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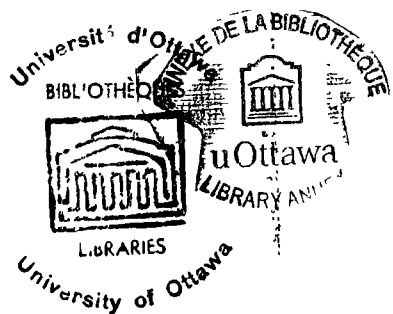
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AN INVESTIGATION OF POSSIBLE RELATIONSHIPS BETWEEN
CRITICAL FLICKER FREQUENCY AND
DIVERGENT THINKING

by Gayle Wm. Dunsday

Thesis presented to the Faculty of
Psychology and Education of the
University of Ottawa as partial
fulfillment of the requirements
for the degree of Master of Arts



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CURRICULUM STUDIORUM

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INTRODUCTION

The investigation of possible relationships between psychophysiological phenomena and intellectual functioning has deep roots in the history of psychology. Based on the early philosophical theorizing of the body-mind problem, psychology has long been interested in the bodily correlates of mental processes. The ultimate aim of such research is to discover the neurophysiological foundations of human behaviour viewing man not as body versus mind but as a whole.

Relationships between neurophysiological and cognitive activity have been sought through study of a variety of variables and numerous theories, largely without success. The inconclusive and frequently discouraging results indicated the need for continued research, but demanded that innovations be introduced in terms of research variables, both psychophysiological and psychometric.

From this background the present study evolved. The literature pointed to the feasibility of relating two variables which previously had not been studied together. Critical Flicker Frequency,¹ selected as the psychophysiological measure, was an "old" phenomenon which had encouraging

¹ Critical Flicker Frequency, or CFE: generally defined as that point where a flashing light is perceived as flicker 50 per cent of the time and as steady or fused 50 per cent of the time; the threshold of Flicker-Fusion.

implications through recent factor analytic studies. Tests of divergent thinking were relatively "new" but offered distinct possibilities as a measure of intellectual functioning.

Studies concerning these two measures and the justification for their use are presented in the Review of the Literature preceded by a critical examination of past attempts to relate psychophysiological phenomena and intellectual functioning. Chapter one concludes with a summary and a statement of the experimental hypothesis.

The second chapter describes the CFF instrumentation and the divergent thinking tests.

Chapter three is devoted to the design of this experiment. Topics include the sample population, experimental procedure, and the statistical analysis of the obtained data.

The first four sections of the last chapter present the statistical findings. Section five discusses these results from both practical and theoretical viewpoints. Suggestions for further research are outlined in the Summary and Conclusions.

CHAPTER I

REVIEW OF THE LITERATURE

The strong interest in the problem of relationships between psychophysiological phenomena and intellectual functioning is demonstrated by the abundant studies reported in the literature. Knowledge of these relationships remains minimal, however, due to the many inconclusive results obtained. The present study is an attempt to add to that knowledge by investigating one aspect of the problem, namely, the relationship between CFF and divergent thinking, the psychophysiological phenomenon and intellectual function, respectively.

This chapter reports and evaluates the main sources of information on the topic. Section one reviews past attempts at relating psychophysiological measures to mental abilities. The second section discusses the phenomenon of CFF in terms of the rationale for its use, the general aspects of the phenomenon, and the relation between CFF and psychometric intelligence. Section three explains the rationale for employing tests of divergent thinking. The chapter concludes with a summary of the present state of the problem and a formulation of the hypothesis to be tested.

1. Psychophysiological Phenomena and Intellectual Functioning.

In 1929, Lashley wrote:

The whole theory of learning and intelligence is in confusion. We know at present nothing of the organic basis of these functions and little enough of either the variety or uniformities of their expression in behaviour. The concepts are so poorly defined that it has not been possible even to imagine a program of physiological research which seemed likely to reveal more than superficial relationships.¹

Almost forty years have passed since Lashley's remarks. Theories of learning and intelligence and the organic basis of these functions have been advanced and certain facts are known. Yet, confusion still exists.

Some of the early studies exemplifying Lashley's remarks were attempts to relate simple and discriminative reaction time to intelligence. Investigators advanced the hypothesis that speed of conduction in nerves and synapses may partly determine the level or quality of intelligence and degree of learning ability possessed by a given individual. In general, the results show that intelligence, memory, and learning all have factors in common with reaction speed. Discriminative reaction time correlates more highly with

¹ K.S. Lashley, "Brain Mechanisms and Intelligence", Chicago, University of Chicago Press, 1929, in R.M. Reitan, "Investigation of the Validity of Halstead's Measures of Biological Intelligence", in Archives of Neurology and Psychiatry, Vol. 73, No. 28, 1955, p. 28.

tests of intelligence than does simple reaction time.^{2,3}

From these findings, psychology has accepted the fact that "speed" is a factor in intellectual functioning. But, reaction time did not account for other facets such as "power".

The reaction time and intelligence studies prompted investigators to approach the problem of the relationship between psychophysiological and cognitive processes from the point of view of motor proficiency and mental abilities. Hertzberg⁴ tested forty-six kindergarten children correlating the results of eighteen tests of motor abilities with mental age. He concluded that "motor development alone does not correlate in any practically significant degree with mental age when the subjects are children of the kindergarten stage."⁵ Kiefer⁶ studied an older age group, eight to twelve years,

2 V.W. Lemmon, "The Relation of Reaction Time to Measures of Intelligence, Memory, and Learning", in Archives of Psychology, No. 94, 1928, p. 38.

3 P.R. Farnsworth, R.H. Seashore and M.A. Tinker, "Speed in Simple and Serial Reaction as Related to Performance in Certain 'Intelligence' Tests", in Journal of Genetic Psychology, Vol. 34, 1927, p. 537-551.

4 Oscar E. Hertzberg, "The Relationship of Motor Ability to the Intelligence of Kindergarten Children", in Journal of Educational Psychology, Vol. 20, No. 7, October 1929, p. 507-519.

5 Hertzberg, Op. Cit., p. 519.

6 Freida A. Kiefer, "Manual Motor Correlation in Superior Children", in Journal of Applied Psychology, Vol. 13, No. 4, August 1929, p. 357-371.

with a sample of 182 children and found that "the difference in performance on manual motor tests of superior and average children are negligible".⁷ Kiefer's average children, however, were not tested for intelligence as was her high I.Q. group. Neither Hertzberg nor Kiefer controlled for sex differences which could have affected their results.

In more sophisticated studies,^{8,9} testing children of retarded and normal intelligence, it has been found that relationships between motor proficiency and intelligence can be predicted for mentally retarded but not for normal children. Sloan concluded that "motor proficiency is not a distinct aspect of functioning which can be isolated from general behaviour, but is, rather, another aspect of the total functioning of the organism".¹⁰

Studies of reaction time and motor proficiency could only reveal superficial relationships, in Lashley's terms,

7 Ibid., p. 371.

8 William Sloan, "Motor Proficiency and Intelligence", in American Journal of Mental Deficiency, Vol. 55, No. 3, January 1951, p. 394-406.

9 Leslie F. Malpass, "Motor Proficiency in Institutionalized and Non-Institutionalized Retarded Children and Normal Children", in American Journal of Mental Deficiency, Vol. 64, No. 6, May 1960, p. 1012-1015.

10 Sloan, Op. Cit., p. 406.

REVIEW OF THE LITERATURE

because they are concerned with peripheral rather than central functions of the organism. In an attempt to provide a comprehensive and centrally-based theory of psychophysiological functioning underlying behaviour, Lashley invoked the concept of "cerebral efficiency".¹¹ This was followed by a number of concepts and theories, which developed, to a large extent, from objective measurements of the perceptual processes. These hypothetical constructs which attempt to account for individual differences in intelligence, learning and personality, include: satiation, metabolic efficiency, neurological efficiency, weak and strong nervous systems, reactive inhibition, cortical conductivity, and cortical inhibition. The reader is referred to Honigfield¹² for a complete review of these concepts and the studies relevant to each.

In his review, Honigfield discusses the numerous significant results obtained in these studies and the important findings in the research relating perceptual processes to intelligence, learning, and personality. Yet, despite some of the encouraging results, Honigfield emphasizes the fact

11 K.S. Lashley, "Brain Mechanisms and Intelligence", Chicago, University of Chicago Press, 1929, as quoted by Gilbert Honigfield, "Neurological Efficiency, Perception, and Personality", in Perceptual and Motor Skills, Vol. 15, No. 2, October 1962, p. 532.

12 Honigfield, Op. Cit., p. 531-553.

that no coherent, inclusive theory had developed. Indeed, the confusion to which Lashley referred many years earlier was still prominent.

In an attempt to clarify the issues, Honigfield conducted a factorial study of "neurological efficiency". Choosing the most valid tests as indicated by the literature he attempted to:

(a) find evidence supporting a relationship between several perceptual, personality, and intellectual ability measures by recourse to factors common to all, and (b) find evidence supporting the notion that such a relationship is best explained by reference to higher rather than lower neurological loci.¹³

The perceptual measures included a number of indices of CFE, the Spiral After Effect, autokinetic movement, apparent movement, and visual acuity. The nine scales of the Guilford-Zimmerman Temperament Survey provided the personality measures. The following intellectual ability measures were administered: Scholastic Aptitude Test of the College Entrance Examination Board, the College Qualification Test, and the Analogies Test of the Concept Mastery Test. The sample consisted of eighty-one female and twenty-four male college volunteers. Intercorrelations were computed and this data was subjected to factor analysis.

¹³ Ibid., p. 547.

From the ten factors extracted, not one could be considered a common factor of neurological efficiency. However, Honigfield interpreted Factor V "as a very limited 'neurological efficiency' factor, with apparent movement, CFP, and Guilford Scales 'O' and 'F' having sizeable factor loadings".¹⁴

In his summary, Honigfield states:

The most important over-all conclusion from this investigation seems to be that to ascribe individual differences in perception, personality and intelligence to a common construct of central 'neurological efficiency' is to over-simplify a complex set of observations. [...] It is probably not an oversimplification to assert that in their enthusiasm to obey the Law of Parsimony, psychologists are often guilty of oversimplification.¹⁵

Honigfield's criticism should be viewed in a positive manner. Psychology, as a science, must continue to try to obey the Law of Parsimony, but at the same time, psychologists must exercise caution in making generalizations particularly in the field of psychoneurology. In this way, concrete facts may still be gathered but oversimplification, and reductionism, avoided.

One area of research, not covered by Honigfield's review, which has drawn much attention is electroencephalography,

¹⁴ Ibid., p. 549.

¹⁵ Ibid.

hereafter referred to as EEG. With its development, the possibility of relating neurophysiological and intellectual activity gained impetus as the EEG was the most direct method found for the analysis of brain functioning.

Reviewing the research dealing with the relationship between EEG and test intelligence, Vogel and Broverman¹⁶ state that correlations are highest in subjects who have either relatively undeveloped intellectual function (i.e., children, feeble-minded subjects) or deteriorated intellectual function (brain-damaged and institutionalized geriatric subjects). Weak and inconclusive results were found for samples of normal adults. The main drawbacks, according to Vogel and Broverman, were methodological problems concerning the measurement of intelligence and conditions of EEG recording and the indices used. Nevertheless, they conclude:

In any case, there is considerable evidence that electrocortical activity and mental activity are positively correlated. The hypothesis deserves further scrutiny that the EEG may be related to a physiological process underlying human intelligence.¹⁷

¹⁶ William Vogel and Donald M. Broverman, "Relationship Between EEG and Test Intelligence: A Critical Review", in Psychological Bulletin, Vol. 62, No. 2, 1964, p. 132-144.

¹⁷ Ibid., p. 142.

Ertl,¹⁸ noting the failures in past attempts employing the usual EEG indices such as alpha rhythm¹⁹ and alpha index,²⁰ investigated the phenomenon of intracortical delay in relation to intelligence as measured by the Wechsler Bellevue Scale of Intelligence. With a sample of eleven males he obtained a Pearson r of .88. The inadequate sample size and a number of uncontrollable factors, however, prevented generalization of the intracortical delay phenomenon.²¹

Wyspianski's²² approach to the problem of the relation between electrophysiological activity and the functioning of the intellect differed from that of other experimenters. He measured EEG brain wave amplitude by weighing the acetate film tracings taken from one second samples of delineated EEG wave forms and in place of I.Q. tests he used Guilford's

18 John P. Ertl, "Intra-Cortical Delay and Intelligence", unpublished Master's thesis presented to the School of Psychology and Education of the University of Ottawa, Ontario, 1961, viii-41 p.

19 Alpha Rhythm: measured by the EEG to determine the excitability of the cortex and the ease with which it accepts trains of impulses from below.

20 Alpha Index: defined as the percentage of time during which the regular alpha pattern persists in a given record.

21 Ertl, Op. Cit., p. 28-30.

22 John O. Wyspianski, "EEG Brain Waves and Creative Thinking", published doctoral dissertation, presented to the School of Psychology and Education of the University of Ottawa, Ontario, 1963, viii-103 p.

tests of creative divergent thinking.²³ Wyspianski classified a sample of thirty university students into three categories of low, middle, and high creative ability and obtained measures of EEG brain wave amplitude for each subject. The EEG was recorded from seven cortical regions and under conditions of rest and photic stimulation.

Wyspianski found significant differences in brain wave amplitude between these three groups. The subjects in the high creativity group obtained the lowest mean amplitude and showed less change in amplitude when photically stimulated. Working within the theoretical framework of Eccles²⁴ who posited that creativity in the human individual is a function of the probabilistic spread of field fronts within the human cortex, Wyspianski concluded that

[...] the smaller the amplitude the higher the frequency; consequently the greater the brain activity. Finally, the greater the initial, or resting brain activity, the lesser the change will be upon stimulation. To put it less formally, the more alert the brain the less effort will it require upon stimulation to respond adequately.²⁵

²³ J.P. Guilford and P.R. Merrifield, "The Structure of Intellect Model: Its Uses and Implications", Report from the Psychological Laboratory, University of Southern California, No. 24, April 1960, p. 1-27.

²⁴ J.C. Eccles, "The Physiology of Imagination", in Scientific American, Vol. 199, No. 3, September 1958, p. 135-146, as quoted by Wyspianski, Op. Cit., p. 1-2.

²⁵ Wyspianski, Op. Cit., p. 78-79.

Chatelain,²⁶ following Wyspianski's promising results, studied auditory discrimination in relation to creative thinking in terms of Eccles' theory. He divided his sample of eighty subjects into two groups of high and low creatives on each of the five tests of creative thinking and the global score. Comparing the mean scores of the auditory discrimination test to the two creativity groups yielded critical ratios significant at the .01 level of confidence for five of the six creativity measures. Because of his sampling procedures, however, Chatelain concludes: "Les resultats de cette investigation ne pouvaient être generalisé, c'est à dire appliqués à une population autre que l'échantillon utilisé ici."²⁷

From Eccles' postulate that the creative brain is highly integrated and characteristically low in its inhibitory effects, Mook²⁸ hypothesized and experimentally investigated a possible inverse correlation between cortical inhibition and creative thinking ability. Cortical inhibition was measured through the visual sense modality by means of the

26 Pierre Chatelain, "La Discrimination Auditive et La Pensée Creatrice", unpublished Master's thesis, presented to the School of Psychology and Education of the University of Ottawa, Ontario, 1965, ix-115 p.

27 Ibid., p. 108.

28 B. Mook, "Retino-Cortical Inhibition and Creative Thinking", paper presented to the Annual Conference of the Ontario Psychological Association, Ottawa, February 1966, p. 1-9.

negative after-image threshold.²⁹ Measures of creative thinking were obtained from Guilford's perceptual-visual tests of divergent thinking. The Pearson r computed between the negative after-image threshold and creative thinking test scores for the ninety-subject sample yielded a value of $-.305$ significant at the one per cent level of confidence. In analysing this significant relationship, Mook states:

The result of this investigation revealed that creative thinkers do not only show a characteristic lack of psychological inhibitions but also a significant lower index of neurophysiological inhibition as measured through the Negative After-Image Threshold apparatus. The findings support Eccles' postulate about the creative brain being low in its inhibitory effects, enabling the brain to maintain a high level of activity.³⁰

These studies concerning electro- and neurophysiological correlates of creative thinking are encouraging. They appear to be a step towards Lashley's hope that the organic basis of learning and intelligence eventually might be realized. Mook's investigation, in particular, leads one to hypothesize that inhibition at the neurological level may be related to the functioning of the intellect. If other psychophysiological variables of a retino-cortical nature and pertaining to the phenomenon of cortical

²⁹ Negative After-Image Threshold: denotes the point where loss of the image occurs as a function of the particular type of field illumination intensity.

³⁰ Mook, Op. Cit., p. 6.

inhibition also correlate with tests of divergent thinking, it would lend support to Mook's findings and might allow greater speculation concerning the biological bases of intelligence. One possible variable, CFF, is discussed in the next section.

2. The Phenomenon of CFF.

A. Rationale for Its Use

When looking at any source of intermittent illumination, the light may appear to flicker or it may appear to be steady, depending upon a variety of circumstances. Within a defined set of conditions, a transition point or threshold may be found where flicker changes to steady light or steady to flicker. This transition point is known as Critical Flicker Frequency, or CFF. The literature indicates that it is a possible measure of the efficiency of the organism and of cortical inhibition.

Halstead³¹ used CFF in his study of brain functions and behavioural potentialities. Administering a battery of psychological and neurophysiological tests to 207 brain-injured and thirty control subjects, he identified four separate entities or factors of biological intelligence by

³¹ Ward C. Halstead, Brain and Intelligence, Chicago, University of Chicago Press, 1947, xiii-206 p.

means of factor analysis. One of these, termed the P or Power factor is described as:

A dynamic factor which, in terms of a single estimation, probably best reflects the overall status of the brain. Its specific physiology is unknown but it would not be surprising should it be found to parallel those vital processes which sustain the brain and cortex at a high level of efficiency.³²

Halstead found CPF to be the purest Power factor and recommends it as a test of P.

To interpret CPF Halstead postulates a neuronal coupling-decoupling effect: "Coupling is direct up to the point (frequency) where fusion occurs, at which point escape or decoupling occurs."³³ In other words, the neuronal synaptic transmission is continuous up to a point where uncoupling or a break in the neuronal conduction takes place. At this point the individual perceives the flickering light as fused. Halstead indicated that the greater the Power factor in an individual, the greater will be the neuronal coupling and, necessarily, the higher the CPF.

Halstead's hypothetical neuronal coupling-decoupling effect is similar to the construct of cortical inhibition.³⁴

³² Ibid., p. 98.

³³ Ibid., p. 77.

³⁴ Cortical Inhibition: "results from a continuous stimulation of a sensory surface leading to an alteration of subsequent responses", as defined by Mook, Op. Cit., p. 1.

Becker³⁵ studied the general theory of cortical inhibition as interpreted by various authors in relation to extraversion-introversion. He employed a group of neurophysiological, psychophysiological and physiological tests to measure the operationally-distinct concepts of basal cortical inhibition, satiation, and reactive inhibition, and tests of extraversion-introversion. The results obtained from sixty-two undergraduate psychology students were factor analyzed. CFE was one of the tests found in the relatively pure cortical inhibition factor:

Factor 3 [...], comes closest to any of the other factors to representing a general cortical inhibition factor. From the predominance of conditioning, CFE, and aniseikonic lense loadings it is apparent that this factor reflects primarily a basal inhibition effect, rather than a reactive inhibition or satiation effect.³⁶

Whether one considers CFE to be a measure of the Power factor or efficiency of the organism and a "decoupling" phenomenon as interpreted by Halstead, or a basal inhibition factor in Becker's terms, its use as a psychophysiological variable is justified. Further, if inhibition and facilitation at the neurological level are basic premises of intellectual functioning, as this author hypothesizes, then

³⁵ Wesley C. Becker, "Cortical Inhibition and Extraversion-Introversion", in Journal of Abnormal and Social Psychology, Vol. 61, No. 1, July 1960, p. 52-66.

³⁶ Ibid., p. 62.

CFE might be related to divergent thinking. The reasoning is as follows: (1) Mook has found an inverse relationship between inhibition and divergent thinking; (2) it is possible to predict that a higher basal cortical inhibition level would act to lower the perception of CFE; ³⁷ hypothetically, then, (3) higher thresholds of CFE (i.e., low inhibitory effects) should be related to higher scores on tests of divergent thinking.

B. General Aspects of the CFE Phenomenon

Halstead states in his study of biological intelligence that CFE is an effective measure of the Power factor or efficiency of the brain and accounts for CFE by a coupling-decoupling effect. Similarly, Becker's research indicates the possibility of defining CFE in terms of cortical inhibition. This section reviews some of the more general but pertinent aspects of the CFE phenomenon.

³⁷ Ibid., p. 55.

From the many facts presented and discussed in reviews of the literature,^{38,39,40,41,42} there emerge a number of laws governing the variation of CFE. The principle laws are:

1. The intensity of illumination is the most basic factor determining CFE. CFE is related to the logarithm of luminance but is not directly proportional. The relationship generally takes the form of a sigmoidal curve.
2. Phase relation (the Light-Dark Ratio).- A maximum CFE is obtained from equal light-dark phases, with a relatively symmetrical decrease for ratios smaller or larger than 0.5.
3. Lower CFEs tend to be obtained under conditions of dark adaptation than under conditions of light adaptation.

38 C. Landis, "Something About Flicker-Fusion", in Scientific Monthly, Vol. 73, No. 5, November 1951, p. 308-314.

39 -----, "Determinants of CFE Threshold", in Physiological Review, Vol. 34, 1954, p. 259-286.

40 G.W. Granger, "Abnormalities of Sensory Perception", in H.J. Eysenck's Handbook of Abnormal Psychology, New York, Basic Books, 1961, p. 108-166.

41 E. Simonson and J. Brozek, "Flicker Fusion Frequency: Background and Applications", in Physiological Review, Vol. 32, 1952, p. 349-378.

42 H. Piéron, "Vision in Intermittent Light: Laws and Mechanisms of the Critical Frequency for Fusion", in William D. Neff (ed.), Contributions to Sensory Physiology, Vol. 1, New York, Academic Press Inc., 1965, p. 179-264.

This is due to the different characteristics of the two receptor systems, rods and cones.

4. CFP obtained by binocular observation is higher than that obtained by monocular vision.
5. On the whole, CFP increases almost rectilinearly as a function of the logarithm of the retinal area stimulated. Evidently, the larger the retinal area stimulated, the greater the probability of including more sensitive regions, and consequently, raising CFP.
6. Within certain limits, CFP increases with the length of the duration of observation of intermittent stimulation. This is a result of the facilitating influence of the increased duration of observation on perceptive discrimination.

Other factors which have been found to affect CFP include chronological age, brain damage, drugs, and stresses such as anoxia and fatigue. Attempts made to relate permanent personality traits such as extraversion-introversion and body type to CFP have been inconclusive.⁴³

Much research has centred upon the neurophysiological foundations of CFP. These studies have emphasized either the peripheral (retinal) determinants or the more central (cortical) factors. The chief exponent of the retinal point

⁴³ Granger, Op. Cit., p. 106-106.

point of view has been Hecht⁴⁴ who outlined a series of photochemical equations to account for CFP. Although he offered many new insights, Hecht himself recognized the limitations of studying the photochemistry of the retina. "The retina is a complicated structure and not enough is known about it to furnish the material for an adequate formulation of so complex a phenomenon as flicker."⁴⁵

On the other hand, Bartley⁴⁶ hypothesized an Alternation-of-Response theory to account for CFP. From his studies, he concluded that "the ultimate crucial point of determination appears to be in the cortex".⁴⁷

Piéron criticizes these approaches for not taking into account the entire process of CFP.

Explanatory theories have generally sought to take account of all the characteristics of CFP at only one level in the visual system: photochemical processes with Hecht, for example, or a perceptive elaboration stage with Segal, or the formation of messages transmitted by the optic nerve with Bartley. We need to examine the actual state of our knowledge of the processes of excitation, the constitution of the message, and the perceptive reaction.⁴⁸

⁴⁴ S. Hecht and C.D. Verrijp, "Intermittent Stimulation by Light. The Relation Between Intensity and CFP for Different Retinal Locations", in Journal of General Physiology, Vol. 17, 1933, p. 273-278, as quoted by Oranger, Op. Cit., p. 128.

⁴⁵ Ibid., p. 128.

⁴⁶ S. Howard Bartley, "Central Mechanisms of Vision", in Handbook of Physiology, Section I; Neurophysiology, Vol. 1, 1959, p. 713-740.

⁴⁷ Ibid., p. 730.

⁴⁸ Piéron, Op. Cit., p. 218.

In his research, Piéron has examined each step of the CPF process using, as a framework, the following order of events within the optic system:

The absorption of photons by the molecules of a photosensitive pigment in the receptor elements instigates an initial process of nervous excitation. The nervous excitation is transmitted by means of a short conducting link (bipolar cells) joined to a web of connecting cells up to the neurons of a retinal nervous centre (ganglion cells). Messages are emitted in the form of a repetitive flux which travels through a single synapse in the lateral geniculate body to the visual projection region of the occipital cortex. Starting at the cortex a perceptive interpretation is elaborated.⁴⁹

Piéron does not attempt to account for CPF in terms of retinal versus cortical determinants but considers the totality of the psychophysiological process. He notes that the positive results of studies relating CPF to EEG variables, if confirmed, would be highly significant. But he adds that "no plausible interpretation has been suggested."⁵⁰

The studies to which Piéron refers were conducted in order to offer support to the notion of a cortical determination for CPF. Reuning,⁵¹ with a sample of twenty-three,

⁴⁹ Ibid., p. 217.

⁵⁰ Ibid., p. 230.

⁵¹ H. Reuning, "A New Flicker Apparatus for Measuring Individual Differences", in Acta Psychologica, Vol. 11, No. 4, 1955, p. 447-466.

found a positive relationship between CFE and EEG alpha frequency. The Pearson r of .545 is significant at the .01 level of confidence. Chyatte⁵² obtained a Spearman rank order coefficient of .851 between CFE and alpha index with the EEG measures taken from the occipital and temporal lobes. With a sample of fourteen and a wide age range of twenty-four to sixty-three years, Chyatte's results are questionable.

This section concerning the general aspects of CFE has attempted to outline the principle laws governing its variation. Research on the retinal versus cortical determinants of CFE was also discussed. The only apparent conclusion is that CFE is a highly complex phenomenon involving all parts of the visual pathways from the photoreceptors to the cortex. It appears justifiable to define CFE as a measure of retino-cortical activity; and, for the purposes of the present study, a possible measure of brain efficiency and retino-cortical inhibition.

C. CFE and Psychometric Intelligence

The possible relationship between CFE and psychometric intelligence has been investigated by many. Results, on the whole, are equivocal.

⁵² C. Chyatte, "A Note on the Relationship of Alpha Index to CFE", in EEG and Clinical Neurophysiology, Vol. 10, 1958, p. 553-554.

Halstead's⁵³ correlation between CFE and the Hermon-Nelson Test of Mental Ability was positive but insignificant at .117.

Kerr and Abrams⁵⁴ correlated the Halstead tests with a number of group tests. Their sample consisted of twenty male subjects in management positions in industry, age twenty to fifty-eight years. An insignificant correlation of .16 was obtained between the Power factor and the Ohio Classification Test of Intelligence.

Several independent studies relating CFE to intellectual functions in geriatric subjects have yielded significant results. Colgan⁵⁵ compared scores on the Wechsler-Bellevue Scale of Intelligence to CFE on a sample of forty males between the ages of sixty-five to ninety-five. A Pearson r of 0.46 was significant at the .01 level of confidence.

Loranger and Misiak⁵⁶ with a sample of fifty female subjects aged seventy-four to eighty obtained significant

⁵³ Halstead, Op. Cit., xiii-206 p.

⁵⁴ W.A. Kerr and P. Abrams, "Halstead Brain Impairment, Boldness, Creativity, and Group Intelligence Measures", in Journal of Clinical Psychology, Vol. 18, No. 2, April 1962, p. 115-118.

⁵⁵ C.M. Colgan, "Critical Flicker Frequency, Age, and Intelligence", in American Journal of Psychology, Vol. 67, No. 4, December 1954, p. 711-713.

⁵⁶ Andrew W. Loranger and Henry Misiak, "Critical Flicker Frequency and Some Intellectual Functions in Old Age", in Journal of Gerontology, Vol. 14, No. 3, July 1959, p. 323-327.

correlations between CFF and the following psychometric tests: the Digit Symbol sub-test from the Wechsler Adult Intelligence Scale, the Raven Progressive Matrices, and the Reasoning Test (untimed) from Thurstone's Primary Mental Abilities. The relationship between CFF and psychometric intelligence in the aged, "is tentatively ascribed to a reduced central neural efficiency in old age, which adversely affects both CFF and some intellectual functions."⁵⁷

Because of the limited age range used by Colgan and Loranger and Misiak, it was difficult to explain what part, if any, intelligence had in determining CFF. In attempting to overcome this limitation, Wilson⁵⁸ selected eight male and eight female subjects representing each of six ten-year age groups from age twenty to eighty inclusive, yielding a total of ninety-six subjects. His CFF testing was well controlled. Intelligence was measured by the Raven Progressive Matrices. By employing analysis of variance and covariance Wilson obtained significant results, concluding that "there is no sex difference in CFF at any age, but that both age and non-verbal intelligence are determinants of CFF."⁵⁹

⁵⁷ Ibid., p. 327.

⁵⁸ T.R. Wilson, "Flicker Fusion Frequency, Age, and Intelligence", in Gerontologia, Vol. 7, No. 1, 1963, p. 200-208.

⁵⁹ Ibid., p. 207.

To date, Wilson's findings concerning non-verbal intelligence and CFP have not been cross-validated.

With a sample of 120 boys at ages six, eight, ten, and twelve years, Cross⁶⁰ investigated the relation between CFP and age, and the relation between CFP and certain mental abilities. The correlation between CFP and I.Q. scores on the Wechsler Intelligence Scale for Children was significant only in the twelve-year old group. Cross concludes that CFP and intelligence are correlated significantly only at those age levels which are associated with extensive physiological change.

Tanner⁶¹ studied CFP in relation to test scores on the A.C.E. Psychological Examination College Edition. The CFP was obtained by varying the dark-period following each intermittent light pulse. With a sample of twenty-one college students significant correlations at the .05 level of confidence were reached between various CFP dark-interval durations, and the total score on the A.C.E.

60 Jane P. Cross, "Relation of Age and Mental Growth to CFP Response in Children", in Child Development, Vol. 34, No. 3, September 1963, p. 739-744.

61 Wilson P. Tanner, Jr., "A Preliminary Investigation of the Relationship Between Visual Fusion of Intermittent Light and Intelligence", in Science, Vol. 112, No. 2903, August 1950, p. 201-203.

Subsequently, Colgan⁶² tested CFE in relation to A.C.E. intelligence scores with a group of ninety college students. His CFE apparatus was similar to Tanner's except that he used an intermittent light having a 1:1 light-dark ratio. He found no significant correlations. Landis and Hamwi⁶³ suggest that the correlations reported by Tanner are examples of random fluctuation.

Criticizing these studies for employing homogeneous groups in terms of intelligence, Korotkin⁶⁴ utilized three groups of subjects ranging in Wechsler I.Q. from fifty to over 120. He found that the higher the CFE the higher the I.Q. but the relationship did not reach statistical significance.

In summary, evidence for the relationship between CFE and psychometric intelligence appears strongest for samples of children and geriatric subjects and weakest for samples of young adults. The psychometric tests may have

62 C.M. Colgan, "The Relation between Critical Flicker Frequency and Several Psychological Variables", unpublished doctoral dissertation, University of Florida, 1954, University Microfilms, Ann Arbor, Michigan, No. 9706, as reported by Carney Landis and Violet Hamwi, "Critical Flicker Frequency, Age and Intelligence", in American Journal of Psychology, Vol. 69, No. 3, September 1956, p. 459-461.

63 Landis and Hamwi, Op. Cit., p. 461.

64 A.L. Korotkin, "Perception and Intelligence: the Relationship of Certain Visual-Perceptual Skills with Intelligence, Age, and Sex", unpublished doctoral dissertation, Temple University, 1960, as reported by Honigfield, Op. Cit., p. 538.

been a factor in the inconclusive results with young adults. Vogel and Broverman⁶⁵ speculate that the intellectual differentiation of the normal young adult frequently goes unrecognized by using standard tests of general intelligence. It is possible that a relationship between CPF and intellectual functioning would be more easily attained in a sample of young adults, if indeed there is such a relationship, by employing cognitive tests of a more specific nature. This notion is elaborated upon in the next section of this chapter.

3. Rationale for Employing Tests of Divergent Thinking.

Past attempts at relating CPF and intelligence in normal adults have been hampered, possibly, by the use of tests of general intelligence. Vogel and Broverman speculate that due to increased differentiation of intelligence:

A normal adult would score very differently on particular tests depending upon which aspects of intelligence were measured by the tests, and depending upon his special mental skills.⁶⁶

Consequently, when employing adults as subjects in a study correlating a psychophysiological variable with intellectual functioning, it would be necessary to use a relatively

⁶⁵ Vogel and Broverman, Op. Cit., p. 132-144.

⁶⁶ Ibid., p. 140.

differentiated and refined psychometric instrument which tests a specific cognitive function. Guilford's tests of divergent thinking⁶⁷ have been designed for this very purpose.

Since 1950, Guilford⁶⁸ has attempted to explore all aspects of intellectual functioning. His investigations, by means of factor analysis, in the areas of creative abilities, reasoning, evaluation, planning, and problem solving, led to the formulation of a theoretical model of the Structure of the Intellect. This model is described in the next chapter.

One section or factor in Guilford's Structure of the Intellect Model which has been experimentally verified is that of divergent thinking. Guilford designed tests of both a verbal and perceptual-visual nature to measure the ability to think divergently. In each test the subject is presented with a stimulus and is required to arrive at as many plausible answers as possible. This necessitates a different thought process compared with tests of convergent thinking where only one answer is applicable.

67 Guilford and Merrifield, Op. Cit., p. 1-27.

68 J.P. Guilford, "Creativity", Presidential Address of the American Psychological Association at Pennsylvania State College, 1950, as reproduced in Sidney J. Parnes and Harold E. Harding, (eds.), A Source Book for Creative Thinking, New York, Charles Scribner's Sons, 1962, p. 152-155.

In discussing the production of tests to assess these factors, Guilford states:

In tests of convergent thinking there is almost always one conclusion or answer that is regarded as unique, and thinking is to be channeled or controlled in the direction of that answer. In divergent thinking, on the other hand, there is much searching about or going off in various directions [...] Divergent thinking is characterized as being less goal-bound. There is freedom to go off in different directions.⁶⁹

As indicated by Mook and hinted at by Guilford, tests of divergent thinking may measure inhibitory effects in the thought processes. Low inhibitory effects would enhance the ability to think divergently.

It is not surprising that tests of divergent thinking have not correlated highly with tests of psychometric intelligence.^{70,71} As Guilford points out, "In an I.Q. test there is usually almost nothing involved in the way of divergent thinking."⁷² Furthermore, the ability to think divergently is a fairly specific cognitive function whereas intelligence tests are broad in scope.

69 J.P. Guilford, A Revised Structure of the Intellect, Los Angeles, University of South California, 1957, p. 6-9.

70 Jacob W. Getzels and Philip W. Jackson, Creativity and Intelligence, New York, John Wiley and Sons, 1952, xvii-293 p.

71 Kaoru Yamamoto, "Role of Creative Thinking and Intelligence in High School Achievement", in Psychological Reports, Vol. 14, No. 3, 1964, p. 783-789.

72 Guilford, "Creativity", p. 163.

Another factor favouring these tests concerns Guilford's ability to apply his theory with measurement skill. "The most important asset of the tests developed by Guilford lies in their theoretically established bases and the careful studies which gave them existence."⁷³

The use of these tests in relation to CFF is justified even more emphatically by the success encountered by Wyspianski, Chatelain, and Mook. Even though Wyspianski and Chatelain used the verbal set of tests and Mook the perceptual-visual set, and despite the fact that each investigated a different psychophysiological variable, all three studies gleaned significant results.

Wyspianski, Chatelain and Mook have interpreted scores on Guilford's divergent thinking tests as measures of creative thinking. The literature indicates that the ability to think creatively involves more than divergent thinking. Guilford himself notes that, "creativity cannot be allocated exclusively to any particular portions of the model."⁷⁴ Hence, for the past several years Guilford has included in creativity, other abilities from his Structure

⁷³ Wyspianski, Op. Cit., p. 14.

⁷⁴ Guilford and Merrifield, Op. Cit., p. 11.

of the Intellect Model.⁷⁵ As well, Golann⁷⁶ reports studies where Guilford's tests, scored for quantity and quality, did not correlate well with the degree of creativity as judged by experts in the subjects' own fields.

Creativity is a relatively new area of study and until Guilford's tests demonstrate greater validity, it is deemed wiser to consider divergent thinking as part of creative thinking rather than equating the two concepts.

In summary, the rationale for employing Guilford's tests of divergent thinking is derived from four sources. First, the cognitive specificity of the measures; second, their sound theoretical and statistical bases; third, the success of other studies using them in relation to psychoneurological variables; and, four, the assumption that divergent thinking tests may be a measure of inhibitory effects in the thought processes.

4. Summary and Hypothesis.

For many years psychology has attempted to relate psychophysiological phenomena to intellectual functioning

⁷⁵ These other abilities include: Redefinition from the Convergent Production category, and Sensitivity to Problems from the Evaluation category.

⁷⁶ Stuart E. Golann, "Psychological Study of Creativity", in Psychological Bulletin, Vol. 60, No. 6, November 1963, p. 552.

with the hope of deriving some understanding of the biological bases of intelligence. This search included a myriad of neurophysiological and psychometric variables and a variety of theories. The results, on the whole, have been inconclusive and rather discouraging.

However, three studies concerning psychophysiological correlates of divergent thinking yielded significant results and led this author to hypothesize that inhibition and facilitation at the neurological level may be related to intellectual functioning.

Factor analytic studies demonstrated that CFP may be a possible measure of brain efficiency and retino-cortical inhibition. Studies relating CFP to psychometric intelligence produced low correlations, indicating the use of tests of a more specific cognitive nature, namely, tests of divergent thinking.

To further substantiate the hypothesis that CFP is related to divergent thinking two theoretical assumptions, based on the literature may be helpful:

1. that, CFP is a measure of retino-cortical inhibition, i.e., inhibition at the neurological level;
2. that, tests of divergent thinking measure inhibition of the thought processes, i.e., inhibition at the psychological level.

For each measure, the lower the inhibitory effects the higher the score. Consequently, high CFF should be related to high scores of divergent thinking. The proposed hypothesis is stated in the null form: there are no significant relationships between CFF and scores on Guilford's verbal tests of divergent thinking.

CHAPTER II

TOOLS OF RESEARCH

This chapter presents the tools, both psycho-physiological and psychometric, used in this study. The first section consists of a detailed description of the CFE instrumentation. Section two discusses Guilford's Structure of the Intellect Model and five of his tests designed to measure divergent thinking.

1. CFE Instrumentation.

The CFE apparatus employed in this study is similar in principle to that of Foley's.¹ It is diagrammed in Figure 1 on the next page and the description follows.

¹ P.J. Foley and J. Kazdan, "Area-Intensity Relations within the Fovea for Flickering White and Part-Spectrum Targets", in Journal of the Optic Society of America, Vol. 54, No. 4, April 1964, p. 547-550.

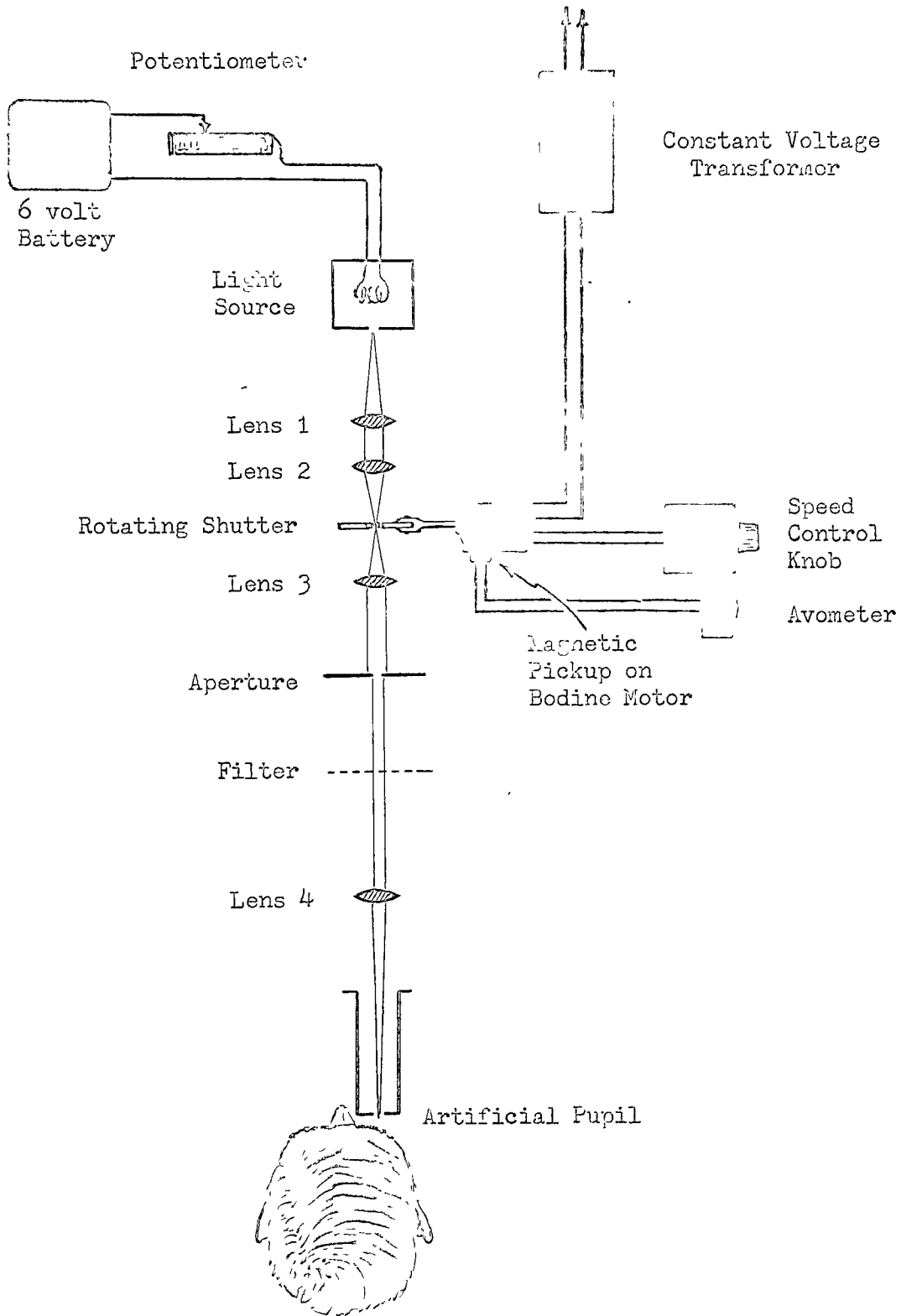


Figure 1.- CEE Apparatus.

The entire optic system was constructed on a steel base 76 cm. long, 19 cm. wide, and 2 cm. deep weighing 40 pounds. The base was placed in the middle of a 6' x 4' adjustable, wooden-topped, steel-reinforced table which also supported the rest of the electrical equipment.

The Light Source was a 6-V General Electric 2331 double filament bulb, generated by a dc 6 Volt Battery connected in series with a 100 ohm potentiometer to regulate the light intensity. The battery generated 6.05 volts and the current in the lamp filament was 1.37 ohms. The light was collimated by Lens 1 and brought to a focus in the centre of the rotating shutter by Lens 2. The rotating shutter was driven by a Bodine dc Motor, No. 2755547, Type NSH-34 with 1725 rpm. To ensure constant voltage the motor was connected in series to a Sola Constant Voltage Transformer, Category No. 30306, Serial No. K0149. The speed of the motor was controlled manually.

A proximity magnetic pickup (tachometer) above the rotating shutter operated a Universal Avometer, Model 6. The number of revolutions of the shutter were read in milliamperes per second on the Avometer. A calibration in flickers per second revealed an approximate linear relationship between milliamperes and flickers. As noted in Appendix 1, .018 mA per second \approx 1.0 flickers per sec. with accuracy at 60 cps. better than one per cent.

The intermittent light with a light-to-dark fraction (L-D-F) of 0.5, was collimated at Lens 3. It then passed through the aperture, 1/16 in. in diameter, through a Kodak Wratten Neutral Filter, of density 2.0, and by means of Lens 4, was brought to a focus at the Artificial Pupil, which was 2 mm. in diameter.

The light intensity was held constant by making minor adjustments to the potentiometer connected in series from the battery to the light source. The intensity was measured with a Photo-Cell, Model 3 PVI, AAB, Sub. 3, and was read in dc Microamperes on a General Electric Meter, Type DC-78. The brightness level was 150 microamperes² measured directly behind Lens 3.

In an attempt to eliminate cues from the change in sound of the Bodine motor at different speeds, white noise³ was introduced as a masking effect. The white noise generated from a tape played on a Wollensak Tape Recorder.

² 150 microamperes equals 22 Foot Candles as measured by a Photo Volt Light Meter.

³ White Noise: a blend of various sound wave frequencies.

This CFE instrumentation satisfies a number of the requirements noted by investigators.^{4,5} Two of the important variables controlled are intensity of illumination and the Light-Dark-Fraction. One disadvantage of this type of apparatus is that the variable speed control of the Bodine motor is not automatic but must be regulated manually.

2. Guilford's Tests of Divergent Thinking.⁶

The psychometric tests designed to measure divergent thinking were selected from Guilford's battery of tests. This ability to think divergently forms a part of Guilford's unified theory of intelligence which is diagrammed in Figure 2.

⁴ C. Landis, "Determinants of CFE Threshold", in Physiological Review, Vol. 34, 1954, p. 255-286.

⁵ O.W. McNemar, "The Ordering of Individuals in Critical Flicker Frequency Under Different Measurement Conditions", in Journal of Psychology, Vol. 32, 1951, p. 3-24.

⁶ J.P. Guilford and P.R. Merrifield, "The Structure of Intellect Model: Its Uses and Implications", Report from the Psychological Laboratory, University of Southern California, No. 24, April 1960, p. 1-27.

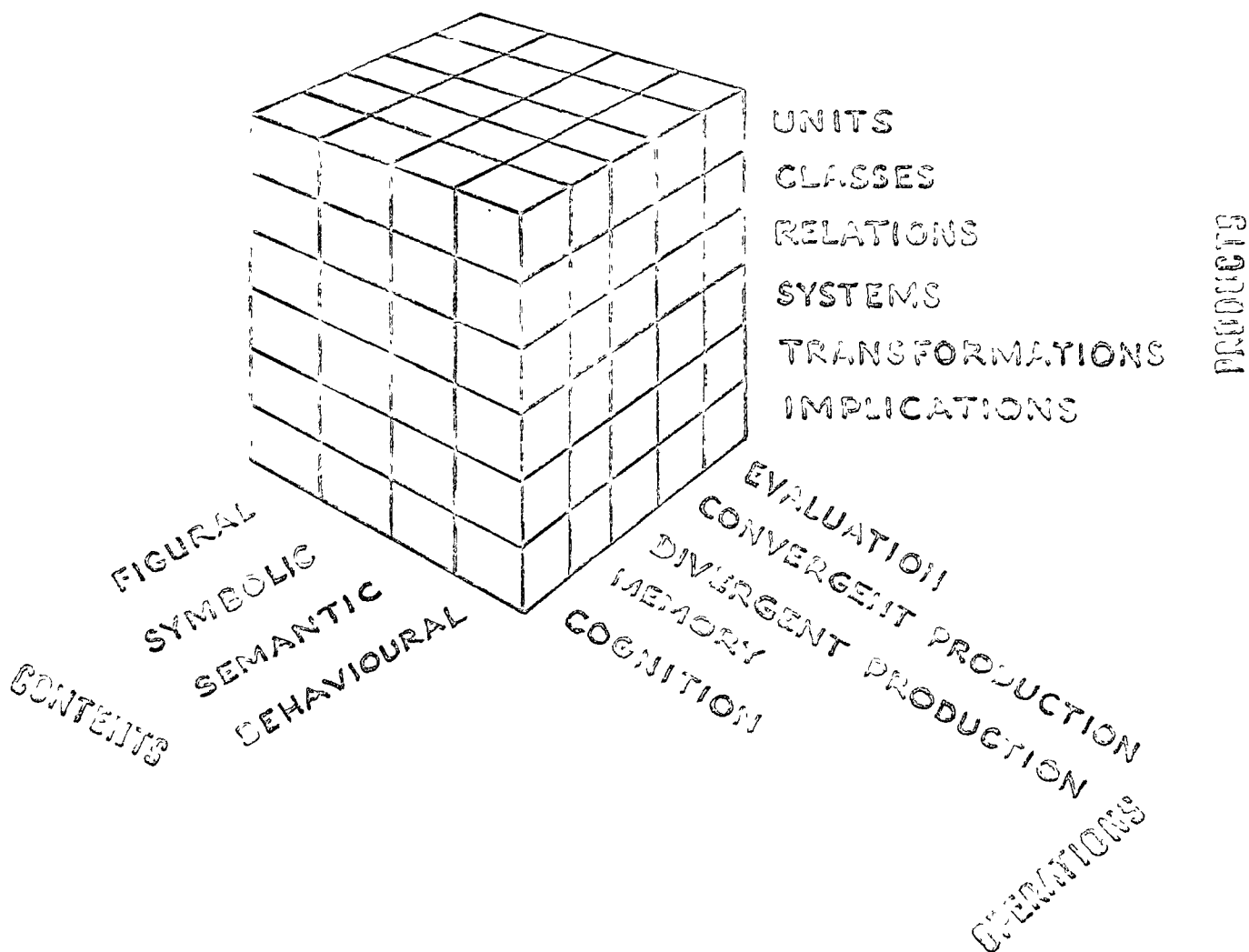


Figure 2.- Guilford's Theoretical Model for the Complete "Structure of Intellect".^a

^a J.P. Guilford, "Creativity: Its Measurement and Development", in Sidney J. Parnes and Harold F. Harding, (eds.), A Source Book for Creative Thinking, New York, Charles Scribners, 1962, p. 161.

According to Guilford⁷ there are three meaningful ways of grouping the factors of intellect. One way is by the kind of operations required or performed. The five fundamental kinds of operations are Cognition, Memory, Divergent and Convergent Production, and Evaluation. A second way of classifying the intellectual factors is according to the kind of material or content involved. Guilford found four kinds: Figural, Symbolic, Semantic, and Behavioural. When different operations are applied to different contents, as many as six general products could be involved: Units, Classes, Relations, Systems, Transformations, and Implications.

As the three classifications, operations, content and products could be combined, Guilford provided a unified theory of intellectual functioning. Each mode of classification became a parameter or dimension of the model. Up to 1963, there were forty-seven known factors of intellect.⁸

From Guilford's battery of tests measuring divergent thinking five were selected for this study. They are described in the order in which they were administered.

⁷ Guilford and Merrifield, Op. Cit., p. 1-27.

⁸ Stuart E. Golann, "Psychological Study of Creativity", in Psychological Bulletin, Vol. 60, No. 6, November 1963, p. 548-565.

The test of Alternate Uses requires the subject to list uncommon, or less common uses of a given object whose common use is stated. There are three sections to the test containing three items each. Four minutes is allowed per section. The score is the total number of acceptable responses as defined in the manual.⁹ Correlations of the test with the original form, Unusual Uses, gave reliability estimates ranging from .68 to .81. The Ns of the samples are not stated.¹⁰

Associational Fluency is a test requiring the individual to list words that bear some relation to a given word. There are four parts with two minutes per part. The score is the number of acceptable responses. The coefficient of reliability, using the alternate form of the test, obtained on a sample of 240 naval air cadets and naval officer candidates is .63.¹¹

The test of Ideational Fluency requires the individual to list ideas in accord with certain requirements. There

9 R.C. Wilson, P.R. Christensen, P.R. Merrifield, and J.P. Guilford, Alternate Uses. Manual of Administration, Scoring and Interpretation, Beverley Hills, California, Sheridan Supply Co., 1960, p. 2.

10 Ibid.

11 P.R. Christensen and J.P. Guilford, Manual for the Christensen-Guilford Fluency Tests, Beverley Hills, California, Sheridan Supply Co., 1959, p. 7.

are four sections with a time limit of three minutes per section. The score is the total number of acceptable responses. The alternate form coefficient of reliability is .76 based on a sample of 219 naval air cadets and naval officer candidates.¹²

The Expressional Fluency test requires the subject to build four-word sentences having been given the four initial letters of each word. The total score is the number of four-word complete sentences containing the specified beginning letters. There are four sections, two minutes each. The authors do not report any reliability estimates for this test.

Word Fluency taps the individual's ability to think of words rapidly, each word satisfying the requirement that it contain a specified letter. The task consists of two parts with a time limit of two minutes per part. The score is the total number of responses containing the stated letter. The alternate form correlation coefficient from a sample of 219 naval air cadets and naval officer candidates is reported to be .73.¹³

These five tests from the Divergent Production category of Guilford's Structure of the Intellect Model

12 Christensen and Guilford, Op. Cit., p. 7.

13 Ibid.

measure the abilities of fluency and originality. Copies of each test are found in the Appendix.

This chapter has described the tools of research, both psychophysiological and psychometric. Chapter three describes the experimental design of this investigation.

CHAPTER III

EXPERIMENTAL DESIGN

This chapter discusses the methods undertaken to test the hypothesis stated in chapter one. It is divided into sections which deal with the sample population, the experimental procedures, and the statistical analysis of the obtained data.

1. The Sample Population.

The selection of subjects for this study was based on the following criteria: (1) that the chronological age of the subjects be within a narrow range; (2) no reported history of brain damage, epilepsy, or use of drugs; (3) evidence of a preferred or dominant eye; (4) normal vision in this preferred eye; and (5) primacy of the English language.

Controlling for age was necessary as CFE is negatively correlated with chronological age.¹ Since brain damage, epilepsy and drugs affect CFE,² subjects in these categories were eliminated.

1 Carney Landis and Violet Hamwi, "Critical Flicker Frequency, Age and Intelligence", in American Journal of Psychology, Vol. 69, No. 3, September 1956, p. 460.

2 Ward C. Halstead, Brain and Intelligence, Chicago, University of Chicago Press, 1947, xlii-206 p.

It was felt necessary to control for the preferred eye as there is some evidence that the preferred or dominant eye is qualitatively superior in its ability to process information compared to the non-dominant eye.^{3,4} Visual acuity in the subject's preferred eye was a criterion for selection since visual acuity can affect CFE.⁵ The requirement of primacy of the English language was determined by the divergent thinking tests which presuppose native facility in that tongue. Another criterion for selection was sex. Only males were used.

To obtain subjects, the experimenter visited a number of undergraduate and graduate classes at the University of Ottawa, briefly describing the project and listing some of the requirements for acceptance as a subject. Forty-one subjects were chosen. All were unpaid volunteer students ranging in age from nineteen to thirty-two years with a mean age range of 23.95.

Although forty-one subjects made up the sampling pool the final N was thirty-nine. Two bilingual subjects had to be eliminated as their mother tongue was not English.

³ M.C. Corballis, "Binocular Interactions in Letter Recognition", in Australian Journal of Psychology, Vol. 16, No. 1, April 1964, p. 38-48.

⁴ Carl H. Delacato, The Treatment and Prevention of Reading Problems, Springfield, Thomas, 1959, xi-123 p.

⁵ P.J. Foley, personal communication, at Defence Research Medical Laboratories, Downsview, Ont., September, 1964.

2. Experimental Procedure.

Three testing sessions were conducted to obtain the data for this study: the CFE testing; a retest to determine reliability; and the administration of Guilford's tests.

To obtain measures of CFE, a room was made available by the Faculty of Psychology and Education at the University of Ottawa. All subjects were tested individually between the hours of 9:30 a.m. and 4:00 p.m.

Prior to the administration of the CFE each subject underwent the following process: a preferred-eye test, the Snellen Visual-Acuity test, and a period of dark adaptation.

The preferred-eye test was conducted in accord with Harris'⁶ instructions for monocular dominance. The subject held a piece of cardboard in front of him at arm's length. The cardboard, 7" x 10", had a one-inch hole in the middle. The experimenter, standing at a distance of ten feet from the subject, held his fist to his nose. The subject was asked to move the cardboard towards his own face while fixing his vision on the experimenter's fist through the hole. When the cardboard was approximately six inches from the subject's face the experimenter raised one or two fingers. The subject was asked to report the number. Three such

⁶ Albert J. Harris, Harris Tests of Lateral Dominance: Manual of Directions for Administration and Interpretation, New York, the Psychological Corporation, 1954, 27 p.

trials were used and the eye to which the subject consistently drew the cardboard was considered the preferred eye. If inconsistencies existed between the choice of eyes, the subject was excluded from the study. Sixty-one per cent of the subjects preferred their right eye.

The Snellen Visual Acuity Test was then administered for the preferred eye with a patch over the non-preferred eye. A Snellen chart read at a distance of twenty feet was used. Only those subjects with 20-20 vision in the preferred eye were acceptable. Subjects who wore glasses were allowed to participate as long as their corrected vision met the 20-20 visual acuity requirement. They also wore their glasses during the CFP testing.

The subject was then dark-adapted by wearing red goggles for ten minutes during which the experimenter described the apparatus and gave the following instructions:

There will be both Ascending and Descending trials. For the Ascending, which is a change from a Flickering to a Steady Light, you will first be warned by the signal, "Going up." I want you to say "Now" when you see the light as steady. I shall reply with "Okay," which means that I've recorded your response. Then, we will have a Descending series, whereby the light will go from Steady to Flicker and the warning is "Going down." This time, I want you to say "Now" when you see the light as Flicker. If you are dissatisfied with any response, tell me, and we will repeat that trial.

After the period of dark-adaptation and instructions, the lights in the room were turned off, the red goggles removed, and the subject, placing the patch over his non-preferred eye entered the experimental booth. The booth, as shown in Figure 3, was 6' x 5' x 6' and constructed of a 1½" x 1½" wooden frame covered with black broadcloth and army blankets around the sides and top to ensure adequate darkness. A small hole was cut in the cubicle covering to expose the Artificial Pupil.

The mouthpiece, chosen instead of a chin rest which allows the head to wobble, consisted of a dowel rod clamped to two upright metal stands. A piece of dental wax (Dencowax No. 43) was attached to the rod upon which the subject placed his upper jaw his teeth biting into the wax, thus keeping his head still and allowing him to talk. The apparatus could be adjusted in three spatial planes to accommodate each subject.

Once the subject was in position, and the equipment ready, four Ascending and four Descending practice trials were administered. The subject was then asked to relax, shut his eyes, and ask questions. The experimenter checked the light intensity at this point. Then, five Ascending and five Descending trials were administered alternately with the starting points for each trial varied to avoid the subject's usage of a time criterion. From the eight

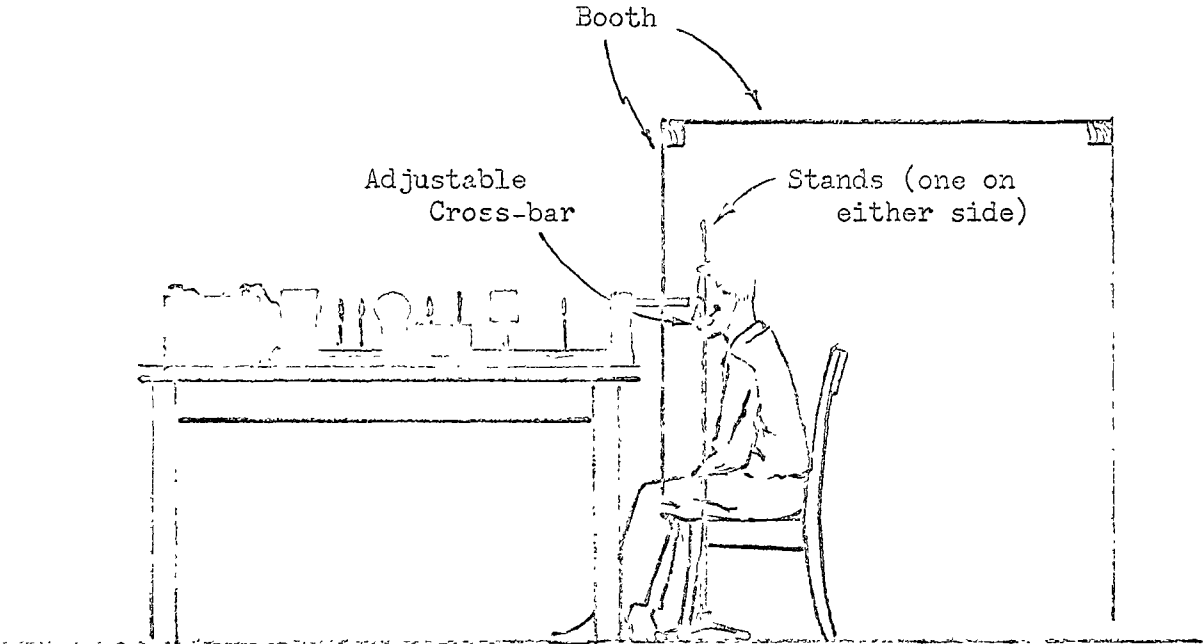


Figure 3.- Booth for CEF Testing.

practice trials the experimenter made a rough estimate of the subject's threshold by calculating the mean of these eight measures. The starting points for each Ascending trial were 15, 9, 17, 11, and 13 milliamperes respectively, below the estimated threshold; and, for each of the five Descending trials the starting points were 9, 17, 11, 13, and 15 milliamperes per sec., respectively, above the estimated threshold. Rather than having fixed starting points for all subjects the above method was employed in an attempt to equalize the duration of exposure for each subject. This psychophysical method for obtaining CFFs is described as a Modified Method of Limits.⁷

The experimenter trained himself to manipulate the variable speed control so that the rate of change of intermittence was .009 mA per sec. (0.5 Fl. per sec.), for each second of elapsed time. When the subject said "Now", the examiner immediately stopped turning the control knob, recorded the response, and adjusted the speed for the starting point of the next trial.

On completion of the ten trials the light intensity was measured to ascertain possible changes. Following this

⁷ R.A. Wagoner, "Differences in Response Variability Between High and Low Anxiety Subjects in a Flicker-Fusion Task", in Journal of Abnormal and Social Psychology, Vol. 61, No. 3, 1960, p. 355-359.

the apparatus was turned off and the subject left the booth. The total testing time was approximately a half hour per subject.

For purposes of reliability, twenty-six subjects were retested within a week using the same procedure excluding the preferred eye and Visual Acuity tests.

The divergent thinking tests were administered following the test-retests of CFP. The testing took place in a classroom at the Faculty of Psychology and Education at the University of Ottawa. Due to conflicts in timetables it was necessary to conduct two testing sessions on consecutive days at 1:00 p.m.

The classroom had adequate lighting and ventilation and the seating was arranged to prevent copying. For each of the five tests, instructions were read aloud by the examiner while the subjects read silently. It took about one hour to test each group. At the end of the first session the group was asked to not discuss the tests until the second session had been completed.

3. Statistical Analysis of Data.

In order to test the hypothesis that there are no significant relationships between CFP and scores on divergent thinking tests, the location of CFP, the criterion variable, was required. Frequently, the mean of the five

Ascending and Descending scores is taken as the threshold.⁹ Dillon,⁹ however, doubts whether this averaging of Ascending and Descending trials is a valid procedure. To determine if the scores could be combined, a three-way classification analysis of variance was chosen.¹⁰

The three variables, Individuals, Occasions, and Directions gave the following interaction:

$$I \times O \times D = 41 \times 5 \times 2 = 410 \text{ scores}$$

With resultant F tests, and t tests where necessary, it would be possible to discover if there were significant differences between the various trials (Occasions) to indicate the effect of choice of starting points, and, between the Ascending and Descending Directions.

Significant differences were obtained between the Ascending and Descending Directions. Therefore, statistics concerning the two thresholds were tabulated to show which CFF value was higher. The following formulae are relevant:

⁸ C. Landis, "Determinants of CFF Threshold", in Physiological Review, Vol. 34, 1954, p. 259-286.

⁹ D. Dillon, "Differences Between Ascending and Descending Flicker-Fusion Thresholds Among Groups of Hospitalized Psychiatric Patients and a Group of Normal Control Persons", in Journal of Psychology, Vol. 48, 1959, p. 255-262.

¹⁰ Cyril H. Goulden, Methods of Statistical Analysis, second edition, New York, John Wiley, 1952, p. 94-97.

Arithmetic Mean: $M = \frac{\sum X}{N}$ ¹¹

Standard Deviation: $\sigma = \frac{1}{N} \sqrt{N(\sum X^2) - (\sum X)^2}$ ¹²

To discover if differences between Ascending and Descending thresholds were consistent the Pearson product-moment coefficient of correlation was computed:¹³

$$\text{Pearson } r: r_{XY} = \frac{N \sum XY - \sum X \sum Y}{\sqrt{N \sum X^2 - (\sum X)^2} \sqrt{N \sum Y^2 - (\sum Y)^2}}$$

where X = Ascending CFP

and Y = Descending CFP

This same formula is applicable for estimating the test-retest reliability of CFP, the X and Y variables being the CFP from test and retest sessions, respectively.

Since differences between Ascending and Descending test-retest estimates of reliability were found the \bar{z} test of differences between Pearson r 's was employed. The necessary formulae for computing a \bar{z} ratio are:

¹¹ Lawrence-T. Dayhaw. Manuel de Statistique, second edition, Ottawa, Editions de l'Universite d'Ottawa, 1963, p. 48.

¹² Ibid., p. 64.

¹³ Ibid., p. 126.

Standard Error of a
Difference between Two
z Coefficients:

$$\sigma_{dz} = \sqrt{\frac{1}{N_1 - 3} + \frac{1}{N_2 - 3}}$$

14

and.

\bar{z} Ratio:

$$\bar{z} = \frac{z_1 - z_2}{dz}$$

To test the main hypothesis concerning the relationship between CFF and divergent thinking the Pearson r formula was used, the X variable being CFF values and the Y variable, scores on the divergent thinking tests.

This chapter has described the design of this experiment in terms of the sample studied, the experimental procedures, and the statistical analysis of the data. The next chapter consists of the presentation and discussion of the findings.

14 J.P. Guilford, Fundamental Statistics in Psychology and Education, third edition, New York, McGraw-Hill, 1956, p. 194.

CHAPTER IV

RESULTS AND DISCUSSION

The final chapter presents and discusses the results. In section one the analysis of variance of CFE is outlined and commented upon, followed by the results of the F tests. Differences between the Ascending and Descending thresholds are presented next. Section three concerns the reliability of CFE. The fourth section offers the correlation coefficients between CFE and divergent thinking as a test of the experimental hypothesis. Section five, which is divided into three subsections, discusses these results.

1. The Analysis of Variance of CFE.

The three-way classification analysis of variance for CFE, summarized in Table I, yielded 4!C cells with one entry per cell. There were three principle effects, three double interactions, and one triple interaction. There was no residual term since all the variance was accounted for with each cell having one entry.

In order to interpret the analysis of variance, that is, to test the significance of the various effects, it was necessary to determine the theoretical model. In this case, the model would be considered to have one random variable and two fixed variables, yielding an "aBC"

Table I.-
Table of Variance for Three Dimensions of CEE.

Source	Sums of Squares	Degrees of Freedom	Variance Estimate
Principle Effects:			
Occasions	.0017801	4	.0004450
Directions	.1091612	1	.1091612
Individuals	.5509981	40	.0132999
Double Interactions:			
O x D	.0012648	4	.0003162
O x I	.0373999	160	.0002337
D x I	.0834888	40	.0020872
Triple Interaction(Remainder):			
O x D x I	.0276352	160	.0001727
Total	.8207281	409	

type model.¹ The "a" refers to Individuals which is a random variable, and "B" and "C" refer to Occasions and Directions which are fixed variables. With this model, the only principle effects which may be treated by the F test are Occasions with the interaction of OxD as the error term, and Directions with the interaction of DxI as the error term. Only one double interaction may be treated by the F test, the interaction of the fixed variables, OxB, with the triple interaction as the error term.²

The resultant F tests are tabulated on the next page. The effect of Occasions was found to be insignificant as was the double interaction of OxD. However, the effect of Directions was found to be significant at the .01 and .001 levels of confidence.

2. Differences Between Ascending and Descending Thresholds.

It is generally necessary to make a t test following a significant F.³ With Directions having one degree of

¹ Lawrence-T. Dayhaw, Manuel de Statistique, second edition, Ottawa, Editions de l'Universite d'Ottawa, 1963, p. 460.

² Lawrence-T. Layhaw, personal communication, April 1965. These notions differ from his book, p. 461.

³ J.P. Guilford, Fundamental Statistics in Psychology and Education, third edition, New York, McGraw-Hill, 1956, p. 263.

Table II.-

Tests of Significance for Two Principle Effects and One
Double Interaction of CFF.

Source	Variance Estimate	Error Term	F	F.05	F.01
Occasions	.0004450 (4) ^a	.0002337 (160)	1.90	2.37	3.43
Directions	.1091612 (1)	.0020872 (40)	52.29	4.08	7.31
O x D	.0003162 (4)	.0001727 (160)	1.83	2.37	3.43

^a The numbers in the parentheses refer to the degrees of freedom.

freedom the formula $F = t^2$ may be used. This formula is applicable whether or not the two Directions are correlated.⁴ The t value of 7.23 for an N of forty-one is significant at the .001 level of confidence.

Since the Ascending and Descending Directions were significantly different it was necessary to consider the two thresholds as different phenomena, or, at least deal with them statistically as separate entities. As Occasions did not prove to be significant the five trials of Ascending were totalled to give the Ascending CFE and the five Descending trials were totalled to give the Descending CFE.

Table III compares the means and standard deviations of the two thresholds along with the Pearson r coefficient of correlation between them. The Pearson r of .78 demonstrates that the Ascending CFE was consistently lower than the Descending CFE at the .01 level of confidence.

3. Reliability of CFE.

The test-retest estimates of reliability for an N of twenty-six yielded Pearson r correlation coefficients of .939 for the Ascending CFEs and .857 for the Descending CFEs. Significance at the .01 level of confidence for 24 degrees of freedom ($N-2$) requires an r of .496.

⁴ Ibid., p. 427.

Table III.-
Comparison of Statistics for Ascending and Descending CFEs
for an *N* of 41.

Statistic	Ascending <u>CFE</u>	Descending <u>CFE</u>
Sum	125.43	132.12
Mean	3.06	3.22
Standard Deviation	.19	.23
Pearson <u>r</u>		.78

Consequently, these reliability estimates were considered acceptable.

To determine if there was a significant difference between these two correlation coefficients, the \bar{z} test of differences between r 's was applied.⁵ Table IV summarizes this data. The \bar{z} of 1.53 was insignificant which means that the difference between test-retest estimates of reliability for Ascending and Descending CFFs are within the limits of chance fluctuation. In other words, the Ascending CFF is not significantly more reliable a measure than the Descending CFF.

4. CFF and Divergent Thinking.

Table V presents the correlation data as a test of the experimental null hypothesis, namely, the relationship between CFF and scores on tests of divergent thinking. With an N of 39, none of the Pearson r coefficients of correlation between Ascending and Descending CFFs and the five tests of divergent thinking were significant at the .01 level of confidence. Five of the ten correlation coefficients were positive and five were negative and all fell within the limits of chance fluctuation.

⁵ Ibid., p. 194.

Table IV.-

Comparison of Ascending and Descending CFR Test-Retest
Estimates of Reliability for an N of 26.

Statistic	Ascending <u>CFR</u>	Descending <u>CFR</u>
Pearson r	.939	.857
z Coefficient	1.74	1.29
Standard Error of Difference between two z coefficients		2.94
\bar{z} Ratio		1.53

Table V.-

Pearson r Correlation Coefficients between Ascending and Descending CFFs and Scores on Five Tests of Divergent Thinking for an N of 39.

Tests of Divergent Thinking	Ascending <u>CFF</u>	Descending <u>CFF</u>
Alternate Uses	-.212	-.390
Associational Fluency	.004	.013
Ideational Fluency	-.188	-.215
Expressional Fluency	.137	-.133
Word Fluency	.260	.132

5. Discussion.

This final portion discusses the results presented in the first four sections of this chapter. Subsection A focuses attention upon the significant difference between the Ascending and Descending Directions of CFP. Subsection B discusses the correlations between CFP and divergent thinking which support the null hypothesis. Theoretical considerations are outlined in Subsection C.

A. Ascending and Descending CFPs

From the analysis of variance a significant difference was found between Ascending and Descending Directions of CFP. This necessitated two thresholds for each individual, an Ascending CFP and a Descending CFP. Each CFP was the total of five trials. Despite the difference between the two thresholds the correlation coefficient between them was high. Therefore, even though Ascending and Descending CFPs must be treated separately there is a high relationship between them.

There has been very little research devoted to differences between Ascending and Descending CFPs. Four possible explanations appear worthy of discussion: (1) the CFP instrumentation; (2) the psychophysical method used to obtain CFP; (3) possible neurophysiological differences

within the organism in perceiving a light going from flicker to fusion as compared to the process of fusion to flicker; and, (4) possible influences of a psychological nature.

(1) In terms of the instrumentation, Mahneke⁶ has noted that to calculate the mean of Ascending and Descending trials requires the acceleration of frequency to be constant, the same for both thresholds, and be independent of the experimenter. In the present study, the frequency of acceleration was controlled manually by the experimenter and although an attempt was made to be consistent within and between subjects, error was no doubt introduced. However, the test-retest estimates of reliability for both Directions based on twenty-six subjects were well beyond the limits of chance. Thus, it seems that whatever errors were produced by the CFE apparatus and/or the experimenter they were relatively constant.

Dillon⁷ found that if the rate of change of intermittence (acceleration) was less than 5 cps. for each second of elapsed time, the Descending thresholds were higher than the Ascending. On the other hand, if

⁶ A. Mahneke, "Flicker-Fusion Threshold", in Acta Ophthalmologica, Vol. 34, 1956, p. 113-120.

⁷ D. Dillon, "Differences Between Ascending and Descending Flicker-Fusion Thresholds Among Groups of Hospitalized Psychiatric Patients and a Group of Normal Control Persons", in Journal of Psychology, Vol. 48, 1959, p. 255-262.

accelerations were greater than 5 cps. the Ascending thresholds were higher. The rate of change in the present experiment was only 0.5 cps. for each second of elapsed time. The results, therefore, are completely in accord with Dillon's findings.

(2) The Modified Method of Limits, the psychophysical method utilized in this study, may have been a factor in producing the Direction differences. The usual psychophysical Method of Limits for the determination of a stimulus limen requires a report from the subject at specific intervals along the scale until there is a change in response.⁸ It was felt by the author that this method would be too time-consuming and might cause fatigue. The Modified Method of Limits, as recommended by Wagoner,⁹ requires only one response for each trial. Although this procedure is physically easier on the subject, it may not be as accurate as the true Method of Limits.

One constant error appears to have been produced by the psychophysical method, namely, the Error of Expectation.¹⁰ The subjects may have been reporting a

⁸ J.P. Guilford, Psychometric Methods, second edition, New York, McGraw-Hill, 1954, p. 101-115.

⁹ R.A. Wagoner, "Differences in Response Variability Between High and Low Anxiety Subjects in a Flicker-Fusion Task", in Journal of Abnormal and Social Psychology, Vol. 61, No. 3, 1960, p. 355-359.

¹⁰ Guilford, Psychometric Methods, p. 102.

change before it had phenomenally occurred due to heightened attention. It was hoped that the experimental procedure of alternate Directions and varying the starting points for each trial would tend to cancel the Error of Expectation. However, with the consistent and significant difference between the Ascending and Descending CFEs it is quite possible that this constant error was in effect. Moreover, since the Ascending CFE was lower than the Descending, it may indicate that the valid or true CFE may, in actuality, fall between the two obtained thresholds.

(3) Characteristics of a neurophysiological nature may account for differences between Ascending and Descending CFEs. Halstead's neuronal coupling theory of CFE was based only on Ascending trials. He noted that "coupling is direct up to the point (frequency) where fusion occurs, at which point escape or decoupling occurs."¹¹ In Ascending trials, therefore, neuronal synaptic transmission goes from a coupling to a decoupling phase. Or, in the frame of reference of this investigation, there is a facilitating effect followed by an inhibitory effect. What happens neurologically, however, when this procedure is reversed in Descending trials, that is, beginning with a decoupling

¹¹ Ward C. Halstead, Brain and Intelligence, Chicago, University of Chicago Press, 1947, p. 77.

or inhibitory phase and changing to a coupling or facilitating phase? Halstead,¹² Bartley,¹³ and Piéron¹⁴ did not concern themselves with this question. Even Dillon¹⁵ and Mahneke,¹⁶ who studied the disparity between the two thresholds, ignored the possible differences in neurological activity.

(4) Another possible influence upon the CFP measures concerns psychological factors.

Four subjects reported an interesting phenomenon. When the experimenter gave the warning, "Going up" or "Going down", these individuals, apparently through the suggestibility of the words, felt that they perceived the light as rising or falling.

Two subjects stated that the light along with the white noise had a hypnotic effect which made discrimination difficult.

12 Ibid., xiii-206 p.

13 S. Howard Bartley, "Central Mechanisms of Vision", in Handbook of Physiology, Section I: Neurophysiology, Vol. 1, 1959, p. 713-740.

14 H. Piéron, "Vision in Intermittent Light; Laws and Mechanisms of the Critical Frequency for Fusion", in William D. Neff, (ed.), Contributions to Sensory Physiology, Vol. 1, New York, Academic Press Inc., 1965, p. 179-264.

15 Dillon, Op. Cit., p. 255-262.

16 Mahneke, Op. Cit., p. 113-120.

Individual differences were noted as to the assuredness of response. A quick response in many subjects was accompanied by a belief that they were definitely correct. Others had a tendency to wait until they were more sure of their response and, even then, appeared to doubt their discriminatory ability.

These psychological factors are not easy to categorize, making their effect rather difficult to analyze. They are likely indicative of personality differences, which, it is hoped, were not of a confounding influence.

For research utilizing the phenomenon of CFE two points appear imperative: first, unless specifically investigating differences between Ascending and Descending thresholds, only one Direction should be measured; and, second, the instrumentation must have an automatic speed control to equalize the rate of acceleration.

B. CFE and Divergent Thinking

The experimental null hypothesis, that there are no significant relationships between CFE and scores on tests of divergent thinking, was upheld. None of the ten correlation coefficients between the two thresholds and the five psychometric tests was significantly different from chance. Moreover, half of the Pearson r 's were negative.

From these results it would appear logical to accept the null hypothesis. However, the author believes that to accept the null hypothesis would be to commit a type II error.¹⁷ From this study, all that can be stated is that significant relationships between the two variables were not found.

Methodological errors in the experimental design may have contributed to the lack of any significant relationships between CFE and divergent thinking. As previously noted, the significant difference between Ascending and Descending thresholds renders questionable the validity of the CFE measures.

Sampling procedures may have influenced the results adversely. The sample size of thirty-nine was not really large enough to employ the Pearson r statistic with confidence. As well, it is more difficult to obtain high correlations with a relatively homogeneous group, in this case, university students, compared to a heterogeneous group of subjects.

An obvious methodological question pertains to the reliability of Guilford's divergent thinking tests. As a test-retest estimate of reliability was not conducted, the

¹⁷ Guilford, Fundamental Statistics in Psychology and Education, p. 215-217.

split-half method, employing the Spearman-Brown Prophecy Formula¹⁸ was considered. But, Thorndike and Hagen caution, "a split-half reliability coefficient becomes meaningless when a test is highly speeded."¹⁹ Since each of the five divergent thinking tests has a short time limit speed is one of the essential factors. Hence, the split-half reliability was not estimated.

Chatelain²⁰ measured reliability by correlating the scores of two independent scorers. The Pearson r correlation coefficients based on a sample of eighty subjects were: Alternate Uses, .93; Associational Fluency, .93; Ideational Fluency, .98; Expressional Fluency, .92; and Word Fluency, .97. With inter-judge reliability estimates at such a high level it was felt unnecessary to repeat the procedure in the present study.

Barry²¹ has indicated that recent literature offers conclusive evidence that Guilford's tests are reliable.

18 Ibid., p. 452.

19 Robert L. Thorndike and Elizabeth Hagen, Measurement and Evaluation in Psychology and Education, second edition, New York, John Wiley and Sons, 1955, p. 180.

20 Pierre Chatelain, "La Discrimination Auditive et La Pensée Creatrice", unpublished Master's thesis presented to the School of Psychology and Education of the University of Ottawa, Ontario, 1965, 1x-115 p.

21 Wm. F. Barry, personal communication, Faculty of Psychology and Education, University of Ottawa, December, 1966.

Nevertheless, the question of the reliability of Guilford's divergent thinking tests for the particular sample studied remains unanswered.

C. Theoretical Considerations

In the Review of the Literature, CFE was defined justifiably as a measure of retino-cortical activity. Further, CFE was considered to be a possible measure of the efficiency of the organism and of retino-cortical inhibition. It should be emphasized that these latter "definitions" are based on factor analytic studies.^{22,23,24} This technique is dependent upon the tests originally included in the battery and upon the experimenter's ability to interpret the resultant factors. Perhaps more conclusive findings could have been obtained in the present study if other neurophysiological tests were administered along with CFE. By isolating this one measure the author may have lost the effect of other measures that had been included in factors of neurological efficiency and inhibition.

22 Halstead, Op. Cit., xiii-206 p.

23 Gilbert Honigfield, "Neurological Efficiency, Perception, and Personality", in Perceptual and Motor Skills, Vol. 15, No. 2, October 1962, p. 531-553.

24 Wesley C. Becker, "Cortical Inhibition and Extraversion-Introversion", in Journal of Abnormal and Social Psychology, Vol. 61, No. 1, July 1960, p. 52-66.

Two theoretical assumptions noted in the first chapter cannot be appraised due to the inconclusive results and possible methodological errors. These assumptions were: (1) that CPF measured inhibition at the neurological level, and, (2) that tests of divergent thinking measured inhibition at the psychological level.

The underlying hypothesis of this investigation, that facilitation and inhibition at the neurological level are basic premisses of intellectual functioning cannot be evaluated because of the inconclusive findings. Even if a significant relationship between CPF and divergent thinking had been obtained this hypothesis could only be discussed at a conjectural level because of the difficulty of defining CPF. Nevertheless, from Mook's²⁵ findings and recent developments in the field of psychoneurology,²⁶ this hypothesis appears to deserve further scrutiny.

25 B. Mook, "Retino-Cortical Inhibition and Creative Thinking", paper presented to the Annual Conference of the Ontario Psychological Association, Ottawa, February 1966, p. 1-9.

26 F.C.R. Chalke and J. Ertl, "Evoked Potentials and Intelligence", in Life Sciences, Vol. 4, No. 13, April 1965, p. 1319-1322.

SUMMARY AND CONCLUSIONS

The initial step in examining the experimental null hypothesis was the computation of CFP. It had been hoped to combine the five Ascending and five Descending trials to obtain the threshold. However, the results of the analysis of variance based on forty-one subjects demonstrated a significant difference between the two Directions. Consequently, Ascending and Descending CFPs were calculated for each subject.

Reliability estimates of the two CFPs from a test-retest of twenty-six subjects were acceptable. The reliability of the divergent thinking tests was not estimated.

With a final N of thirty-nine, each of the ten correlation coefficients between the Ascending and Descending CFPs and the five tests of divergent thinking were insignificant. Thus, the null hypothesis, that there are no significant relationships between CFP and scores on tests of divergent thinking, was supported. But, the author concluded that the null hypothesis could not be accepted because of possible methodological errors, namely, the validity of the CFP values, sampling procedures, and lack of reliability measures for the divergent thinking tests.

The underlying hypothesis of this investigation, that inhibition and facilitation at the neurological level

may be related to intellectual functioning, remains at a hypothetical level because of the inconclusive results.

Recommendations for further research are as follows:

1. A quantitative and qualitative study of the relationship between Ascending and Descending CFPs and various EEG indices in an attempt to ascertain possible differences in neurological functioning between the two CFP Directions.
2. A correlation study between CFP and evoked cortical potentials since both apparently measure organismic efficiency.
3. Investigation of CFP in relation to the negative after-image threshold with the goal of clarifying and/or defining the CFP phenomenon.
4. A study relating CFP to Guilford's perceptual-visual tests of divergent thinking.

BIBLIOGRAPHY

Becker, Wesley C., "Cortical Inhibition and Extraversion-Introversion", in Journal of Abnormal and Social Psychology, Vol. 61, No. 1, July 1960, p. 52-66.

Well-written critique of inconsistencies and redundancies in the literature on the inhibition phenomenon. In the factor analytic study, CPF found to be one of the measures in the factor entitled, "general cortical inhibition". Valuable reference for theoretical background.

Chatelain, Pierre, "La Discrimination Auditive et La Pensée Creatrice", unpublished Master's thesis, presented to the School of Psychology and Education of the University of Ottawa, Ontario, 1965, ix-115 p.

Significant relationship found between auditory discrimination and creative divergent thinking. Although lacking a strong theoretical framework, it supports the use of Guilford's verbal tests of divergent thinking.

Eccles, J.C., "The Physiology of Imagination", in Scientific American, Vol. 199, No. 3, September 1958, p. 135-146.

Provided the theory for previous studies relating neurophysiological phenomena to divergent thinking. Used only indirectly.

Guilford, J.P. and P.R. Merrifield, "The Structure of Intellect Model: Its Uses and Implications", in Report from the Psychological Laboratory, University of Southern California, No. 24, April 1960, p. 1-27.

"Structure of Intellect Model" fully described along with tests and research findings. The main reference for tests of divergent thinking.

Halstead, Ward C., Brain and Intelligence, Chicago, University of Chicago Press, 1947, xiii-206 p.

One of the pioneer efforts in the field of "biological intelligence". Four main factors found, one of which, the Power factor, led to choice of CPF in the present study.

Honigfield, Gilbert, "Neurological Efficiency, Perception, and Personality", in Perceptual and Motor Skills, Vol. 15, No. 2, October 1962, p. 531-553.

Factor analytic study of neurological efficiency. Literature review covers both theory and research findings. Supports the use of CPF.

Landis, C., "Determinants of CFF Threshold", in Scientific Monthly, Vol. 73, No. 5, November 1951, p. 259-286.

Covers all the important factors involved in testing CFF. Very helpful in designing the CFF experimental procedure.

Mook, B., "Retino-Cortical Inhibition and Creative Thinking", paper presented to the Annual Conference of the Ontario Psychological Association, Ottawa, February 1966, p. 1-9.

Concise summary of Master's thesis. A significant relationship was found between the negative after-image threshold and perceptual-visual tests of divergent thinking. A prime source, particularly in terms of the concept of retino-cortical inhibition and general theory.

Parnes, Sidney J., and Harold E. Harding, A Source Book for Creative Thinking, New York, Charles Scribner's Sons, 1962, xiv-393 p.

The prominent theories and research on the subject of creativity are included in this compendium. A complete bibliography. Good reference book.

Pieron, H., "Vision in Intermittent Light; Laws and Mechanisms of the Critical Frequency for Fusion", in Contributions to Sensory Physiology, Vol. 1, ed. by William D. Neff, New York, Academic Press Inc., 1965, p. 179-264.

A translation from the French. Probably the best review of CFF literature to date. However, very difficult reading.

Vogel, William, and Donald M. Broverman, "Relationship Between EEG and Test Intelligence: A Critical Review", in Psychological Bulletin, Vol. 62, No. 2, 1964, p. 132-144.

A complete and critical review of studies relating EEG indices and psychometric intelligence. Numerous implications.

Wyspianski, John O., "EEG Brain Waves and Creative Thinking", published doctoral dissertation presented to the School of Psychology and Education of the University of Ottawa, Ontario, 1963, viii-178 p.

The significant relationship between EEG brain wave amplitude and creative thinking opened a new field of research possibilities. Recommendations led to the present investigation.

APPENDIX 1

GRAPH FOR CONVERSION OF MILLIAMPERES PER SECOND
TO FLICKERS PER SECOND FOR THE CFF APPARATUS

APPENDIX 1

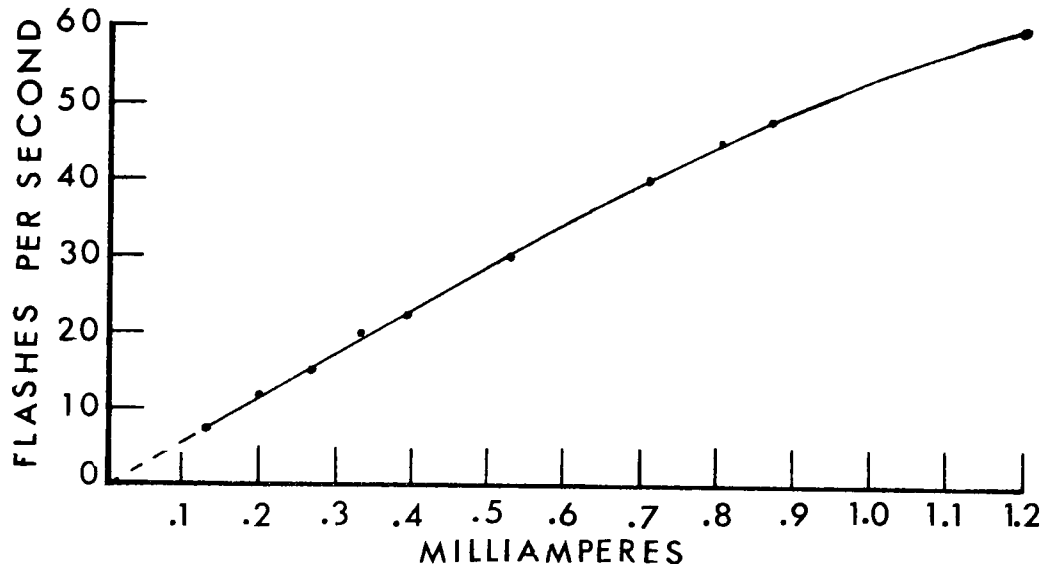


Figure 4.- Graph for Conversion of Milliamperes per Second to Flashes per Second for the GEE Apparatus.

APPENDIX 2

GUILFORD'S TESTS OF DIVERGENT THINKING

1. Alternate Uses
2. Associational Fluency
3. Ideational Fluency
4. Expressional Fluency
5. Word Fluency

FORM "A"

Paul R. Christensen, J. P. Guilford, Philip R. Merrifield
and Robert C. Watson

NAME _____ SEX M _____ SCORES: I _____
F _____ II _____
III _____
GROUP _____ DATE _____ Total _____

In this test, you will be asked to consider some common objects. Each object has a common use, which will be stated. You are to list as many as six other uses for which the object or parts of the object could serve.

EXAMPLE:

Given: A NEWSPAPER (used for reading). You might think of the following other uses for a newspaper.

- a. start a fire
- b. wrap garbage
- c. swat flies
- d. stuffing to pack boxes
- e. line drawers or shelves
- f. make up a kidnap note

Notice that all of the uses are different from each other and different from the primary use of a newspaper. Each acceptable use must be different from others and from common use.

Do not spend too much time on any one item. Write down those uses that occur to you and go on to the others in the same Part. You may return to the incomplete items in a Part if time for that Part permits.

There are three parts to this test, with three items per part. You will have 4 minutes for each part.

If you have any questions, ask them now.

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

PART I

List as many as six possible uses for each of the following objects:

1. SHOE (used as footwear)

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____
- f. _____

2. BUTTON (used to fasten things)

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____
- f. _____

3. KEY (used to open a lock)

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____
- f. _____

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

PART II

List as many as six possible uses for each of the following objects:

4. CHAIR (used for sitting)

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____
- f. _____

5. WATCH (used for telling time)

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____
- f. _____

6 SAFETY PIN (used for fastening)

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____
- f. _____

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

PART III

List as many as six possible uses for each of the following objects:

7. WOODEN PENCIL (used for writing)

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____
- f. _____

8. AUTOMOBILE TIRE (used on the wheel of an automobile)

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____
- f. _____

9. EYEGLASS (used to improve vision)

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____
- f. _____

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

ASSOCIATION FLUENCY I

Form "A"

By Paul R. Christensen and J. P. Guilford

NAME _____ SEX: M _____ F _____ SCORES: I _____ II _____ Total _____

In this test you are to write words similar in meaning to the given word.

SAMPLE ITEM:

Write words similar in meaning to the word HARD.

HARD:

difficult severe
solid unfeeling
tough _____
stiff _____

Notice that the words written above are all somewhat like the word HARD in meaning. In the test you are to write as many words as you can that are similar in meaning to the given word.

WAIT FOR THE SIGNAL BEFORE TURNING THIS PAGE.

Write as rapidly as you can. Avoid using a word more than once. Your score will be the total number of words you write (similar in meaning to the given word).

There are two parts to this test. You will have 2 minutes for each part.

Are there any questions?

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

PART I

a. CALM:

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b. FOUL:

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STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

IDEATIONAL FLUENCY 1

Form " A "

By Paul R. Christensen and J. P. Guilford

NAME _____ SEX: M _____ SCORES: I _____
F _____ II _____
III _____
IV _____

GROUP _____ DATE _____ Total _____

In this test you are to name things that belong in certain classes.

SAMPLE ITEM:

Name FLUIDS that will
BURN.

gasoline
Kerosene
hydrogen
alcohol

In this sample item, the task is to make a list of fluids that will burn. Four such fluids have been listed by way of example. Of course, there are many other answers that could be listed.

For this test, a fluid is any non-living thing that is liquid or gas. A solid is any non-living thing that is not liquid or gas.

The items in this test will be somewhat like the sample item above. Your task will be to write as many things as you can that belong to certain classes. If you are not certain whether a thing fits the class, write it down anyway and try to think of another suitable thing.

WAIT FOR THE SIGNAL BEFORE TURNING THIS PAGE.

There will be four parts to this test. You will have 3 minutes per part. Are there any questions?

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

EXPRESSIONAL FLUENCY

FORM " A "

By Paul R. Christensen and J. P. Guilford

NAMA				M	1
(Print)	Last	First	Middle	SEX	SCORE
				F	11
					111
					1V

GROUP	DATE	Total
_____	_____	_____

In this test you are to write sentences using words that begin with the given letters: K, u, y, and i, in that order. The test contains items similar to this one. You will be required to write as many four-word sentences as you can, using words that begin with the given letters.

WAIT FOR THE SIGNAL BEFORE TURNING THIS PAGE.

SAMPLE ITEM:

K *keep* *u* *up* *y* *your* *i* *interest*

K *kill* *u* *release* *y* *yellow* *i* *insects*

K *kidnapping* *u* *insects* *y* *young* *i* *infants*

K _____ *u* _____ *y* _____ *i* _____

The task in this item is to write sentences using words that begin with the given letters: K, u, y, and i, in that order. The test contains items similar to this one. You will be required to write as many four-word sentences as you can, using words that begin with the given letters.

WAIT FOR THE SIGNAL BEFORE TURNING THIS PAGE.

All sentences should make sense and be complete. Avoid using the same word twice. Your score will be the number of acceptable sentences you write in the time allowed.

There are four parts to this test. You will have 2 minutes for each part. Are there any questions?

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

PART 1V

a r g
a r g
a r g
a r g
a r g
a r g
a r g
a r g
a r g
a r g
a r g
a r g
a r g
a r g
a r g
a r g
a r g
a r g

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

WORD FLUENCY

Form "A"

By Paul R. Christensen and J. P. Guilford

NAME _____ SEX: M _____ SCORES: 1 _____
F _____ 11 _____
GROUP _____ DATE _____ Total _____

In this test you are to write words that contain a certain letter of the alphabet. This will be a different letter in each item of the test.

SAMPLE ITEM:

Write words containing the letter O

<u>load</u>	<u>provide</u>	_____
<u>pot</u>	<u>fought</u>	_____
<u>over</u>	<u>loss</u>	_____
<u>too</u>	_____	_____

All the words written above contain the letter "O" at least once.

WAIT FOR THE SIGNAL BEFORE TURNING THIS PAGE

Avoid using a word more than once; avoid even different forms of the same word, such as "bond" and "bonded." Your score will be the number of words that you write containing the given letter during limited time, so work rapidly.

There are two parts to this test. You will have 2 minutes for each part.

Are there any questions?

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

APPENDIX 3

ABSTRACT OF

An Investigation of Possible Relationships Between
Critical Flicker Frequency and
Divergent Thinking

APPENDIX 3

ABSTRACT OF

An Investigation of Possible Relationships Between Critical Flicker Frequency and Divergent Thinking¹

With roots in the age old body-mind problem, possible relationships between psychophysiological phenomena and intellectual functioning have long been of concern to psychology.

This paper proposed and experimentally investigated possible relationships between CFF and divergent thinking, the psychophysiological and intellectual activity, respectively. The literature indicated that CFF may be associated with the ability to think divergently, the common element being inhibitory effects, both neurological and psychological. The underlying hypothesis stated that facilitation and inhibition at the neurological level are basic premises of intellectual functioning.

Testing a total of thirty-nine subjects, a significant difference was obtained between Ascending and Descending Directions of CFF. Insignificant relationships were found

¹ Gayle Wm. Dumsday, Master's thesis presented to the Faculty of Psychology and Education of the University of Ottawa, Ontario, February 1967, viii-81 p.

between these thresholds and scores on tests of divergent thinking, thus supporting the experimental null hypothesis.

From evidence pertaining to the possible introduction of methodological errors the author concluded that acceptance of the null hypothesis was unjustified.

Suggestions are made for further research.