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The Critical Flicker Frequency in Relation to the Muller-Lyer Illusion

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THE CRITICAL FLICKER FREQUENCY IN RELATION TO THE MÜLLER-LYER ILLUSION

by

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LIFE

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TABLE OF CONTENTS

CHAPTER I

STATEMENT OF THE PROBLEM

The specific purpose of this investigation is to relate two apparently distinct phenomena, the critical flicker frequency (CFF),[1] variably known as the flicker fusion threshold (FFT),[2] and the flicker fusion frequency (FFF),[3] with the Müller-Lyer illusion. The critical flicker frequency may for the purposes of this study be defined as "the rate of presentation of the successive stimuli which is just necessary to produce complete fusion,"[4] or "the number of light-dark cycles per second at which a physically intermittent light is just perceived as a steady light,"[5] whereas the Müller-Lyer illusion is defined as "an

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[1] A. Dondero, P.R. Hofstaetter, and J.P. O' Connor, "Critical Flicker Frequency in Light-and Dark Adaptation," J. Gen. Psychol., LVIII (1958), 11-16.

[2] Sanford Goldstone, "Flicker Fusion Measurements and Anxiety Level," J. Exp. Psychol., IL (1955), 200-202.

[3] E. Simonson, N. Enzer, and S.S. Blankenstein, " The Influence of Age on the Fusion Frequency of Flicker," J. Exp. Psychol., XXIX (1941), 252-255.

[4] W.S. Duke-Elder, Textbook of Opthalmology, I, (St. Louis, 1940), p. 949.

[5] J. Brozek and A. Keys, "Changes in Flicker-Fusion Frequency with Age," J. Conslt. Psychol., IX (1945), 87.

illusion of visual space perception, in which two physically equal distances appear unequal, due to the partial enclosure of one distance and an apparent widening of the other lines, arrow-heads."[6]

That a relationship between the critical flicker frequency and the Müller-Lyer illusion, either positive or negative, seems plausible may be seen from a number of facts. First of all, the critical flicker frequency decreases with age, as reported by Brozek and Keys,[7] Simonson, Enzer, and Blankenstein,[8] and Misiak,[9] [10] while the Müller-Lyer illusion either decreases with age, as reported by Binet, Van Biervliet, Rivers, and Pintner and Anderson, or increases with age, as reported by Cramaussel,[11] and Hartmann and Triche.[12] Certain of the afore-mentioned studies will be described at a more appropriate place (Review

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[6] H. C. Warren, Dictionary of Psychology (Boston,1934), p.118

[7] Brozek and Keys, pp. 87-90.

[8] Simonson, Enzer, and Blankenstein, pp. 252-255.

[9] H. Misiak, "Age and Sex Differences in Critical Flicker Frequency," J. Exp. Psychol., XXXVII (1947), 318-332.

[10] H. Misiak, "The Decrease of Critical Flicker Frequency with Age," Science, CXIII (1951), 551-552.

[11] Sister Annette Walters, "A Genetic Study of Geometrical-Optical Illusions," Genet. Psychol. Monogr., XXV (1942), 142-143.

[12] G. W. Hartmann and A Triche, "A Differential Susceptibility of Children and Adults," J. Genet. Psychol., XXXXII (1933), 498.

of the Literature).

Secondly, both phenomena under consideration are generally considered as centrally organized. Fred H. Ireland[13] found it necessary to postulate some central mechanism of the brain to account for binocular CFF shifts. He summarized both the conclusion and the basis upon which it is founded as follows:

> Results indicate clearly that, compared to monocular CFF, the CFF for binocular in-phase stimulation is relatively higher, while that for binocular out of phase stimulation is reliably lower. In view of these frequency shifts, obtained during binocular stimulation, it seems necessary to postulate some interaction between the two eyes, an interaction which seems possible only by way of some central mechanism of the brain.[14]

As regards the optical illusions (including the Müller-Lyer illusion), Postman and Egan state the following: "---One thing stands out clearly from what we know about perceptual processes: The retinal image is only a first step in the perceptual processes."[15]

Very recently, Munn[16] defined any illusion centrally as a "false" perception.

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[13] Fred H. Ireland, "A Comparison of Critical Flicker Frequency under Conditions of Monocular and Binocular Stimulation," J. Exp. Psychol., XXXX (1950), 284.

[14] ibid., 286.

[15] L. Postman and J. P. Egan, Experimental Psychology (New York, 1949, p.170.

[16] N. L. Munn, Psychology: The Fundamentals of Human Adjustment (Boston, 1956), p.322.

The underlying aim of this study will then be to test the above stated assertion by the use of the obtained coefficient of correlation.

Besides the above stated aims, it is the author's intention to formulate a satiation theory explaining the critical flicker frequency in terms of its obtained relationship with the Müller-Lyer illusion.

Empirically stated the hypothesis of this study is as follows: There does exist at least a moderate correlation (.40 and upwards)[17] between the critical flicker frequency and the Müller-Lyer illusion.

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17 J.P. Guilford, Fundamental Statistics in Psychology and Education (New York, 1956), p. 145.

CHAPTER II

REVIEW OF THE LITERATURE

Experimentally the study of flicker fusion began with the paper entitled "Experiments on Light," which was read by its author, Henry Fox Talbot, M.P., F.R.S., before the Royal Society of London on June 9, 1834.[18] In this paper he formulated what is now known as Talbot's law, a principle later confirmed by Plateau in 1935.[19] It states the now well-established[20] principle that "at a high rate of repetition, flashes lose their identity and the sensation is that of a uniform illumination of a level equivalent to that produced if the total amount of light were equally distributed in time."[21]

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18 C. Landis, "Something About Flicker Fusion," Scientific Monthly, LXXIII (November 1951), 309.

19 ibid.

20 R.S. Woodworth and H. Schlosberg, Experimental Psychology (New York, 1945), p. 382.

21 S.H. Bartley, Vision, A Study of Its Basis, (New York, 1941), p. 118.

The next important scientific advance in the area of flicker fusion was the formulation of the Ferry-Porter law[22] which states that "the critical flicker frequency is directly proportional to the logarithm of the light intensity."[23] In 1892 Ferry stated this law in the following manner: "Retinal persistence varies inversely as the logarithm of the luminosity,"[24] while Porter phrased the same principle as follows: "The speed with which the discs must be driven in order that flicker may just vanish varies directly with the logarithm of the illumination of the discs."[25] Thus, the higher the intensity of light, the higher the critical flicker frequency. This relationship is valid, however, only under certain special conditions. It holds over moderate ranges of illumination of the test object when the image is restricted

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[22] Landis, p. 309.

[23] C.H. Best and N.B. Taylor, The Physiological Basis of Medical Practice (Baltimore, 1950), p. 1106.

[24] Ervin S. Ferry, "Persistence of Vision," American Journal of Science, XLIV (1892), 207.

[25] T.C. Porter, "Contributions to the Study of Flicker," Proceedings of the Royal Society, LXX (July 29, 1902), 318.

to the fovea. The relationship between the logarithm of the intensity and the critical flicker frequency does not hold above and below this middle range.[26]

As we have already seen the critical flicker frequency value depends upon the intensity of light. Besides this one extremely important factor, there exist a number of physical, physiological, and psychological factors which influence the critical flicker frequency.

Thus, the relative duration of the light and dark phases of the cycle also affects the critical flicker frequency. The longer the light phase, the higher the intensity required for a given critical flicker frequency, but the longer the dark phase, the more complete the recovery and the more nearly zero is the dark phase.[27]

Granit and Harper[28] have brought out the fact that the size of the test patch is another factor influencing the critical flicker frequency. The critical flicker frequency is said to increase with the area of the flickering field.

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[26] Best and Taylor, p. 1106.

[27] P.W. Cobb, "The Dependence of Flicker on the Light-Dark Ratio of the Stimulus Cycle," J. of the Optical Society of Amer., XXIV (1934), 107-113.

[28] R. Granit and P. Harper, "Comparative Studies on the Peripheral and Central Retina: II. Synoptic Reactions in the Eye," Am. J. Physiol., XCV (1930), 211- 228.

It is recognized that the critical flicker frequency resulting from the rods is highest with dark surrounds, and in like manner the fusion frequency due to the cones is increased by bright surrounds, the maximum being reached when the brightness of the surrounds and of the test object are equal.[29]

The critical flicker frequency is usually said to be higher in the periphery than in the fovea. Although it is highest in the fovea, the apparent discrepancy is due to the greater spatial summation in the periphery.[30]

Miller[31] in 1942 utilized forty-four boys and thirty-four girls between the ages of six and eighteen years in an experiment on flicker fusion. He found an increase in the critical flicker frequency for both sexes over a period of five test sessions. Besides, there was found a reduction of the variability in the determinations of flicker fusion. He claimed his finding to be indicative of the presence of a definite practice effect.

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29 Best and Taylor, p. 1107.

30 Woodworth and Schlosberg, p. 381.

31 V. L. Miller, "The Critical Frequency Limen for Visual Flicker in Children Between the Ages of Six and Eighteen," Genetic Psychology Monographs, XXVI (August 1942), 3-53.

His finding, however, has not been corroborated. In fact, Lythgoe and Tansley in 1929, O'Brien in 1939, Simonson and Enzer in 1941, Brozek and Keys in 1944, Tyler in 1947, Misiak in 1948, Miles in 1950, and Fabricant and Murrows in 1951 failed to find any evidence in support of a practice effect.[32] Misiak[33] regards the critical flicker frequency as an "inherent and stable characteristic of the individual."

Since 1945 there has flourished an ever growing interest in the application of the flicker method to abnormal or pathological problems.[34] Studies on the critical flicker frequency in its relation to fatigue, anoxia, anxiety, hypothyroidism, cerebral lesions, and age have been manifold.

Simonson and Enzer,[35] observing laboratory technicians and office workers, reported a depression of ten to fifteen per cent in the critical flicker frequency during the working day. A

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[32] Robert F. Medina, "The Long Term Effects of Prefrontal Lobotomy on the Flicker Fusion Frequency of Light," Loyola University Thesis, (June 1953), 12-13.

[33] H. Misiak, "Practice on Critical Flicker Frequency Measures," J. Gen. Psychol., XXXVIII (1948), 255.

[34] Landis, p. 309.

[35] E. Simonson and N. Enzer, "Measurement of Fusion Frequency of Flicker as a Test for Fatigue of the Central Nervous System—Observations on Laboratory Technicians and Office Workers," J. Indust. Hyg. and Tox., XXIII (1941), 83-89.

better controlled study by Brozek, Simonson, and Keys,[36] consisting in strenuous visual identification of very small moving letters, revealed a significant drop in the flicker fusion level after only four hours of such visual work under five foot-candle illumination. Jones[37] found a decrement in the fusion level after hours of truck driving. Brozek and Keys[38] similarly encountered a decrease in the critical flicker frequency level when the subjects performed hard labor under high temperature or with inadequate food intake. Miles[39] and Tyler,[40] however, found no changes in the critical flicker frequency which could be related to fatigue. Consequently, the influence of fatigue upon the critical flicker frequency remains a moot question.

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[36] J. Brozek, E. Simonson, and A. Keys, "Changes in Performance and in Ocular Functions Resulting from Strenuous Visual Inspection," Am. J. Psychol., LVIII (1950), 51-66.

[37] R.R. Jones et al, "Fatigue and Hours of Service of Interstate Truck Drivers," U. S. Public Health Serv. Bull., No. 265 (Wash., D.C., 1941), 195-208.

[38] J. Brozek and A. Keys, "Flicker Fusion Frequency as a Test of Fatigue," J. Indust. Hyg. and Tox., XXVI (1944), 168-174.

[39] P.W. Miles, "Flicker Fusion Fields: II. Technique and Interpretation," American Journal Ophthalmology, XXXIII (1950), 1069-1077.

[40] D.B. Tyler, "The Fatigue of Prolonged Wakefulness," Federation Proceedings Amer. Soc. Exp. Bio., VI (1947), 218-224.

Gellhorn and Hailman[41] obtained a decrease in the fusion level in anoxia produced by inhaling an air mixture containing 8.6 per cent and 7.8 per cent of oxygen respectively. Mc Farland, Halperin, and Niven[42] have also demonstrated the effects of anoxia upon the critical flicker frequency.

In 1947 Krugman[43] found a lowered critical flicker frequency in combat air crew personnel suffering from anxiety. Goldstone[44] in 1955 found that groups which were designated as low anxiety groups had a higher flicker fusion threshold than those groups which were designated as high anxiety groups.

Enzer, Simonson, and Blankenstein[45] studied the relation of hypothyroidism to the critical flicker frequency. A group

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[41] E. Gellhorn and H. Hailman, "The Effect of Anoxia on Sense Organs,", Federation Proceedings Amer. Soc. Exp. Biol., II (1943), 122-126.

[42] R.A. Mc Farland, M.H. Halperin, and J.I. Niven, "Visual Thresholds as an Index of the Modification of the Effects of Anoxia by Glucose," Am. J. Physiol., CXLIV (1945), 378-388.

[43] H. E. Krugman, "Flicker Fusion Frequency as a Function of Anxiety Reaction; An Exploratory Study," Psychosom. Med. IX, (1947), 269-272.

[44] Goldstone, p. 202.

[45] N. Enzer, E. Simonson, and S.S. Blankenstein, "The State of Sensory Centers in Patients with Hypothyroidism," Annals of Internal Medicine, XV (1941), 649-665.

of forty-five normal subjects had an average critical flicker frequency of 45.0 c.p.s. Thirteen hypothyroid patients, however, had a mean critical flicker frequency value of 39.3 c.p.s.

A number of studies on the flicker fusion frequency in relation to brain lesions have been reported. Halstead,[46] for example, found that frontal lobe injury has had a depressive effect on the critical flicker frequency. Medina,[47] on the other hand, found that lobotomized subjects do not experience flicker fusion at a lower level than normals.

Marquis[48] demonstrated discriminatory ability after bilateral occipital lobectomy in the dog. This ability to discriminate between a dimly lighted alley and an unlighted alley argues for rod function after occipital lobectomy, and implies furthermore that cone vision is dependent upon the cerebral cortex. Moreover, Fulton[49] states that Malmo reported that "after removal of the occipital lobes [in the rhesus monkey], the visi-

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46 W. C. Halstead, Brain and Intelligence, (Chicago, 1947).

47 Medina, p. 89.

48 D. G. Marquis, "Effects of Removal of the Visual Cortex in Mammals with Observations on the Retention of Light Discrimination in Dogs," Res. Publ. Ass. nerv. ment. Dis., XIII (1934), 558-592.

49 J. F. Fulton, A Textbook of Physiology (Philadelphia, 1950), p. 480.

bility curve even at high illumination is that characteristic of rods." Consequently, cone vision is dependent upon the visual cortex in the animal, which fact, if true for man, supports an assertion which will be made later (Summary and Conclusions).

Age in relation to the critical flicker frequency has been amply studied. In 1941 Simonson, Enzer, and Blankenstein[50] noted that Cobb in 1934, Riddell in 1939, and Ferree and Rand in 1934 had surmised that a decrease in the critical flicker frequency occurs with an increase in age. Since then Hartmann, Simonson, Enzer, and Blankenstein, Miller, Brozek and Keys, and Misiak had performed studies on the relation between flicker fusion and age.

Hartmann[51] in 1934 used thirty children and thirty adults with normal visual acuity and normal color discrimination. The ages of these young children ranged from six to eleven years, and that of the adults from eighteen to twenty-five. A disc composed of two cardboards of 180 degrees each was rotated by a D.C. motor with regulated speed which could be read off at any given moment from an engineering tachometer coupled to the shaft.

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50 Simonson, Enzer, and Blankenstein, p. 252.

51 G.W. Hartmann, "Comparison of the Flicker Threshold in Children and Adults," Child Development, V (1934), 122-126.

of the motor. At first Hartmann found a higher frequency for children. But in a later series of experiments no differences were observed. This led him to conclude that the basic mechanisms involved in the critical flicker frequency mature comparatively early. He did find a higher critical flicker frequency, however, in male children and adults. The computed average deviations indicated less variability in adults than in children, and less in females than in males.

In 1941 Simonson, Enzer, and Blankenstein[52] utilized forty-seven normal subjects whose ages ranged from fourteen to eighty years and whose vision and ocular structures were normal in all respects. They divided their subjects into four age groups: (1) 10-19, (2) 20-29, (3) 30-39, and (4) over 40. Respectively the number of subjects in each category were as follows: 4, 18, 10, and 15. To determine the fusion frequency, they used a rotator arrangement where the beam of light from an electric bulb (25 watt) was interrupted by a rotating disc with four identical openings. The size of the test area was 100 sq. mm. which, at one meter, subtended a visual angle of one-half degree. Binocular

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[52] Simonson, Enzer, and Blankenstein, p. 252-255.

central vision was used. The speed of rotation was measured by a mechanical revolution counter with a stopwatch. The authors found that the difference of the mean values was not significant from the statistical point of view which might be attributed to the large standard deviation in the age group ranging from 10 to 29. But it was found that a definite decrease of fusion frequency with age was demonstrated by average and maximum values. Their findings, however, indicated that the standard deviation had diminished with age. The decrease of the critical flicker frequency with age was interpreted by the authors in terms of a "decrease of a fundamental sensory function of the central nervous system."

In 1942 Miller[53] used a beam of light interrupted by a rotating sector disc driven by an adjustable speed reducer. The subjects consisted of two groups, forty-four boys and thirty-four girls ranging in age from six to eighteen years. A telegraph key was utilized by the subjects to signal fusion. The experimenter found that the range of the critical flicker frequency extended from 31.6 to 73.0 cycles per second with no significant change of the critical flicker frequency with age. The boys

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[53] Miller, pp.3-53.

showed higher critical flicker frequency values than the girls, a finding in agreement with Hartmann's results. The variability of the readings decreased with successive sittings, but the mean critical flicker frequency increased from the first to the second sitting. This, the author interpreted, as practice effect.

Brozek and Keys[54] in 1945 utilized as their subjects fifty-six women doing clerical and microscopic work. The subjects ranged in age from 18 to 60. A flashlight bulb (Mazda No. 14, 2.5 volts) was used as a light source. The light was interrupted by a motor-driven rotating disc with two open sectors, and diffused by an opal glass 2.5 cm. in diameter. The subjects viewed the light stimulus from a distance of forty centimeters. The experimenters divided the subjects into four age groups. They are: (1) 18-25, (2) 26-35, (3) 36-45, and (4) 45-60 years with 19, 17, 8, and 12 subjects respectively. The average values of the flicker fusion frequency for these groups were 46.7, 45.74, 45.39, and 40.92 flickers per second with standard deviations of 4.18, 3.59, 2.89, and 3.27.

In 1947 Misiak[55] used an electronic apparatus which had a three watt neon lamp, giving an intermittent light at a rate

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[54] Brozek and Keys, pp. 87-90.

[55] Misiak, pp. 318-332.

determined by three adjustable resistors. The diameter of the circular test patch was five millimeters subtending a visual angle of forty-eight minutes. The brightness of the test patch was six foot-candles. All the subjects were free from visual abnormalities. They viewed the test patch from a distance of 13.8 inches. Two groups of subjects were used. One group ranging in age from 19 to 30 years and the other from 63 to 87 years. But both groups were equally distributed as to age. The author found a significant difference in the critical flicker frequency values between young and old age for both dominant and non-dominant eyes. But no sex differences were found which would be significant. This finding he confirmed in a later (1951) study.[56] In that study he found that the critical flicker frequency decreases with age (significantly after fifty-five years), and that the standard deviation of age groups tends to increase with age.

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[56] Misiak, pp. 551-552.

James said: "The study---of illusions has been the key to the right comprehension of perception."[57] The present study expects a better understanding of a perceptual phenomenon (the critical flicker frequency) through another perceptual phenomenon (the Müller-Lyer illusion). It too attempts a true comprehension of perception through the study of illusion.

Since the discovery of the Müller-Lyer figure in 1889 by Müller-Lyer, its reproductions in the psychological texts have been numerous over the last sixty-five years. Müller-Lyer himself contributed over a dozen variant forms of the original figure. However, the amount of the illusion itself in several of its forms was measured by Heymans in 1896.[58] He found that the average amount of the illusion is twenty-five per cent below optimum conditions, when the oblique segments are one-fourth as long as the horizontal segments and make only a small angle with the horizontal.[59]

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[57] W. James, The Varieties of Religious Experience , A Mentor Book (New York, April 1958), p. 35.

[58] E. G. Boring, Sensation and Perception in the History of Psychology (New York 1942), p. 243.

[59] Woodworth and Schlosberg, p. 420.

Boring[60] and Titchener[61] have each summarized some twelve theories purporting to explain the Müller-Lyer illusion. A brief review of certain theories will next be given.

Müller-Lyer himself attempted to explain the illusion in terms of the principle of "confluxion," a "flowing" of the main line in the direction of the wings.

Delboeuf thought that the wings attract the attention away from the main lines so as to create the illusion.

According to Lipps, the proponent of the empathy theory, the Müller-Lyer illusion is explained by the fact that perception is an act and that the acute-angled wings limit the activity, whereas the obtuse-angled wings free it.

For Brentano the illusion is explained by the principle that acute angles tend to be overestimated and obtuse angles underestimated.

Thiery propounded the perspective theory which holds that the illusion is due to the fact that the perception of even simple drawings is affected by a suggestion of three dimensions.

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60 Boring, pp. 243-245.

61 E. B. Titchener, Experimental Psychology. Qualitative (New York 1901), pp. 321-327.

Wundt, one of the proponents of the eye-movement theory, held that the extensive judgement involved in the perception of the illusion was mediated by eye-movement, while Heymans' theory postulated only tendencies towards eye-movement that the wings would create.

A number of studies have been carried on to test some of these theories. Judd, for example, used a camera to photograph eye-movements during the inspection of the illusions. He found that eye-movements did not correspond to the subject's judgement as Wundt's theory demands.[62] Consequently, the eye-movement theory has been discredited. But the other theories have likewise not withstood the rigour of time and experiment. Boring[63] believes that the problem of illusions has now been bequethed to Gestalt Psychology.

Heymans in 1896 and others had noticed that continued exposure to a certain figure diminished the amount of the illusion.[64] Since then Judd, Lewis, Seashore, Crosland et al, and

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62 Woodworth and Schlosberg, p. 420.

63 Boring, p. 245.

64 Woodworth and Schlosberg, p. 422.

Köhler and Fishbach have investigated this extremely interesting phenomenon.

Judd[65] [66] found that the Müller-Lyer illusion disappears with repetition. In 1902, he summarized his conclusions as follows:

> The most important fact is of course the final result. The illusion disappears after practice. It disappears not by any process of judgement or any process of indirect correction. The line comes to look differently than it did at first. A most striking exhibition of the change which has taken place can be seen by setting a line, after practice is complete, at length at which the records show that one set is early in the experiment. It seems so strikingly and so clearly too short to the now trained eye that it is almost unbelievable that the illusion could ever have been so strong. We have here, then, a change in the perceptual process, which has taken place gradually through repeated efforts to deal directly with the object perceived.[67]

Thus, Judd claims that the illusion disappears with practice. Lewis,[68] contends, however, that the illusion disappears only when the figures are exposed for prolonged periods.

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[65] C. H. Judd, "The Müller-Lyer Illusion," Psychol. Rev., Mon. Suppl., VII (1905), 55-81.

[66] C. H. Judd, "Practice and Its Effects on the Perception of Illusions," Psychol. Rev., IX (1902), 27-39.

[67] ibid., pp. 29-31.

[68] E. O. Lewis, "Confluxion and Contrast Effects in the Müller-Lyer Illusion," British Journal of Psychology, III (1909), 21-41.

Momentary exposure of the illusion does not result in its disappearance, according to Lewis.

Seashore et al[69] present evidence that the influence of practice depends upon a number of factors, such as attitudes and knowledge of results. They summarize their findings in the following manner: "--- When the observer proceeds to the experiment with full knowledge of the conditions and does not expect the illusion to disappear, it does pass away, and without leaving any introspective evidence of the change; when the observer proceeds to the experiment without any knowledge of illusion, and is led to suspect any illusion, the force of the illusion remains unchanged throughout long continued practice; and when the observer suspects the illusion but has no definite knowledge of its cause, it tends to disappear in the case of specific knowledge of it."[70]

Crosland et al[71] found that practice results in an initial increase in the Müller-Lyer illusion followed by a gradual decrease in the illusory effect.

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69 Seashore et al, "The Effect of Practice on Normal Illusions," Psychol. Rev., Mon. Suppl., IX (1908), 103-148.

70 ibid., p. 138.

71 H. R. Crosland, H. R. Taylor, and S.J. Newsom, "Practice and Improvability in the Müller-Lyer Illusion in Relation to Intelligence," J. Gen. Psychol., II (1929), 290-304.

Köhler and Fishback,[72] however, contend that they have experimental evidence which suggests that repeated measurements destroy the Müller-Lyer illusion by satiation rather than by learning. The facts which they marshalled in favor of this thesis are as follows: (1) The destruction of the illusion can be brought about by not informing the subjects that they are dealing with an illusion pattern, and also when they are kept in ignorance as to the comparison of their results with objective facts, (2) when measurements are largely replaced by satiation periods, the illusion can be destroyed, (3) negative illusions of considerable size may be established, provided that the destruction of the illusion experiments are continued, (4) there exists some evidence that the illusion cannot be completely destroyed with all subjects, (5) "when after destruction of the illusion a 'normal' test pattern is presented in the area of the illusion figure, this pattern exhibits the after effect which is to be expected if the illusion is destroyed by satiation."[73]

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72 W. Köhler and J. Fishback, "The Destruction of the Müller-Lyer Illusion in Repeated Trials: An Examination of Two Theories," J. Exp. Psychol., XXXX (1950), 267-281.

73 ibid., p. 280.

(6) the illusion is still present in other positions, when the illusion has been destroyed in one position, (7) "The fact that the illusion can be more rapidly destroyed in new positions has been derived from the theory of satiation,"[74] (8) "The observation that the illusion cannot be destroyed in tachistoscopic experiments, and that after its destruction under ordinary conditions it hardly appears affected in tachistoscopic tests, follows from the theory of figural after-effects,"[75] and (9) generally, "experiments in which given situations are presented many times in succession can be made only with considerable caution, because under such conditions satiation may affect the situations under investigation."[76]

Herr[77] found that the illusion obtained in a natural setting can be reduced by one-third when the subjects are told to "Try to eliminate the working of the wings." He also found

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74 ibid., pp. 280-281.

75 ibid., p. 281.

76 ibid., p. 281.

77 V. V. Herr, "Die isolierende Einstellung bei Kontrast-Erscheinungen," A Dissertation (Bonn 1939), p. 41.

striking individual differences in the reduction of the illusory effect. In fact, some subjects showed a greater amount of the illusion when they were instructed to take an isolating attitude, whereas others displayed significantly diminished values of the illusion.[78]

The importance of attitudes in the studies of illusion has been brought out by Benussi in 1904. Benussi found that when the subject was instructed to observe with a whole-perceiving attitude the illusion was greater than when the subject was instructed to observe with a part-isolating attitude.[79]

Walters[80] stated that experimental studies of age and susceptibility to illusions have given us contradictory and ambiguous results. Binet, Van Biervliet, Rivers, and Pintner and Anderson report a decrease in the Müller-Lyer illusion with age. Cramaussel, however, found the illusion to increase with age.

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[78] ibid., pp. 44-49.

[79] Woodworth and Schlosberg, p. 421.

[80] A. Walters, "A Genetic Study of Geometrical-Optical Illusions," Gen. Psychol. Monographs, XXV (1942), 142.

In 1933 Hartmann and Triche[81] performed an extensive study on illusions. He used a group of 249 subjects. It consisted of elementary school children and junior college students. The figure was presented for a period of ten seconds. The older group showed a significantly greater illusory effect than did the younger group, a finding, which when seen in relation to the decrease of the critical flicker frequency with age, would suggest a negative relationship between the Müller-Lyer illusion and the critical flicker frequency. This suggestion of a negative relationship has been verified as will be seen in the section entitled "Results of the Experiment."

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[81] Hartmann and Triche, pp. 493-498.

CHAPTER III

EXPERIMENTAL PROCEDURE

The foveae of the subjects were stimulated intermittently by a series of light flashes produced by the reflecting light from a rotating disc. The disc was divided into alternate black and white sectors and reduced in size by a white reduction screen to a square whose sides equaled one inch each. The intensity of illumination of the small test patch as measured by a General Electric lightmeter was sixteen foot-candles. The test area subtended a visual angle of one degree at 86.5 inches away from the subjects' retinae. Consequently, binocular foveal vision was insured under non-dark adapted conditions. The speed of the rotating disc could be altered minutely and measured by a mechanical revolution counter with a stop watch.

Fifty healthy college girls ranging in age from eighteen to twenty-five were subjects for this experiment. The justification for the selected age range is to be sought in the studies of Brozek and Keys (1945), and Misiak (1947), having been mentioned previously in the "Review of the Literature." All the subjects included in the experiment were tested for visual acuity and color-blindness. Any visual abnormality which

would invalidate the results was considered valid ground for the exclusion of that subject's results from the final data sheet.

After moments of relaxation the experimenter clearly demonstrated to the subjects the difference between flicker and fusion. They were instructed to make their judgments of either flicker or fusion as quickly as is possible as soon as they heard the word "now." After each trial the subject had time to relax his eyes, but was told not to close them..A series of five measures, both from flicker-to-fusion and fusion-to-flicker, were administered. The average of these measures was designated as the critical flicker fusional rate for a particular subject.

The Müller-Lyer figures (one of them always having its position reversed with respect to the other one) were drawn in white ink on a perfectly black cardboard. The variable pattern of the Müller-Lyer figure was sketched on a cardboard strip which was placed against the back of a second cardboard, upon which the standard pattern was drawn. The cardboard strip was fastened to the back part of the second cardboard in such a way that the main lines of the illusion always met regardless of how much the cardboard strip was moved inwards or outwards. In the back of the variable pattern was placed a millimeter scale which enabled the experimenter to read off the amount of error.

Essentially the proportions of both figures were taken over from Köhler and Fishback. Thus, the standard main line

equalled seven centimeters, and the line forming the angles equalled 2.7 centimeters. The size of the angles was equal to sixty degrees in each case. All the lines were one millimeter wide.

The same subjects, as were used in the other part of the experiment, served for this part of the experiment also. Under light adapted conditions, being seated nine feet away from the illusion pattern, the subjects were instructed to fixate a small white dot painted one centimeter underneath the center of each figure, and to compare the two main lines as to equality. The judgments of equality or non-equality were to be made within two or three seconds, otherwise the judgments were discounted. The method of average error was used. The mean constant error was computed for each subject from the results of the four trials. The mean then served as the index of the illusory effect for a particular individual.

In order, then, to relate the two phenomena the writer computed the Pearson's product-moment coefficient of correlation and the Spearman's rho from the final averages obtained in each case separately.

CHAPTER IV

RESULTS OF THE EXPERIMENT

The computed averages of the critical flicker frequency and the Müller-Lyer illusion for each individual subject are given in the appendix. Using the regular correlation chart and the given averages, the writer found a -.31 relationship. This represents a definite relationship even though it is small. A -.32 relationship was obtained when the Spearman's rho was computed from the same data.

The hypothesis as stated in the first chapter is denied on the basis of the computed relationship.

No conclusive statement can be made as regards the relationship between the critical flicker frequency and age, because of an unequal distribution of cases in the different age groups. Furthermore, no such statement seems warranted, because the age groups do not cover a considerable range as is usually needed for studies dealing with this problem specifically. The author, however, invites and encourages the reader to examine the scores given in the appendix, and possibly speculate as to their worth to future theorization. This problem, though interesting, is not the heart of the matter of this study.

It should be noted that the method involved in the determination of the amount of the illusory effect limited the range of scores to only 1.85 centimeters. The fixation of the white dot, which accounted for this limited range, certainly was not the ideal condition for the central factors to be operative. A whole attitude on the part of the subjects probably would have yielded more meaningful results, since the critical flicker frequency part of the experiment had been geared towards the involvement of some central mechanism in the brain.

On the basis of the obtained -.31 relationship, it can be reported that the true relationship is not zero. The standard error of the obtained Pearson's product-moment coefficient of correlation is .129. Thus, it can be said that two thirds of sample r's are expected to lie between -.18 and -.44.

CHAPTER V

SUMMARY AND CONCLUSIONS

Since both the critical flicker frequency and the Müller-Lyer illusion are said to be central phenomena, and since there does exist some inverse relationship between the two phenomena as attested in their relationship with the age factor, it seemed plausible to the author that there might exist a moderate negative relationship (-.40 and up) between the two factors in question.

In order to test this hypothesis, fifty college girls who were free from visual defects were utilized in the experiment. Reflected light from a rotating disc served as the stimulus in the determination of flicker fusion. Five flicker-to-fusion and five fusion-to-flicker trials were administered under standard and controlled conditions. The average of ten trials was used as the index of the critical flicker frequency for a particular individual.

The method of average error was used to determine the amount of the illusory effect for each individual. Four ascending-and-descending trials were given in mixed order. The

average of these trials represented the index of the amount of the illusory effect for a particular individual.

The computed Pearson's product-moment coefficient of correlation was -.31, and the Spearman's rho computed from the same data amounted to a negative relationship of .32. The obtained -.31 relationship does not confirm the hypothesis as stated, but did suggest that the method employed in the illusion experiment had worked against or even prevented a possibly higher relationship.

The attempt to verify statistically that the critical flicker frequency and the Müller-Lyer illusion are centrally organized has ended in partial failure, since the obtained relationship (-.31) is too small. The results, however, suggest a tendency towards one of the four possible alternate propositions in connection with this problem. The four alternatives are: (1) the critical flicker frequency is peripherally organized, whereas the Müller-Lyer illusion is centrally patterned, (2) the critical flicker frequency is centrally organized, while the Müller-Lyer illusion is peripherally patterned, (3) both the critical flicker frequency and the Müller-Lyer illusion are peripherally organized, and (4) both the critical flicker frequency and the Müller-Lyer illusion are centrally patterned.

Alternatives three and four are in greater agreement with the obtained results than are possibilities one and two. It follows, then, that either possibility three or four is the most probable alternative in which to place trust. Since, as we have seen previously, foveal vision implies some cerebral action in the animal, it would seem reasonable to assume that the fourth alternative is the best alternative because the critical flicker frequency was obtained under foveal vision. Consequently, this study suggests that both phenomena are centrally patterned, but that different pathways might be involved.

Köhler and Wallach[82] used the term satiation to mean an alteration in the brain medium brought about by the prolonged presence of a given figure in a particular cortical area. Köhler and Fishback found that illusion is lessened by long fixation periods, a finding which is a corroboration of the Köhler-Wallach theory of satiation. The relationship obtained in this study will now be used to explain the two phenomena in terms of the satiation theory. Thus, continual flicker in one spot creates a highly satiated area in the cortex which impedes the perception of the flickered light as continuous,

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[82] W. Köhler and H. Wallach, "Figural After-Effects: An Investigation of Visual Processes," Proc. Amer. Phil. Soc., LXXXVIII (1944), 269-357.

thereby resulting in a high CFF threshold,[83] while in the case of the Müller-Lyer illusion a highly satiated cortical region builds up the resistance in the neighboring tissue and impedes the spread from the affected cortical region.

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[83] H. H. Spitz, "The Present Status of the Köhler-Wallach Theory of Satiation," Psychol. Bulletin, LV (January 1958), 1-28.

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APPENDIX

THE COMPUTED AVERAGES OF THE CRITICAL FLICKER FREQUENCY AND THE MÜLLER-LYER ILLUSION FOR EACH INDIVIDUAL SUBJECT

Subject	Age	Fusion Mean in Cycles per sec.	Illusory Effect in centimeters.
1. T. F.	18	42.72	2.20
2. M. K.	18	47.00	2.40
3. B. M.	18	44.58	1.93
4. D. Z.	19	45.69	1.75
5. B. D.	19	46.62	1.53
6. V. Z.	19	43.59	1.63
7. S. O.	19	46.71	1.73
8. B. F.	19	48.60	1.83
9. M. K.	19	45.83	1.90
10. P. L.	19	48.68	2.05
11. B. K.	19	41.70	2.10
12. A. M.	19	45.50	2.00
13. M. C.	19	43.26	2.90
14. M. L.	19	47.59	2.65
15. M. D.	19	39.79	2.50
16. K. M.	19	43.56	2.50

APPENDIX (continued)

Subject	Age	Fusion Mean in Cycles Per Sec.	Illusory Effect in Centimeters.
17. C. M.	19	40.91	2.30
18. E. M.	19	51.58	2.38
19. M. B.	19	44.45	2.48
20. P. P. N.	19	47.40	1.10
21. S. S.	19	44.08	2.10
22. K. D.	19	47.11	1.68
23. B. P.	20	42.85	1.43
24. P.A.	20	45.84	2.53
25. M. G. R.	20	47.94	2.15
26. D. L.	20	44.34	2.05
27. B. M.	20	44.80	1.90
28. M. C.	20	47.12	1.90
29. S. B.	20	42.83	1.93
30. N. S.	20	44.40	1.65
31. T. M.	20	45.87	1.43
32. M. B.	20	42.34	2.30
33. S. S. M.	20	45.23	1.90
34. M. J. G.	20	48.25	1.63
35. M. C.	21	50.56	2.05
36. M. R.	21	47.12	1.78
37. C. A.	21	47.84	2.15

APPENDIX (continued)

Subject	Age	Fusion Mean in Cycles Per Sec.	Illusory Effect in Centimeters.
38. R. K.	21	41.68	2.95
39. M. J. M.	21	44.01	2.40
40. M. J.	21	45.10	2.40
41. J. I.	21	45.57	2.35
42. A. L.	21.	49.76	1.98
43. G. C.	22	48.51	1.85
44. J. S.	22	41.11	2.03
45. B. C.	22	45.31	1.40
46. P. M.	23	50.01	1.85
47. M. A. W.	23	43.84	2.33
48. G. G.	24	47.75	1.68
49. J. K.	25	42.56	2.30
50. S. O.	25	48.37	1.78

APPENDIX (continued)

MAXIMUM, MEAN, AND MINIMUM FUSION VALUES FOR DIVERSE AGE LEVELS OF FIFTY SUBJECTS

Age Level	N	Maximum Frequency (Cycles/Sec)	Mean Frequency (Cycles/Sec)	Minimum Frequency (Cycles/Sec)
18	3	47.00	44.77	42.72
19	19	51.58	45.40	39.79
20	12	48.25	45.15	42.34
21	8	50.56	46.45	41.68
22	3	48.51	44.98	41.11
23	2	50.01	46.92	43.84
24	1	47.75	47.75	47.75
25	2	48.37	45.47	42.56

APPROVAL SHEET

The thesis submitted by Paul Martin has been read and approved by three members of the Department of Psychology.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

Nov. 24, 1958
Date

Edmund P. Marx
Signature of Adviser