	1.2	2.8	5.7	2.0	3.8
13	2.9	1.9	1.4	3.2	5.5	1.8	3.6	4.8	2.2	3.2
14	2.9	1.5	1.1	2.1	5.9	1.6	3.6	4.4	1.7	2.9
15	3.8	2.0	1.7	3.6	5.9	3.0	3.1	3.9	2.5	2.2
16	3.8	2.0	2.1	3.3	5.2	3.3	3.5	5.6	3.0	3.8
17	2.7	1.3	2.2	3.8	2.0	1.7	2.6	4.4	1.2	2.6
18	4.2	1.7	2.3	3.4	3.8	3.4	3.6	5.5	1.8	1.5
19	3.6	2.0	1.9	3.6	3.1	2.2	4.0	4.7	1.0	2.6
20	3.3	2.4	.7	3.5	1.5	3.0	1.9	4.5	.8	3.6
21	2.7	2.3	1.4	4.9	1.0	1.3	3.1	5.3	1.4	4.1
22	2.9	2.6	1.7	1.7	3.0	2.7	3.4	5.4	.6	3.4
23	3.9	2.3	2.0	4.3	2.9	2.5	2.3	5.9	.5	3.1
24	3.4	2.5	2.2	1.9	-.8	2.5	2.3	5.6	2.0	2.9
25	2.0	1.2	1.8	2.3	2.8	1.4	2.4	5.2	.1	1.7
26	2.4	2.0	1.4	1.6	-.8	.7	3.6	5.2	.7	3.2
27	3.1	2.3	1.4	2.2	1.5	.2	3.3	4.4	.9	2.7
28	3.0	2.0	1.0	1.6	.4	2.7	3.3	4.6	.8	3.8
29	4.0	1.5	1.2	2.5	3.0	2.7	2.9	4.4	1.0	3.1
30	3.3	2.0	1.3	3.8	2.4	2.9	3.0	4.5	.9	2.4
31	3.5	1.7	2.2	3.7	.8	2.1	2.8	4.1	.7	3.7
32	1.9	2.1	1.6	4.5	2.3	1.5	3.2	4.0	1.6	1.0
33	2.8	2.1	1.7	2.5	.8	.9	3.6	4.6	.5	3.4
34	3.8	1.4	1.8	4.3	3.0	.7	3.4	4.6	1.3	2.0
35	3.3	1.9	1.3	4.3	3.7	2.0	2.9	5.0	1.0	.6
36	2.9	1.8	2.1	3.9	1.5	2.3	2.7	4.6	.6	2.1
37	1.8	2.4	1.7	4.0	3.5	1.1	2.8	4.3	.4	3.1
38	3.2	1.8	2.6	4.8	3.3	2.6	2.2	4.1	.4	0.0
39	3.7	1.7	1.9	3.5	.7	2.8	3.0	3.7	-.1	1.9
40	4.2	2.5	1.5	2.8	3.0	1.9	2.4	4.6	-1.0	3.0
41	2.8	1.6	2.1	2.5	1.9	2.8	1.5	3.9	1.2	2.8
42	2.8	1.2	1.5	2.6	1.2	1.4	2.1	5.2	.8	.5
43	2.8	1.7	1.9	4.2	1.1	1.6	2.9	4.6	1.1	2.5
44	3.4	2.2	1.3	4.2	-.2	.6	3.1	4.4	1.0	1.4
45	2.9	2.9	2.3	4.3	.4	1.7	2.7	5.3	-.1	2.1
46	2.5	2.0	1.9	3.8	1.3	2.5	2.9	5.4	.9	1.9
47	2.9	1.4	1.6	4.1	1.2	.8	3.2	5.6	.5	3.5
48	2.6	2.0	1.7	2.8	.3	1.8	2.6	5.2	.8	1.1

Experiment II. Group with 8 pretraining trials

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
1	.4	-.2	2.7	1.1	4.0	2.9	3.0	2.0	5.5	3.6
2	2.3	1.1	2.8	1.7	2.5	3.6	4.0	2.5	4.0	2.6
3	1.8	2.9	2.8	-1.0	2.1	3.8	2.5	2.3	5.1	4.2
4	-.9	2.0	1.7	.3	1.1	3.7	3.0	2.5	4.5	2.3
5	-.3	2.4	3.6	.1	1.5	3.4	2.9	2.2	6.0	4.2
6	1.6	1.5	2.8	.7	3.2	3.9	2.3	1.0	5.6	4.8
7	-1.0	3.3	1.7	2.5	3.2	3.3	1.7	3.4	4.2	3.6
8	1.2	2.7	1.8	1.9	1.2	4.2	1.5	1.8	3.9	3.1
9	-.3	3.0	1.0	1.2	2.1	3.6	3.0	2.2	4.7	4.4
10	2.4	1.5	.5	1.6	4.1	3.8	2.5	1.8	5.1	2.7
11	2.7	1.0	.8	.9	3.6	3.4	2.0	2.9	3.6	2.8
12	2.8	1.8	2.3	.4	3.9	4.0	1.6	4.0	3.8	3.8
13	-.2	1.4	4.1	-.1	1.6	3.6	2.5	1.7	3.8	3.0
14	-.2	2.5	-.3	-.4	2.3	3.5	2.8	2.9	5.2	3.5
15	2.6	1.3	.5	.5	1.6	3.1	1.8	2.3	4.8	2.5
16	2.5	2.1	1.2	-.1	2.2	3.1	2.7	1.6	4.9	3.9
17	-1.2	1.2	1.9	.5	2.0	3.9	3.8	2.3	3.8	3.2
18	2.5	2.3	-.1	.3	.4	3.5	1.7	3.8	4.3	3.0
19	2.3	1.2	1.0	-.1	.4	3.7	2.2	3.2	4.2	2.1
20	-.8	2.3	1.3	-.4	.8	4.5	3.0	2.3	4.1	2.9
21	2.1	1.6	.3	.7	.9	4.5	3.5	1.9	3.9	3.1
22	-.5	.7	1.9	1.2	.4	4.3	2.7	1.7	3.6	2.6
23	.4	2.3	.7	.5	1.5	3.2	1.2	1.7	3.9	3.0
24	2.0	1.0	3.5	1.5	1.7	2.7	1.5	2.2	3.9	2.9
25	1.5	1.5	-.6	-.7	1.0	2.5	1.3	2.5	4.3	3.7
26	-.1	.8	1.2	.3	1.3	3.0	.9	2.7	2.8	3.4
27	1.4	1.9	-2.1	.6	2.5	3.6	2.2	2.1	2.4	2.4
28	-.8	1.2	-2.1	.8	1.9	3.1	2.0	1.5	3.3	3.8
29	.3	1.7	2.3	.4	1.6	3.9	1.8	1.6	2.6	3.7
30	2.9	.4	-.9	17	2.7	4.1	1.9	1.7	2.0	3.2
31	.1	1.6	1.8	1.0	1.7	3.9	.5	2.8	3.4	3.1
32	2.4	.7	-.2	.5	2.9	3.6	.9	1.8	1.6	1.9
33	1.9	1.5	-.4	1.4	2.8	3.6	1.0	2.3	2.7	2.9
34	-.1	2.8	-1.3	.6	2.2	2.6	-.6	2.6	2.1	3.1
35	1.8	1.5	.6	.2	1.3	2.7	.7	1.6	2.1	3.4
36	-.3	2.2	-.4	1.1	2.7	3.1	2.2	1.1	2.7	3.2
37	2.2	1.5	-.1	.8	2.7	3.6	1.0	-1.3	.7	1.9
38	.9	3.0	.4	-.5	2.7	3.4	.5	-.1	1.7	2.5
39	-.9	2.4	0.0	-1.3	2.3	3.5	2.0	3.0	1.0	2.4
40	2.0	2.9	2.3	-1.1	1.8	3.8	.3	2.0	3.0	3.0
41	2.5	2.8	.5	-.5	.9	2.8	1.3	3.7	2.3	3.5
42	1.9	2.6	1.2	-1.5	2.7	2.9	1.4	2.2	1.8	3.0
43	.4	2.2	.8	11.1	2.5	2.3	1.5	3.0	1.9	2.9
44	2.5	1.8	2.4	-.7	3.1	2.4	1.8	2.4	2.2	2.6
45	.7	1.5	.4	-1.0	3.4	3.0	1.8	2.2	1.7	3.4
46	.4	2.0	1.7	-.3	1.9	3.4	1.5	1.4	2.0	3.2
47	.4	.4	1.7	-1.5	3.4	2.7	1.1	2.7	2.1	1.7
48	-1.0	1.3	-.2	-.7	3.4	3.5	1.2	1.9	3.1	2.3

Experiment II. Group with 40 pretraining trials

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
1	3.0	-.5	.4	2.5	1.2	1.1	4.5	1.7	1.3	1.4
2	1.8	2.2	2.0	1.0	..9	1.1	2.7	1.3	1.5	1.8
3	2.2	1.6	1.7	2.0	.7	-1.0	.5	1.4	2.7	2.6
4	1.4	1.3	1.6	3.3	.5	-.1	3.2	.9	3.0	2.5
5	3.1	2.0	1.1	2.2	1.7	-.9	4.8	.4	4.1	2.0
6	1.4	1.6	.9	1.3	1.1	1.4	1.9	.9	2.5	2.2
7	2.9	2.7	1.0	.8	1.6	-.3	3.0	1.0	2.2	2.0
8	2.2	.8	2.3	1.0	.6	-.6	4.0	2.2	2.1	2.7
9	3.1	-.3	1.8	1.2	1.6	-.3	1.9	1.4	3.7	2.0
10	2.9	1.6	1.9	1.8	1.2	-.7	2.9	1.0	2.7	1.9
11	.4	1.2	.3	2.4	.8	1.5	1.5	1.3	2.1	1.9
12	1.2	1.2	1.4	2.5	-.5	1.4	2.9	.9	1.8	-.6
13	2.1	1.8	1.1	1.8	.2	.5	3.5	1.7	2.0	0.0
14	0.0	.8	1.4	1.3	.9	-.6	3.0	1.8	1.5	1.0
15	2.7	2.2	1.4	1.4	.3	.6	3.8	1.1	1.6	1.6
16	2.4	1.0	1.9	1.8	-.1	1.2	1.3	1.2	1.9	1.7
17	1.1	.7	1.7	3.5	1.6	-.3	1.9	1.8	2.1	.6
18	1.4	.5	1.9	2.6	0.0	1.0	3.3	1.6	2.1	1.8
19	2.8	-.2	1.3	1.6	-.3	.8	3.9	1.6	2.7	1.7
20	1.7	-.7	1.1	3.0	.6	.1	3.2	1.4	2.3	1.8
21	2.8	1.0	1.3	.8	.5	.5	2.6	2.1	2.5	2.0
22	2.3	1.4	1.2	1.9	1.2	-1.0	1.0	1.8	1.9	1.0
23	.5	1.6	.9	2.6	.5	.4	3.2	1.3	2.3	.1
24	1.2	.4	1.5	3.2	1.1	.7	3.5	1.7	1.9	2.1
25	1.8	.9	1.8	2.5	1.0	-.1	2.9	1.8	1.9	2.2
26	1.2	-.3	1.8	2.3	.5	.6	2.0	1.6	1.4	2.7
27	1.5	-.3	1.5	2.5	.8	-1.3	2.7	1.6	2.5	1.7
28	.3	.9	2.0	2.5	2.1	.6	2.7	1.5	1.2	.3
29	.8	1.6	1.5	2.3	1.5	.1	3.4	1.7	1.8	-.5
30	1.4	.9	1.1	2.4	.9	-1.1	3.3	1.2	2.2	1.0
31	.1	-.1	1.1	2.4	.8	-1.3	1.9	1.8	2.3	3.8
32	-1	-.6	2.1	.6	1.4	-.5	4.0	2.1	2.1	2.6
33	.6	-.1	.8	.8	.6	.7	3.0	1.8	2.7	1.5
34	-.2	-1.0	2.1	2.2	-.3	-1.0	4.8	1.9	2.0	1.6
35	0.0	.7	1.2	1.7	1.3	.4	2.5	1.4	1.3	1.8
36	1.7	-.8	1.7	.4	0.0	.3	2.5	1.6	2.0	2.8
37	1.8	-.4	.9	1.3	0,0	.1	2.8	1.8	2.4	1.3
38	1.4	.4	.9	.4	-.2	1.8	4.1	1.3	2.9	1.3
39	-.7	2.2	1.1	1.2	.2	-.5	3.5	1.8	2.6	2.0
40	.4	.8	.9	.7	.7	-.9	3.3	2.0	3.3	1.7
41	-1.0	.7	1.1	1.1	.2	-.7	3.1	1.5	1.9	.9
42	2.2	.1	1.4	.6	.5	0.0	2.2	1.7	1.7	1.7
43	1.5	-.2	1.5	2.1	1.1	1.5	3.2	1.7	1.6	2.3
44	3.3	-.6	1.5	.1	.2	1.8	4.0	1.6	1.9	2.0
45	1.8	1.2	1.3	1.8	.1	0.0	2.0	1.4	2.4	1.7
46	.7	.6	.8	1.6	1.3	-.7	3.3	1.5	2.2	3.1
47	1.5	.3	.7	1.8	.7	1.7	2.3	1.1	1.5	1.6
48	.4	-.4	.3	1.6	.4	1.6	2.0	1.5	2.4	2.4

Experiment II. Group with 8 warm-up trials

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
1	1.8	3.2	3.7	3.8	4.1	2.5	3.8	4.7	4.7	5.3
2	1.8	3.1	1.9	3.2	4.4	3.5	4.5	4.1	4.1	6.0
3	1.9	2.7	2.3	3.0	1.2	3.1	1.5	2.3	4.3	4.5
4	3.5	2.0	3.2	2.0	3.2	3.8	3.6	3.8	3.4	4.7
5	4.0	2.2	2.3	.5	2.9	2.6	3.5	2.7	3.4	3.3
6	3.9	3.4	1.8	2.1	4.7	3.5	.7	4.2	4.0	4.8
7	2.9	3.0	2.1	0.0	3.8	3.2	1.0	4.1	4.0	5.4
8	1.7	2.0	2.8	2.0	4.5	3.3	3.4	2.8	4.5	4.9
9	2.6	1.9	2.5	-.3	3.9	2.7	2.0	3.4	4.1	5.2
10	3.2	2.8	3.0	-.1	2.0	4.7	3.2	3.5	4.3	5.1
11	0.6	2.7	3.1	1.5	2.7	3.9	1.3	2.0	3.9	2.8
12	1.5	1.7	3.3	2.4	2.3	3.2	2.7	2.5	4.5	4.2
13	2.0	1.9	2.7	2.5	3.8	2.6	1.7	2.5	4.2	4.7
14	2.1	.8	2.7	2.1	1.1	3.2	3.0	3.1	3.4	4.2
15	2.7	3.0	3.9	.6	3.0	3.7	2.3	3.2	5.1	2.8
16	2.1	2.2	2.7	.6	1.4	3.1	1.7	2.0	5.4	3.1
17	2.9	3.9	2.5	-.3	1.8	3.4	3.0	3.3	4.9	5.0
18	1.4	4.0	3.0	-.2	2.4	3.1	1.2	2.7	5.0	2.1
19	2.2	2.0	2.3	0.0	1.2	3.4	2.4	3.1	5.0	3.9
20	1.2	2.5	4.3	-.7	-.8	3.6	2.4	3.5	6.0	3.1
21	.8	2.4	3.1	-1.2	2.2	3.2	1.3	2.6	5.0	4.7
22	.6	2.4	2.9	.7	.2	3.3	2.4	2.7	4.5	3.4
23	1.6	2.4	2.5	1.8	-.1	4.1	3.1	2.6	4.8	3.0
24	1.8	1.8	2.1	1.8	1.5	3.2	1.2	2.8	4.5	5.0
25	2.7	1.0	2.2	.3	1.8	3.5	2.0	3.6	4.6	5.2
26	.6	2.2	3.2	-.8	1.5	3.3	3.3	4.1	4.4	3.2
27	1.6	1.1	2.6	-.5	1.2	3.1	2.4	2.6	4.1	2.6
28	1.5	1.3	2.9	-.2	1.7	3.3	2.3	3.5	4.7	2.3
29	1.6	1.5	3.2	-.6	2.0	3.4	1.9	3.7	4.6	3.5
30	1.5	2.2	3.4	1.7	1.6	4.1	2.4	2.8	4.5	4.9
31	1.8	1.4	2.7	.5	2.2	4.0	2.9	3.4	4.6	4.2
32	2.1	1.5	2.7	-.7	1.0	2.8	2.0	4.0	4.6	3.6
33	1.4	1.3	3.1	-.7	1.0	3.7	2.0	4.1	4.5	4.2
34	1.4	1.6	2.6	1.9	.9	3.5	1.5	3.6	4.5	4.7
35	-.1	1.7	2.3	.2	1.2	3.6	1.7	3.1	5.2	3.2
36	1.0	1.5	2.8	-.8	1.1	3.9	1.7	3.3	5.4	2.7
37	.9	1.8	2.9	1.3	2.2	3.6	2.3	3.2	6.0	3.3
38	.6	.6	1.7	1.9	1.7	4.4	2.4	2.9	5.9	3.6
39	-1.0	1.6	2.6	2.2	1.8	3.2	1.7	2.9	5.7	3.1
40	2.3	.9	1.5	2.8	1.2	3.5	.8	3.7	5.3	2.7
41	1.4	1.5	1.7	1.9	.6	3.5	1.2	3.6	4.8	1.7
42	.3	1.7	2.1	1.7	.2	3.5	2.2	3.2	5.5	2.9
43	.1	1.1	2.4	0.0	.8	3.7	2.1	2.9	5.2	2.0
44	1.7	1.8	1.7	2.1	1.4	3.8	.8	3.6	5.4	2.4
45	2.1	1.3	2.4	1.1	.7	3.9	1.2	3.2	5.3	2.3
46	.4	1.9	3.7	.6	.3	3.7	2.0	3.3	5.2	4.4
47	-.2	2.1	2.9	2.8	.9	3.5	2.0	2.6	5.2	3.8
48	-.1	2.1	3.2	.7	.7	3.6	1.8	2.9	5.5	1.9

Experiment II. Group with 40 warm-up trials

Subjects

Trials	1	2	3	4	5	6	7	8	9	10
1	2.1	3.0	3.7	4.2	2.8	2.5	3.9	4.6	5.0	4.0
2	1.3	2.1	1.6	4.1	5.4	4.7	4.2	4.0	4.1	4.5
3	1.7	2.9	2.0	2.9	4.2	3.5	4.2	3.7	4.2	4.9
4	4.2	2.3	3.2	1.9	3.1	5.0	3.7	4.0	3.3	4.8
5	1.3	3.3	3.7	2.3	4.8	4.4	3.7	3.6	5.1	4.7
6	1.8	3.4	4.3	4.3	2.8	4.2	3.9	3.8	3.0	5.7
7	1.8	2.6	3.4	4.0	2.5	3.0	4.0	2.0	4.4	5.0
8	3.4	3.2	3.1	3.0	4.3	3.6	3.5	1.2	2.8	2.1
9	3.6	3.4	2.3	3.0	3.8	3.3	4.0	2.9	3.7	2.9
10	3.5	2.6	2.4	3.9	2.2	3.4	4.7	3.2	2.9	2.4
11	3.2	2.4	2.9	4.9	2.4	3.5	4.2	3.1	2.6	3.0
12	1.5	2.4	3.2	3.2	3.6	2.7	4.1	1.9	2.9	2.7
13	2.8	2.4	2.1	4.5	3.3	2.7	4.7	1.7	2.6	4.5
14	2.8	2.1	3.0	3.9	2.6	3.8	5.3	1.4	.7	3.9
15	2.7	2.7	3.3	4.1	2.7	3.3	5.3	3.0	1.1	4.5
16	3.1	1.8	2.0	4.6	3.9	3.4	4.1	2.7	3.1	4.6
17	2.9	2.2	3.5	3.6	3.4	3.1	4.5	3.0	2.8	4.4
18	2.2	2.3	3.3	3.4	3.4	3.4	3.9	2.8	2.7	4.0
19	1.7	2.1	2.6	3.5	2.7	3.6	4.0	1.7	1.8	3.6
20	3.5	1.9	1.8	3.7	2.9	4.1	3.7	1.8	1.8	3.9
21	3.1	2.5	2.8	4.0	3.9	2.8	3.0	1.8	.6	3.5
22	2.2	2.5	2.9	4.0	3.2	2.0	4.5	1.7	.8	3.4
23	3.5	2.9	2.9	4.2	2.9	3.2	4.5	2.7	2.4	2.8
24	3.8	2.7	2.0	4.1	2.7	3.6	4.5	2.6	2.0	3.6
25	1.7	2.8	1.7	3.3	1.7	3.2	4.0	1.7	.8	4.1
26	2.3	1.9	1.7	3.4	3.0	3.5	3.6	1.4	2.9	3.5
27	2.6	1.8	2.0	2.8	2.9	3.8	4.3	1.5	.2	3.7
28	2.1	1.9	3.1	4.3	2.7	4.1	3.1	2.4	.8	3.7
29	2.5	1.8	3.2	4.3	2.5	4.1	3.9	2.5	2.5	3.5
30	2.9	2.2	1.4	4.7	4.0	3.6	4.7	1.9	.6	3.7
31	3.0	1.2	2.3	4.8	3.5	2.9	4.7	2.5	2.4	3.8
32	2.7	1.7	3.0	4.0	2.4	3.2	4.6	2.4	2.8	3.2
33	3.0	1.7	1.8	4.5	2.6	2.7	3.6	2.0	2.4	3.0
34	2.5	2.1	2.8	4.4	2.7	2.7	4.2	1.8	1.4	4.9
35	2.5	.8	3.5	4.9	3.9	4.0	4.7	1.5	-.7	4.5
36	3.8	1.4	2.5	5.1	3.5	3.5	4.1	.9	-.6	4.6
37	2.6	1.5	1.9	3.5	3.6	3.2	4.2	2.2	.6	4.5
38	2.0	1.9	2.8	4.7	1.6	3.6	4.6	2.8	2.8	4.0
39	3.1	1.7	3.1	2.8	1.7	3.4	4.4	1.2	2.6	4.8
40	3.9	2.0	2.3	3.4	1.8	3.7	4.5	2.2	1.8	4.6
41	2.6	1.2	1.7	4.7	3.5	3.1	4.6	2.2	.4	4.0
42	3.0	2.4	2.9	2.9	3.9	2.8	3.7	2.5	1.9	4.6
43	2.6	3.2	2.0	3.7	2.7	4.4	4.6	.8	1.0	4.1
44	3.0	1.7	2.8	3.3	1.8	4.2	4.2	2.2	-.2	4.2
45	3.4	1.9	3.3	4.2	2.6	4.8	4.5	2.3	.5	3.5
46	3.4	1.2	2.8	3.5	3.1	4.8	4.1	1.1	1.4	4.0
47	3.0	1.2	3.1	4.2	3.2	4.4	4.2	.9	1.3	3.8
48	1.8	2.0	3.3	4.6	1.2	4.1	4.8	1.7	1.5	3.3