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# Influence of Handedness of the Application of Acetylcholine and Glutamic Acid to the Motor Cortex of the Albino Rat

Donald G. Doehring

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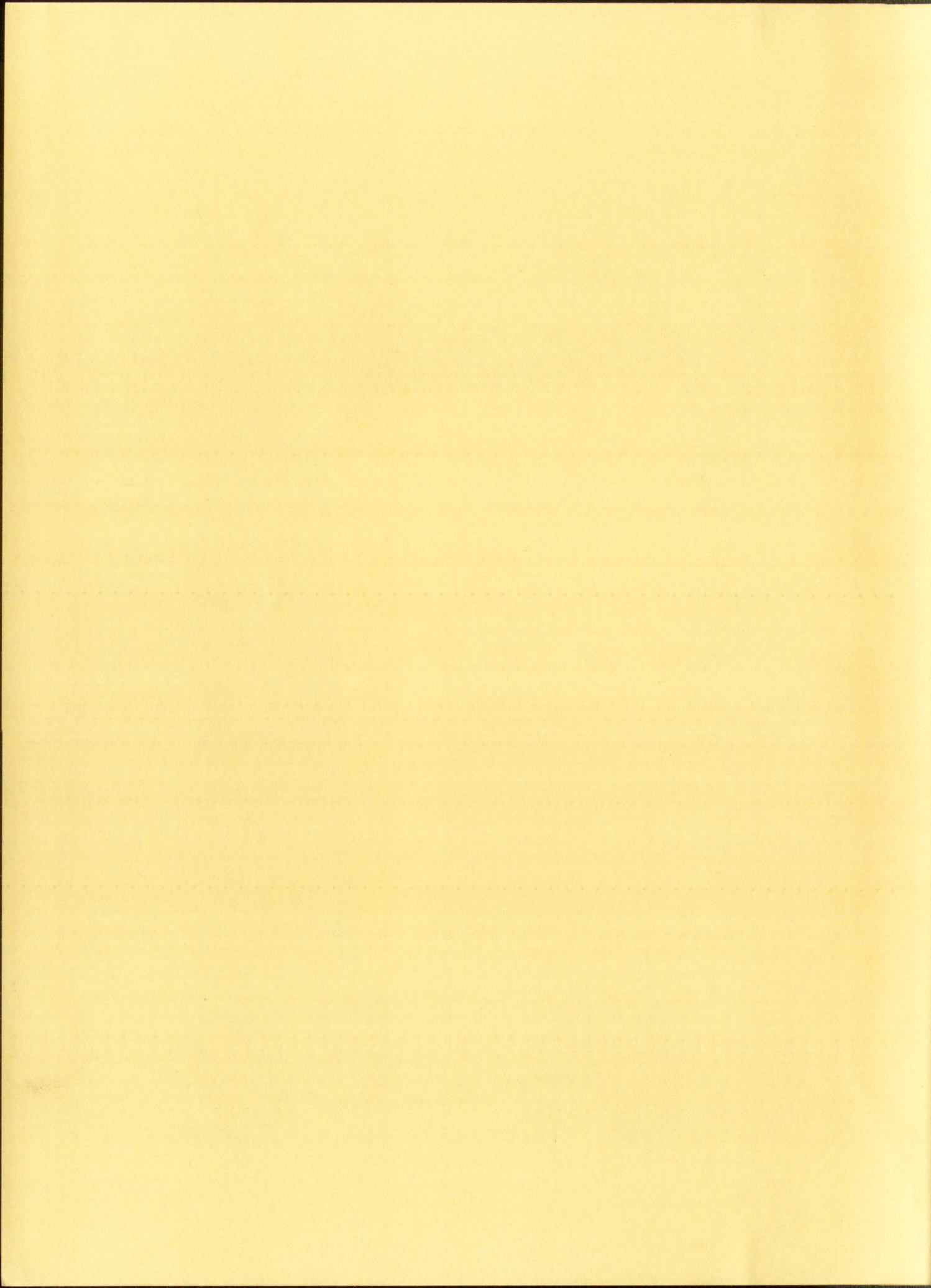
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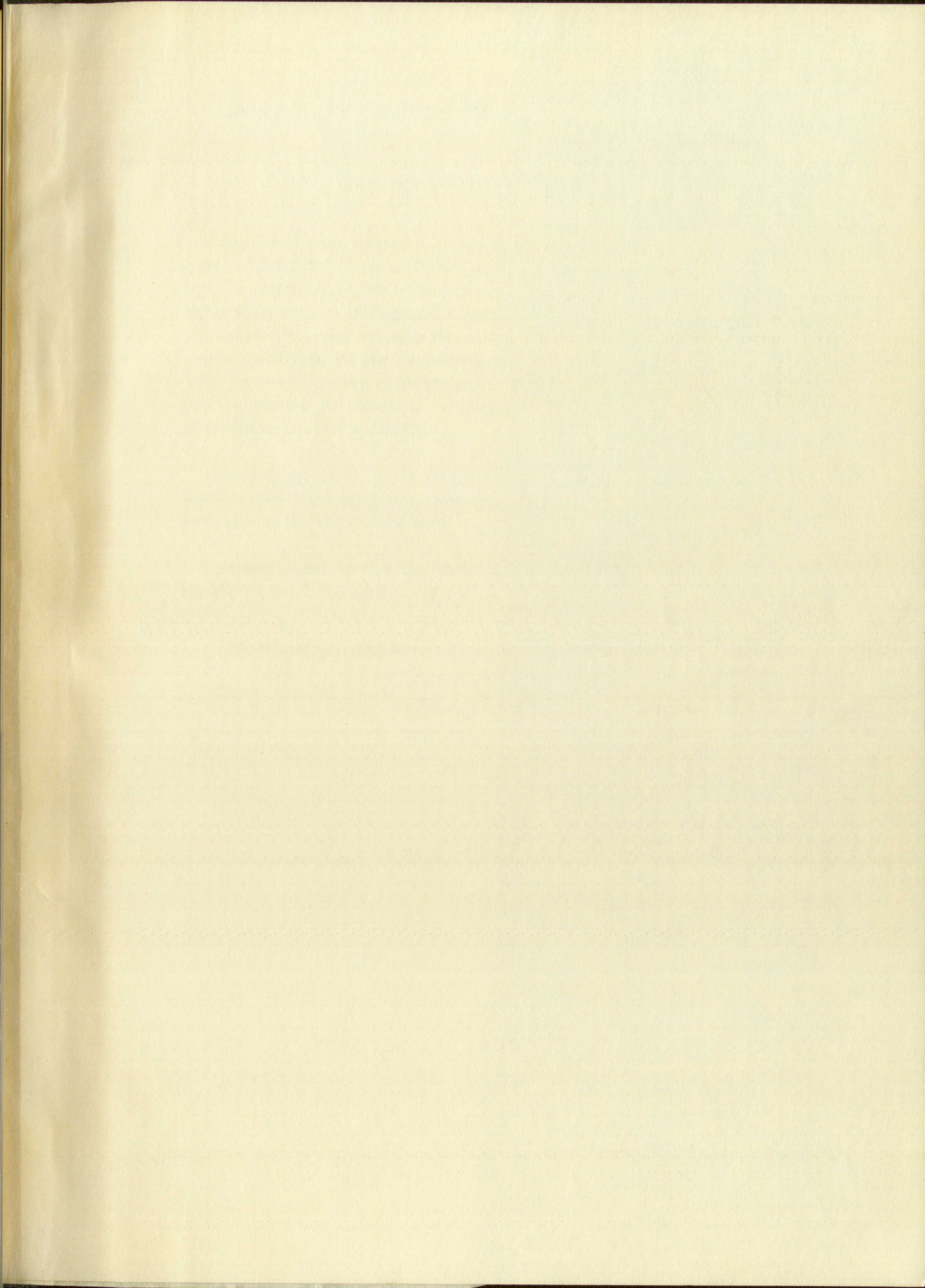
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INFLUENCE ON HANDEDNESS OF  
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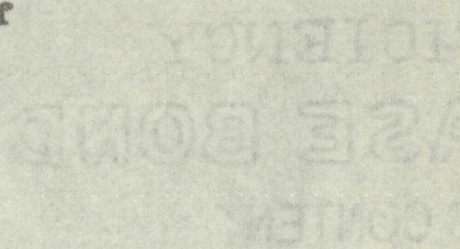
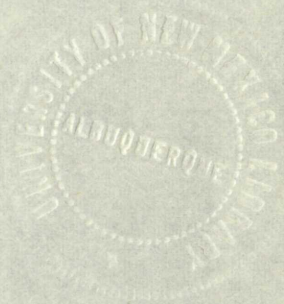
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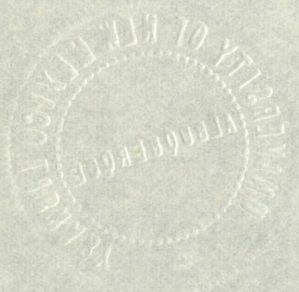
In partial fulfillment of the  
Requirements for the Degree of  
Master of Arts in Psychology

The University of New Mexico  
1951





THE UNIVERSITY OF KENTUCKY  
THE APPLICANTS OF THE UNIVERSITY OF KENTUCKY  
GEORGIAN ACID TO THE MOTOR COMPANY OF THE STATE OF



1911

1911

in partial fulfillment of the  
requirements for the degree of  
Master of Arts in Education

EFFICIENCY  
BASE BOND  
CONTENT

The University of the South  
1911



This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

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Introduction and Statement of the Problem. Neuro-physiologists have devoted much time to the study of the method of transmission of the nerve impulse. After the development of adequate electrical measuring instruments the best explanation of transmission seemed to be in terms of electrical changes. The impingement of a stimulus results in a depolarization of the cell membrane at the region of impingement. This depolarization in turn depolarizes the adjacent region of the neuron and so on, resulting in a difference in electrical potential which travels to an appropriate region of the nervous system. Later investigators found evidence of chemical transmission of impulses in certain parts of the organism. Further investigation revealed that the chemical involved could be found in other parts of the nervous system and a theory of chemical transmission of nerve impulses throughout the entire nervous system was formulated. The mode of chemical transmission which was discovered involves acetylcholine (Ach). The Ach theory did not supplant the electrical theory, but was used in conjunction with it. It was postulated that Ach aids in the electrical transmission of nerve impulses by acting as the agent which depolarizes the neuron membrane.

In explaining learning some psychologists make use of the nervous system and some do not. Those who do not



Introduction and Statement of the Problem.

Physiologists have devoted much time to the study of the method of transmission of the nerve impulse. After the development of accurate electrical measuring instruments the best explanation of what has been observed is that in the region of electrical changes, the impingement of a stimulus results in a depolarization of the cell membrane at the region of impingement. This depolarization in turn depolarizes the adjacent region of the neuron and so on, resulting in a difference in electrical potential which travels to an appropriate region of the nervous system. Later investigators found evidence of chemical transmission of impulses in certain parts of the organism. Further investigation revealed that the chemical involved could be found in other parts of the nervous system and a theory of chemical transmission of nerve impulses throughout the entire nervous system was formulated. The mode of chemical transmission which was described involved acetylcholine (ACh). The ACh theory did not support the electrical theory, but was used in conjunction with it. It was postulated that ACh acts in the electrical transmission of nerve impulses by acting as the agent which depolarizes the neuron membrane.

In explaining learning some psychologists make use of the nervous system and some do not. Those who do not



make use of the nervous system consider that it is best to postulate an "empty organism" and build up learning theories based on observation of the overt behavior of the organism. Despite the influence of such theories investigations of the neurology of learning have been carried on for many years. The immense structural complexity of the cerebral cortex possesses a great attraction for theorists who would like to explain learning in terms of the establishment of fixed patterns of cortical connections. The repeated passage of impulses through a certain part of the motor cortex, for instance, would lay down a neural "trace," which would make it easier for impulses to pass through that part of the cortex again. Since the motor cortex controls movements, the laying down of a trace or path in a certain area should make it easier for the organism to make the movements which are controlled by that area. Thus practice would result in the formation of more or less fixed neural pathways for impulses in the motor cortex.

Peterson thought that it would be worth while to investigate practice in terms of the establishment of neural connections. Since Ach facilitates the passage of nerve impulses, he thought that application of Ach to a specific area of the motor cortex might result in spontaneous firing of the neurons of the region. Practice is assumed to consist



make use of the nervous system and that it is best to postulate an "empty organ" and build up learning theories based on observation of the overt behavior of the organism. Despite the fallacies of this behaviorist approach, the neurology of learning have been reported in many years. The immense structural complexity of the cerebral cortex possesses a great attraction for theorists and would like to explain learning in terms of the establishment of fixed patterns of cortical connections. The repeated passage of impulses through a certain part of the motor cortex, for instance, would lay down a neural "trace", which would make it easier for impulses to pass through that part of the cortex again. Since the motor cortex controls movements, the laying down of a trace or habit in a certain area would make it easier for the organism to make the movements which are controlled by that area. This practice would result in the formation of more or less fixed neural pathways for impulses in the motor cortex.

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in part of neural action in a specific cortical area; therefore the application of Ach to a specific area might act as practice for the movements controlled by that area. Preferential handedness is a relatively simple and clear-cut movement pattern. Peterson had located the cortical handedness area of the rat and had shown that handedness preference can be influenced by forced practice in the food situation.<sup>1,2</sup> Therefore he thought that if application of Ach to the handedness area of a rat's cortex resulted in a swing over to the use of the contra lateral (non-preferred) limb it would provide evidence for a neural explanation of practice.

The first investigation carried out by Peterson consisted of the application of Ach to that motor cortex which controlled the non-preferred hand.<sup>3</sup> Both ambidextrous and single-handed rats were used and a certain amount of change in preferential handedness was noted in some of the rats. No control rats were used. Later investigations made use of

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<sup>1</sup>G. M. Peterson, "Mechanisms of Handedness in the Rat," Comparative Psychology Monographs, 1934, 9, 1-67.

<sup>2</sup>G. M. Peterson, "Transfers of Handedness in the Rat from Forced Practice," Journal of Comparative Psychology, In Print.

<sup>3</sup>G. M. Peterson, "Changes in Handedness in the Rat by Local Application of Acetylcholine to the Cerebral Cortex," Journal of Comparative and Physiological Psychology, 1949, 42, 404-412.



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1. D. M. Peterson, "Mechanisms of Handedness in the  
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2. D. M. Peterson, "Transfer of Handedness in the  
Rat from Forced Practice," Journal of Comparative Psychology,  
In Print.

3. D. M. Peterson, "Changes in Handedness in the Rat by  
Local Application of Anesthesia to the Cerebral Cortex,"  
Journal of Comparative and Physiological Psychology, 1957,  
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Ach by itself and in combination with other chemical substances which had been found to prevent the breaking-up of Ach for a certain period of time.<sup>4, 5</sup> As yet none of these studies have produced consistently positive results.

The Problem. The purpose of this study was to repeat the experimental design used in Suess' study, i. e., to attempt to influence the handedness of ambidextrous rats by application of Ach and glutamic acid to the motor cortex.<sup>6</sup> This study was a slight departure from that of Suess in that more post-operational reaches were taken.

Importance of the Study. If Ach or glutamic acid or a combination of the drugs would cause a statistically significant transfer in preferential handedness it would give some indication of the role of the motor cortex in practice and justify further investigation along the same lines. Such investigations, if successful, would throw some light on the physiological processes involved in

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<sup>4</sup>G. M. Peterson and J. W. Rigney, "Influence on Handedness of Acetylcholine Locally Applied with other Chemicals to the Cerebral Cortex of the Rat," Journal of Comparative and Physiological Psychology, 1950, 43, 264-272.

<sup>5</sup>E. R. Suess, "Influence on Handedness of Local Application of Acetylcholine with Glutamic Acid to Cerebral Cortex of the Rat," (unpublished Master's thesis, The University of New Mexico, Albuquerque, 1949).

<sup>6</sup>Ibid.



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<sup>1</sup>U. A. Peterson and J. W. Riney, "Influence on Hardness of Acetylcholine Locally Applied and Other Chemicals to the General Cortex of the Rat," Journal of Comparative and Physiological Psychology, 1950, 43, 264-272.

<sup>2</sup>E. R. Sness, "Influence on Hardness of Local Application of Acetylcholine with Vitamin Acid to Motor Cortex of the Rat," (unpublished master's thesis, The University of New Mexico, Albuquerque, 1949).

<sup>3</sup>Ibid.



learning.

Review of the Literature. I. Acetylcholine. As stated previously, an electrical theory was the first theory which seemed to fit the observed manifestations of neural activity. Chemical theories, however, had already been propounded for special cases of neural transmission. In 1905 T. R. Elliott suggested that an adrenalin-like substance might be liberated at sympathetic nerve endings which acted upon the effector cells.<sup>7</sup> Loewi, in 1921, found that when the vagus nerve leading to the heart of a frog was stimulated a substance could be found in the Ringer solution in the heart which would cause an effect similar to vagus stimulation, when applied to another heart. He called the substance "Vagusstoff," thinking that it was released from the vagus nerve. He also found that the effect of the Vagusstoff was heightened when it was used in conjunction with eserine.<sup>8</sup>

Vagusstoff has been identified as acetylcholine (Ach), an unstable ester of choline. It is formed from acetic acid and choline. Its structural formula is:

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<sup>7</sup>D. Nachmansohn, "The Role of Acetylcholine in the Mechanisms of Nerve Activity," Vitamins and Hormones, 1945, 3, p. 338.

<sup>8</sup>Ibid., pp. 338-339.



Review of the literature. I. Acetylcholine. 22

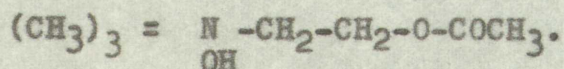
stated previously in electrical theory was the first theory which seemed to fit the observed manifestations of neural activity. Chemical theories, however, had already been propounded for special cases of neural transmission. In 1902 T. N. Sillcock suggested that an adrenaline-like substance might be liberated at sympathetic nerve endings which acted upon the effector cells. Lewis, in 1921, found that when the vagus nerve leading to the heart of a frog was stimulated a substance could be found in the Ringer solution in the heart which would cause an effect similar to vagus stimulation, when applied to another heart. He called this substance "Vagusstoff", thinking that it was released from the vagus nerve. He also found that the effect of the Vagusstoff was heightened when it was used in conjunction with eserine.<sup>6</sup>

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<sup>6</sup> D. Neumann, "The Role of Acetylcholine in the Mechanism of Nerve Activity," Wiley and Sons, 1945, p. 338.

<sup>6</sup> Ibid., pp. 338-339.





It is hygroscopic, very soluble in water and alcohol, and is easily decomposed by heat and alkali.<sup>9</sup> Ach is broken down by an enzyme, cholinesterase. The action of cholinesterase is impeded by eserine, explaining Loewi's results.

Dale and Kibjakow suggested that Ach acted as a transmitter across ganglionic synapses and neuromuscular junctions, using as evidence the same type of experiments as those performed by Loewi. In all of these experiments Ach was considered to function in bridging the gap at synaptic junctions. The evidence used was the presence of Ach in perfusion fluid after neural stimulation.<sup>10</sup>

Nachmansohn approached the study of Ach from a different angle.<sup>11</sup> He reasoned that since cholinesterase hydrolyzed Ach, the presence of Ach in neural tissue could be inferred from the presence of cholinesterase, and the rate of removal of Ach could be inferred from the degree of concentration of cholinesterase in a given tissue. This method was used because of the difficulty of obtaining Ach from

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<sup>9</sup>Goodman and Gilman, The Pharmacological Basis of Therapeutics. New York: The MacMillan Company, 1941, p. 351.

<sup>10</sup>Nachmansohn, op. cit., p. 339.

<sup>11</sup>Ibid., p. 341.







neural tissue.

It was believed that a major objection to a chemical theory of transmission was that Ach could not be removed fast enough to account for the very rapid rate of conduction in certain parts of the nervous system. Nachmansohn showed in several experiments that the concentration of cholinesterase was high enough to account for a sufficiently rapid removal of Ach.<sup>12</sup>

Besides showing that Ach could be removed rapidly enough to account for rapid neural conduction, Nachmansohn suggested a new role for Ach.<sup>13</sup> Instead of acting as a synaptic transmitter he said that it acted along the membrane of the neuron in conjunction with the transmission of electrical current along the neuron. The increase in end arborizations at the synapse would create sufficient current to bridge the synaptic gap without postulating a special substance of transmission. The action of Ach along the neural membrane, then, was to increase the permeability of the membrane. In the resting state of the neuron the membrane is selectively permeable to potassium ions. When the

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<sup>12</sup>Ibid., pp. 341-346.

<sup>13</sup>Ibid., pp. 358-360.



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12 1918, pp. 361-366.

13 1918, pp. 358-360.



permeability is increased a free flow of ions occurs, resulting in depolarization of that portion of the membrane. This depolarization induces a depolarization of the adjacent portions of the neuron, where the Ach has successively increased the permeability of the membrane. This process continues along the neuron and across the synapse to its eventual destination, and the total result is a nerve impulse. Ach, then, at all times acts in conjunction with the flow of current and thus this theory is in accordance with an electrical theory of transmission.

One of the proofs advanced for the theory was Nachmansohn's experiment on electric eels.<sup>14</sup> He found that voltage in the electric organ of *Electrophorus electricus* varies in an S-shaped curve from head to tail. The quantity of cholinesterase was found to vary in exactly the same manner. This indicates that the strength of electrical charges is positively correlated with the amount of Ach present.

Nachmansohn explains the common discovery of Ach at synaptic junctions in two ways:

- (1) Since there are a multitude of end arborizations

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<sup>14</sup>Ibid., pp. 351-358.



permeability is increased a free flow of ions occurs, resulting in depolarization of that portion of the membrane. This depolarization induces a secondary depolarization of the adjacent portions of the neuron, where the ACh has successive-ly increased the permeability of the membrane. This process continues along the neuron and a rapid wave of depolarization, or action potential, is set up. The total result is a nerve impulse. ACh, then, at all times acts in conjunction with the flow of current and thus this theory is in accordance with an electrical theory of transmission.

One of the proofs advanced for this theory was Washburn's experiment on electric eels. He found that voltage in the electric organ of *Electrophorus electricus* varies in an S-shaped curve from half to full. The quantity of cholinesterase was found to vary in exactly the same manner. This indicates that the strength of electrical charges is positively correlated with the amount of ACh present.

Washburn's explanation of the common discovery of ACh at synaptic junctions is the way:

(1) Since there are a multitude of end-plates



at the synapse Ach leaks out into the perfusion fluid, being originally contained within the cell membrane.<sup>15</sup>

(2) The reason that Ach is not found at the surface of the neuron is that axonal surface membranes are impervious to Ach, probably because Ach is lipid insoluble and there is a lipid membrane surrounding all axons. The end arborizations do not have this lipid coating, allowing the Ach to escape into the perfusion fluid.<sup>16</sup>

As to the generality of Ach action, Nachmansohn and others showed by experiments with cholinesterase inhibitors that it is "highly probable that the Ach system plays an identical role in the conducting mechanism of all types of nerve and of muscle."<sup>17</sup>

Electrocorticogram changes resulting from the application of Ach to the cortex have been found. For example, Miller, Stravraky and Woonton found that the application of esserine to the cortex of cats and rabbits depressed

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<sup>15</sup>Ibid., pp. 370-371.

<sup>16</sup>Rothenberg, Sprinson and Nachmansohn, "Site of Action of Acetylcholine," Journal of Neurophysiology, 1948, 11, 111-116.

<sup>17</sup>T. H. Bullock, H. Grundfest, D. Nachmansohn, and M. A. Rothenberg, "Generality of the Role of Acetylcholine in Nerve and Muscle Conduction," Journal of Neurophysiology, 1947, 10, 11-22.



at the synapse act back out into the perisynaptic fluid  
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 M. A. Rosenbaum, "Generality of the Role of Acetylcholine  
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 1947, 10, 11-22.



slow and fast waves of the electrocorticogram.<sup>18</sup> When Ach was applied to the eserinizied cortex large rapid waves consisting of diphasic spikes appeared. These spikes were similar to those produced by strychninization of the cortex. Chatfield and Dempsey, using cats, applied Ach to the cortex, which had previously been treated with prostigmine, and found that fast large waves were produced in the somesthetic, motor, and auditory areas, but not in the association area.<sup>19</sup>

II. Glutamic Acid. Glutamic acid is officially classified as a "non-essential" amino acid, but it seems to be the only amino acid which is metabolized by brain tissue.<sup>20</sup> There are two forms of glutamic acid, the l ( ) and d (-) forms. The l ( ) form is the natural glutamic acid but Kogl states that glutamic acid obtained from the proteins of cancerous tissues contains the d (-) form.<sup>21</sup> According to Krebs, glutamic acid is of special importance

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<sup>18</sup>F. R. Miller, G. W. Stravraky, and G. A. Woonton, "Effects of Eserine, Acetylcholine and Atropine on the Electroencephalocorticogram," Journal of Neurophysiology, 1940, 3, 131-138.

<sup>19</sup>Chatfield and Dempsey, American Journal of Physiology, 1941, 135, 663.

<sup>20</sup>B. Harrow, Textbook of Biochemistry, Philadelphia and London: W. B. Saunders Company, 1947.

<sup>21</sup>Ibid., p. 52.



slow and fast waves of the electrocorticogram.<sup>19</sup> When ACh was applied to the unanesthetized cortex large rapid waves consisting of biphasic spikes appeared. These spikes were similar to those produced by administration of the cortex. Chastell and Demsey, using cats, applied ACh to the cortex, which had previously been treated with picrotoxin, and found that fast large waves were produced in the somesthetic, motor, and auditory areas, but not in the association areas.<sup>19</sup>

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<sup>19</sup> R. Miller, G. W. Staszewsky, and G. W. Woodson, "Effects of Serine, Acetylcholine and Atropine on the Electrocorticogram," Journal of Neurophysiology, 1940, 3, 131-138.

<sup>20</sup> Chastell and Demsey, American Journal of Physiology, 1941, 135, 663.

<sup>21</sup> G. Harrow, Textbook of Biochemistry, Philadelphia and London: W. B. Saunders Company, 1937.



in the metabolism of nervous tissue.<sup>22</sup>

The petit mal form of epilepsy has been successfully treated with glutamic acid, the number of attacks sometimes being reduced by as much as eighty-five per cent. Rats which were fed the l form of glutamic acid showed a statistically significant increase in learning ability, according to an experiment reported by Harrow.<sup>23</sup> The use of glutamic acid on human subjects has failed to confirm the results reported by Harrow.<sup>24</sup>

Of more importance to this study is an experiment of Nachmansohn where it is shown that l glutamic acid increases the rate of formation of Ach in dialyzed brain tissues. The d form had only a small effect.<sup>25</sup> On the basis of such evidence Harrow believed that glutamic acid may be a coenzyme of choline acetylase, the substance which synthesizes Ach.<sup>26</sup>

III. Handedness. In 1934 Peterson published a comprehensive report on handedness in rats, including the

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<sup>22</sup>Ibid., p. 373.

<sup>23</sup>Ibid., p. 537.

<sup>24</sup>D. G. Ellison, P. R. Fuller, and R. Urmston, "The Influence of Glutamic Acid on Test Performance," Science, 1950, 112, 248-250.

<sup>25</sup>Nachmansohn, op. cit., pp. 366-367.

<sup>26</sup>Harrow, op. cit., p. 539.



in the metabolism of nervous tissue.<sup>22</sup>

The pathic form of epilepsy has been success-

fully treated with glutamic acid, the number of attacks sometimes being reduced by as much as eighty-five per cent.

Rats which were fed the  $\beta$  form of glutamic acid showed a statistically significant increase in learning ability, ac-

cording to an experiment reported by Barron.<sup>23</sup> The use of glutamic acid on human subjects has failed to confirm the

results reported by Barron.<sup>24</sup>

Of more importance to this study is an experiment

of Nechemson where it is shown that  $\beta$  glutamic acid in-

creases the rate of formation of ACh in diseased brain

tissues. The  $\beta$  form has only a small effect.<sup>25</sup> On the

basis of such evidence Barron believed that glutamic acid

may be a coenzyme of choline acetylase, the substance

which synthesizes ACh.<sup>26</sup>

III. Henderson. - In 1934 Peterson published a

comprehensive report on Henderson in rats, including the

<sup>22</sup> Ibid., p. 273.

<sup>23</sup> Ibid., p. 237.

<sup>24</sup> D. G. Willson, F. G. Fuller, and E. Umston, "The Influence of Glutamic Acid on Test Performance," Science, 1950, 112, 248-250.

<sup>25</sup> Nechemson, op. cit., pp. 366-367.

<sup>26</sup> Barron, op. cit., p. 237.



results of a number of experiments which he had conducted.<sup>27</sup> He found that right handedness and left handedness probably occur with equal frequency in rats, and ambidexterity occurs much less frequently. Handedness is stable in a given situation, but may be different in different situations. The portion of the cerebrum which is primarily involved in controlling handedness seems to be somewhere in the frontal part of the contralateral hemisphere; the approximate area can be determined by electrical stimulation of the cortex. Small destructions in this area result in apparently permanent transfer of handedness, but re-education of the formerly preferred limb is possible. Large destructions not involving the area do not effect preferential handedness, indicating a relatively high localization of function for this trait.

Peterson and Carter found that the application of strychnine, alcohol, potassium cyanide, atropine sulphate and caffeine sulfate to either the homolateral or contralateral area had no influence on preferential handedness.<sup>28</sup>

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<sup>27</sup>G. M. Peterson, "Mechanisms of Handedness in the Rat," Comparative Psychology Monographs, 1934, 9, 1-67.

<sup>28</sup>G. M. Peterson and G. W. Carter, "The Local Application of Drugs to the Motor Cortex of the Rat," Journal of Comparative Psychology, 1936, 22, 123-129.



results of a number of experiments which he has conducted. He found that right handedness and left handedness probably occur with equal frequency in rats, and ambidexterity occurs such less frequently. Handedness is stable in a given situation, but may be different in different situations. The portion of the cerebrum which is primarily involved in controlling handedness seems to be somewhere in the frontal part of the contralateral hemisphere; the approximate area can be determined by electrical stimulation of the cortex. Small destructions in this area result in apparently permanent transfer of handedness, but re-education of the formerly preferred limb is possible. Large destructions not involving the area do not affect preferential handedness, indicating a relatively high localization of function for this trait.

Peterson and Carter found that the application of strychnine, alcohol, potassium cyanide, atropine sulphate and caffeine sulfate to either the neocortex or contralateral area had no influence on preferential handedness.

27. M. Peterson, "Mechanism of Handedness in the Rat," Comparative Psychology Monographs, 1936, 1, 1-27.

28. M. Peterson and G. W. Carter, "The Local Application of Drugs to the Motor Cortex of the Rat," Journal of Comparative Psychology, 1936, 29, 123-129.



Peterson and Fracarol performed a number of operations in various cortical locales in 1938, using ambidextrous rats.<sup>29</sup> From the results they concluded that the cortical region for the control of handedness can be specifically localized in a region 250 microns posterior to the genu of the corpus callosum, directly over the dorsal convexity of the caudate nucleus, and lies below layer III of the cortex, probably in level V.

Peterson and Chaplin concluded on the basis of results of cerebellar and cortical operations that the pyramidal systems of the cortex predominate in controlling handedness of the rat.<sup>30</sup>

In view of the evidence for the role of Ach in neural conduction Peterson applied it to the handedness area which controlled the non-preferred limb in order to ascertain whether it would facilitate transfer of handedness.<sup>31</sup> 108

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<sup>29</sup>G. M. Peterson, and L. C. Fracarol, "The Relative Influence of Locus and Mass of Destruction Upon the Control of Handedness by the Cerebral Cortex," Journal of Comparative Neurology, 1938, 68, 173-190.

<sup>30</sup>G. M. Peterson and J. P. Chaplin, "Extrapyramidal Mechanisms in Handedness in the Rat," Journal of Comparative Psychology, 1942, 33, 343-361.

<sup>31</sup>G. M. Peterson, "Changes in Handedness in the Rat by Local Application of Acetylcholine to the Cerebral Cortex," Journal of Comparative and Physiological Psychology, 1949, 42, 404-412.







single handed rats and forty-two ambidexters were used. Transfer occurred in two of the single handed rats and fifteen of the ambidexters. This indicated that not only did the drug seem effective, but ambidextrous rats were more sensitive to the influence. Clonic contractions of the contralateral fore-limb after application of the drug showed that the drug was affecting the proper cortical area.

Peterson and Rigney used a combination of drugs along with Ach in a factorial design.<sup>32</sup> They found that Ach had a barely significant positive effect in influencing handedness, glycine had no effect and di-isopropylfluorophosphate tended to have a negative effect. In a preliminary study not employing a factorial design they found that in one of two cases an application of Ach and glutamic acid to the handedness area controlling the non-preferred limb produced transfer, and in a single case where Ach, glutamic acid and eserine were applied transfer occurred.<sup>33</sup>

Peterson and Suess employed a factorial design to test the effects of Ach and the two forms of glutamic acid

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<sup>32</sup>G. M. Peterson and J. W. Rigney, "Influence on Handedness of Acetylcholine Locally Applied with Other Chemicals to the Cerebral Cortex of the Rat," Journal of Comparative and Physiological Psychology, 1950, 43, 264-272.

<sup>33</sup>Ibid., pp. 264-265.



single handed rats and two handed rats were used.  
Transfer occurred in two of the single handed rats and  
fifteen of the two handed rats. This indicated that not only  
did the drug seem effective, but single handed rats were  
more sensitive to the influence. Similar contractions of  
the contralateral forelimb after application of the drug  
showed that the drug was effective in the proper control  
area.

Peterson and Gliner used a combination of drugs along  
with Ach in a factorial design.<sup>32</sup> They found that Ach had  
a barely significant positive effect in inflicting hand-  
ness, glycine had no effect and di-terephthaloylserine  
tended to have a negative effect. In a preliminary study  
not employing a factorial design they found that in one of  
two cases an application of Ach and glycine led to the  
handedness area controlling the non-preferred limb produced  
transfer, and in a single case where Ach, glycine and  
serine were applied transfer occurred.<sup>33</sup>

Peterson and Gliner employed a factorial design to  
test the effects of Ach and the two forms of terephthaloyl

**RESEARCH BUREAU**  
360, N. Peterson and J. W. Gliner, "Influence on  
Handedness of Acetylcholine locally applied with Glycine  
Chemicals to the Central Cortex of the Rat," *Journal of  
Comparative and Physiological Psychology*, 1950, 43, 264-272.

33Ibid., pp. 264-265.



upon ambidextrous rats.<sup>34</sup> No significant results were obtained for any of the combinations used. Ten of the ambidexters used by Suess were artificial, being created by subjecting them to forced reaching with the non-preferred hand. Many of the rats used in the design were "poor" ambidexters in that they showed considerable inconsistency in day-to-day reaching with the non-preferred hand. Only the fifty reaches immediately preceding and following the operation were taken into consideration in statistical treatment of the data. For these reasons it was decided that the study should be repeated with the addition of several improvements to the design.

Procedure. Age, sex, and the previous amount of reaching in the food situation of the rats used in the study were not controlled. It was felt that none of these factors would affect the performance of the rats, since the criterion for ambidexterity was solely based upon the reaches taken during pre-operational observations.

I. Recording of Reaches. The method for obtaining information on handedness was that developed by Peterson.<sup>35</sup>

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<sup>34</sup>Suess, op. cit., pp. 1-41.

<sup>35</sup>G. M. Peterson, "Mechanisms on Handedness in the Rat," Comparative Psychology Monographs, 1934, 9, 1-67.



upon amblyotropic rats. The amblyotropic rats were ob-  
tained for any of the experimental cases. Part of the amb-  
lyotropic rats used by Guess were amblyotropic, being created by  
subjecting them to forward teaching with the non-procedure  
hand. Many of the rats used in the design were "good"  
amblyotropic in that they showed considerable improvement  
in day-to-day teaching with the non-procedure hand. Only  
the fifty rats immediately preceding and following the  
operation were taken into consideration in this study.  
Treatment of the data. For these reasons it was decided  
that this study should be reported with the addition of  
several improvements to the design.

Procedure. Age, sex, and the previous amount of

teaching in the food situation of the rats used in the  
study were not controlled. It was felt that some of these  
factors would affect the performance of the rats, since  
the criterion for amblyopia was solely based upon the  
teaches taken during pre-operative observations.

1. Recording of Rats. The method for obtaining  
information on amblyopia was that developed by Peterson, 32

31 Guess, op. cit., p. 141.

32 E. M. Peterson, "Amblyopia in Rats," Journal of Experimental Psychology, 1934, 9, 1-67.



The rat was placed in a small cage to which a canary-type feeding dish was attached. Part of the dish extended inside the cage and contained grain mash. The rat might eat by mouth feeding at first, but when the food reached a certain level the rat was forced to obtain food by grasping with the fore-paw. When the rat reached into the dish, brought back a handful of food to its mouth and ate, a reach was recorded.

The rats were kept in a state of food deprivation which was sufficient to produce the required number of reaches per day. 350 pre-operation and 550 or more post-operational reaches were recorded for each rat used in the factorial design, with the exception of the records of the animals which were utilized from Suess' study. As has been stated previously, a limited number of post-operational reaches were taken on these rats. The reaches of the rats in this study were recorded according to the following plan:

Day 1. 100 reaches were taken in two consecutive periods of fifty reaches each.

Day 2. Same as Day 1.

Day 3. Same as Days 1 and 2.

Day 4. Fifty reaches were taken and the rat was immediately operated upon. After the rat had recovered enough to eat 150 more reaches were taken.



The rat was placed in a small cage to which a canary-type feeding dish was attached. Part of the dish extended inside the cage and contained grain mash. The rat might eat by mouth feeding at first, but when the food reached a certain level the rat was forced to obtain food by grasping with the fore-paw. When the rat reached into the dish, brought back a handful of food to its mouth and ate, a record was recorded.

The rats were kept in a state of food deprivation which was sufficient to produce the required number of reaches per day. 350 pre-operation and 750 or more post-operational reaches were recorded for each rat used in the factorial design, with the exception of the records of the animals which were utilized from Green's study. As has been stated previously, a limited number of post-operational reaches were taken on these rats. The reaches of the rats in this study were recorded according to the following plan:

Day 1. 100 reaches were taken in two consecutive periods of fifty reaches each.

Day 2. Same as Day 1.

Day 3. Same as Days 1 and 2.

Day 4. Fifty reaches were taken and the rat was immediately operated upon. After the rat had recovered enough to eat 150 more reaches were taken.



Day 5. 100 reaches were taken in two consecutive periods of fifty reaches each.

Day 6. Same as Day 5.

One week after Day 6, 100 reaches were taken in two periods of fifty. One week after that 100 more reaches were taken in the same way.

The above was the standard procedure used, but there were several exceptions to the post-operational procedure. Some rats were re-operated upon after Day 6 and some were re-operated upon after the entire procedure had been completed. These variations are shown in the records of reaching.

After all reaching had been completed the brain was removed and examined for damage in the handedness area upon which the drugs had been placed. Those rats which had damage in that area are indicated in the records of reaching (Table IX). Only cases in which the cortex was found to be undamaged were placed in the experimental design.

II. Operational Procedure. After having finished fifty reaches on Day 4 the rat was immediately etherized. The hair covering the top of the skull was then clipped and an incision was made which exposed the skull. A trephine one eighth inch in diameter was used to drill a hole in the skull tangent to the frontal and midline sutures, directly



Day 7. 100 reaches were taken in the consecutive periods of fifty reaches each.

Day 8. Same as Day 7.

One week after Day 8, 100 reaches were taken in two periods of fifty. One week after that 100 more reaches were taken in the same way.

The above was the standard procedure used, but there were several exceptions to the post-operative procedure. Some rats were re-operated upon after Day 6 and some were re-operated upon after the entire procedure had been completed. These variations are shown in the records of teaching.

After all teaching had been completed the brain was removed and examined for damage in the handness area upon which the drugs had been placed. Those rats which had damage in that area are indicated in the records of teaching (Table IX). Only cases in which the cortex was found to be undamaged were placed in the experimental design.

II. Operational Procedure. After having finished fifty reaches on Day 1 the rat was immediately anesthetized. The hair covering the top of the skull was then clipped and an incision was made which exposed the skull. A trephine one eighth inch in diameter was used to drill a hole in the skull tangent to the frontal and midline sutures, directly



over the handedness area. This exposed the dura mater of the cerebrum. The openings were always made over the handedness area contralateral to the non-preferred limb. A small cotton bolus saturated with the desired liquid was placed over the hole and the skin was closed with wound clips. The rat was placed in the reaching cage during the period of recovery.

In re-operations the wound clips were removed and the cotton bolus was replaced with another saturated with the same liquid. The wound was then closed with wound clips.

III. Drugs. In accordance with the requirements of the experimental design the following drugs were applied:

(1) Ach-A five per cent solution of the drug in tap water was used on all original operations. A ten per cent solution was used in re-operation.

(2) Glutamic Acid-Equal parts of a saturated solution of either l or d glutamic acid at room temperature and a ten per cent solution of Ach were combined to make the five per cent Ach solutions with glutamic acid, when this treatment was called for. Otherwise, equal parts of tap water and a saturated solution of glutamic acid (d or l) were prepared where the treatment called for omission of Ach.

(3) Tap water was used on the control rats of the



over the handness area. This exposed the dura mater of  
the cerebrum. The operation was always made over the  
handness area contralateral to the handness area.  
A small cotton point saturated with the handness liquid was  
placed over the hole and the handness area was covered with  
clips. The rat was placed in a box for a period of  
period of recovery.

In re-operations the wound clips were removed and  
the cotton point was replaced with another saturated with  
the same liquid. The wound was then closed with wound  
clips.

III. Drugs. In accordance with the requirements  
of the experimental design the following drugs were  
used:

(1) Act-A five per cent solution of the drug in tap  
water was used on all original operations. A ten per cent  
solution was used in re-operations.

(2) Glutamic Acid-Knows parts of a saturated solution  
of either I or II glutamic acid at room temperature was  
ten per cent solution of Act-A were combined to make the five  
per cent Act solutions with glutamic acid, when this treat-  
ment was called for. Otherwise, equal parts of tap water  
and a saturated solution of glutamic acid (I or II) were  
prepared where the treatment called for omission of Act.

(3) Tap water was used on the control rats of the



design.

IV. Factorial Design. Following the procedures of Rigney and Sness a factorial design was used which could be statistically treated by analysis of variance.<sup>36, 37, 38</sup> The following symbols were used to denote the application or non-application of drugs:

- A - Ach
- a - no Ach
- B - l-glutamic acid
- B'- d-glutamic acid
- b - no glutamic acid

The symbol "R" denoted that the right side of the cortex had been operated upon and "r" denoted that the left side had been operated upon.

The factorial design was as follows:

- ABR Ach and l-glutamic on the right cortex
- ABr Ach and l-glutamic on the left cortex
- AB'R Ach and d-glutamic on the right cortex
- AB'r Ach and d-glutamic on the left cortex
- AbR Ach on the right cortex

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<sup>36</sup>Peterson and Rigney, op. cit., p. 266.

<sup>37</sup>Suess, op. cit., p. 21.

<sup>38</sup>R. A. Fisher, The Design of Experiments, New York: Hafner Publishing Company, 1949.



designs.

IV. Factorial Design. Following the procedures of

Ritney and Guess a factorial design was used which could be statistically treated by analysis of variance.<sup>36</sup> The following symbols were used to denote the application of

non-application of drugs:

- A - Ach
- a - no Ach
- B - L-glutamic acid
- B' - D-glutamic acid
- b - no glutamic acid

The symbol "R" denoted that the right side of the cortex had been operated upon and "r" denoted that the left side had been operated upon.

The factorial design was as follows:

- ABR Ach and L-glutamic on the right cortex
- ABr Ach and L-glutamic on the left cortex
- AB'R Ach and D-glutamic on the right cortex
- AB'r Ach and D-glutamic on the left cortex
- AbR Ach on the right cortex

<sup>36</sup>Peterson and Ritney, op. cit., p. 266.

<sup>37</sup>Guess, op. cit., p. 21.

<sup>38</sup>H. A. Fisher, The Design of Experiments, New York: Hafner Publishing Company, 1949.



Abr Ach on the left cortex  
aBR l-glutamic on the right cortex  
aBr l-glutamic on the left cortex  
aB'R d-glutamic on the right cortex  
aB'r d-glutamic on the left cortex  
abR tap water on the right cortex  
abr tap water on the left cortex

It was intended that one replication of the design should be made, resulting in two rats for each combination of drugs, or twenty-four rats in all.

V. Criterion of Ambidexterity. It was decided that a good measure of ambidexterity would be the number of non-preferred reaches taken in the 350 pre-operational reaches. Merely deciding which rat seemed to be the best ambidexter on examination of the reaching record might bring in the bias of the selector, since the rats for the design were not selected until the post-operational records of many of them were known. Suess had obtained 350 pre-operational reaches for each of his rats; therefore the same method of selection was used in deciding which of his cases to include in the design. The twenty-four rats of the factorial design were selected on this basis, with a few exceptions. The exceptions were cases where Suess' rat took only a few more non-preferred reaches than the rat of this investigator in



- spr Ach on the left cortex
- sBR I-glutamate on the right cortex
- sBR I-glutamate on the left cortex
- sB'R d-glutamate on the right cortex
- sB'r d-glutamate on the left cortex
- sBR tap water on the right cortex
- sBR tap water on the left cortex

It was intended that one replication of the design should be made, resulting in two rats for each combination of drugs, or twenty-four rats in all.

V. Criticism of Ambidexterity. It was decided that

a good measure of ambidexterity would be the number of non-preferred reaches taken in the 350 pre-operational reaches. Merely deciding which rat seemed to be the best ambidexter on examination of the reaching record might bring in the bias of the selector, since the rats for the design were not selected until the post-operational records of many of them were known. Swass had obtained 350 pre-operational reaches for each of his rats; therefore the same method of selection was used in deciding which of his cases to include in the design. The twenty-four rats of the factorial design were selected on this basis, with a few exceptions. The exceptions were cases where Swass' rat took only a few more non-preferred reaches than the rat of this investigator in



a certain category of the design. In such a case Suess' rat was not used, since it is not known which of his rats were the "artificial" ambidexters previously mentioned. In the modified design using only twelve rats the same criterion of ambidexterity was used in the selection of cases.

Results. Approximately 300 rats were observed for ambidexterity in the period of one year. From these rats fifty-four were selected for further observation of possible ambidexterity. Seventeen of the fifty-four rats were discarded, having lost their ambidexterity quickly. The thirty-seven remaining rats were operated upon. Their records of reaching are shown in Table IX. Examination of the reaching records will show that many of the rats took very few ambidextrous reaches, some averaging less than one-non-preferred reach per fifty reaches. The original intention of the study was to find twenty-four good ambidexters to repeat the design used by Suess, since the animals used by Suess displayed poor ambidexterity. Over a two semester period, however, the required twenty-four "good" ambidexters were not obtained. It was decided, therefore, to utilize the best ambidexters found in both studies to complete the design. Such a design could make use of only the fifty pre-operational and post-operational reaches of the rats, for reasons mentioned previously. The animals were selected



a certain category of the design. In such cases, however, it was not used, since it is not known what of his rate were the "artificial" amblyopia previously mentioned. In the modified design using only twenty-four and some criteria of amblyopia was used in the selection of cases.

Results. Approximately 300 rats were observed for amblyopia in the period of one year. From these rats fifty-four were selected for further observation of possible amblyopia. Seven of the fifty-four rats were discarded, having lost their amblyopia records. The thirty-seven remaining rats were operated upon. Their records of teaching are shown in Table IX. Examination of the teaching records will show that many of the rats had very low amblyopia rates, some averaging less than one-half preferred reach per fifty reaches. The original intention of the study was to find twenty-four good amblyopia rats to repeat the design used by Oakes, since the animals used by

Oakes displayed poor amblyopia. Over a two-month period, however, the reduced twenty-four good amblyopia rats were not obtained. It was decided, therefore, to utilize the best amblyopia found in both studies to complete the design. Such a design could have one of only the fifty pre-operational and post-operational reaches of the rats for reasons mentioned previously. The animals were selected

EXPERIMENTAL  
BASE  
CONTRIBUTOR



according to the criterion of ambidexterity stated previously. Table I gives the numbers of the rats selected and the fifty pre-operational and fifty post-operational reaches taken by each rat.

As stated previously, only those rats which evidenced no cortical damages were used in the factorial design. It was assumed that there had been no cortical damage in any of the cases taken from Suess, since these rats had been utilized in his factorial design.

Table II shows the results of an analysis of variance of the data given in Table I. None of the results is significant, indicating no influence resulting from any of the combinations of drugs used.

In order to make use of a greater number of pre-operational and post-operational reaches in the statistical analysis, twelve of the best ambidexters found in this study were selected. Since the rats had already been operated upon it was necessary to select the best ambidexter which had been operated on in each category of the design. Three analyses of variance of the non-preferred reaches of these rats were run. The comparisons made were fifty pre-operational reaches to fifty post-operational, 150 pre-operational to 150 post-operational and 350 pre-operational to 350 post-operational reaches. The rats selected and reaches



according to the criterion of ambidexterity stated previously. Table I gives the number of the rats selected and the fifty pre-operational and fifty post-operational reaches taken by each rat.

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taken are shown in Tables III, IV, and V. Analysis of variance of the data is shown in Tables VI, VII, and VIII. The results of the analysis show no significance for any of the meaningful combinations of drugs. In one case no variability resulted from operating on different cortical hemispheres with Ach. This merely indicates that the side of the cortex that is operated on by itself does not have any influence on a change of handedness.

Since reoperations were not done in all cases, there is no statistical treatment of reoperation results. It will be remembered that the same solutions were applied in reoperation as in the original operations, except that where Ach was required it was used in a ten per cent solution. An examination of equal periods of pre-operational and post-operational reaches in reoperations gives little evidence of strong influence of the drugs. Only animals whose brains were found intact were considered in this comparison. In seven cases, more post-operational non-preferred reaches were taken. In four of the cases the differences were marked. An ABR rat showed 119 more non-preferred post-operational reaches in eight periods and an AbR rat showed 61 more reaches. These were more than balanced, however, by two control rats, which showed 190 and 147 more non-preferred reaches, respectively, in eight post-operational periods.



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Since operations were not done in all cases, there is no statistical treatment of operation results. It will be remembered that the same solutions were applied in operation as in the original operations, except that where Ach was required it was used in a ten per cent solution. An examination of equal periods of pre-operational and post-operational reaches in operations gives little evidence of strong influence of the drug. Only animals whose brains were found intact were considered in this comparison. In seven cases, more post-operational non-preferred reaches were taken. In four of the cases the differences were marked. An ABR test showed 117 more non-preferred post-operational reaches in eight periods and an ABR test showed 61 more reaches. These were more than balanced, however, by two control rats, which showed 130 and 147 more non-preferred reaches, respectively, in eight post-operational periods.



Discussion. As shown in Tables I, III, V, and VII post-operational non-preferred reaches were in general fewer than pre-operational reaches. This does not necessarily indicate that the drugs had a negative effect. If the Ach and glutamic acid cases took significantly more non-preferred reaches than the control rats after the operation, it would indicate a positive influence even though the results were negative as a whole. The general negative influence could then be attributed to the affects of the operation. As stated previously, however, no significance was found.

The purpose of this study was to repeat Suess' experimental design with better ambidexters. This was done on the assumption that the more non-preferred reaches are taken the easier it will be to influence a change of handedness.

Twenty-four good ambidexters were not found, but with the use of the data for eight of Suess' best ambidexters the design was completed. The fact that it was necessary to use only his best rats shows that the rats used in this design were a better group as a whole in regard to ambidexterity. Unfortunately even though the group was undoubtedly better an examination of the reaching records shows that many of the rats used were unsatisfactory in ambidexterity. There are three possible



Discussion. As shown in Tables I, II, V, and VI

post-operational non-preferred reaches were in general lower than pre-operational reaches. This does not necessarily indicate that the subject had a negative effect. It is not and yoked trials were used to control for any possible effects. It would indicate a positive influence even though the trials were negative as a whole. The general negative influence could then be attributed to the effects of the operation. As stated previously, however, no significant was found.

The purpose of this study was to repeat Sauer's experimental design with better amblyopes. This was done on the assumption that the more non-preferred reaches are taken the easier it will be to introduce a change of hand-edges.

Twenty-four good amblyopes were not found, but with the use of the data for eight of Sauer's best amblyopes the design was completed. The fact that it was necessary to use only his best data shows that the data used in this design were a better group as a whole in regard to amblyopia. Unfortunately, the examination of the group was unambiguously certain in examination of the records shows that many of the best were amblyopic in amblyopia. There are three possible



reasons for this:

(1) Suess did not designate which of his rats had been given forced reaching. Some of his rats included in this study may have been from the forced-reaching group. Suess says that these rats are for all intents and purposes as good as natural ambidexters. This is not necessarily the case, however. It has not been proven that the ambidexterity of single-handed rats given forced reaching is equivalent to that of natural ambidexters. Thus those rats which had been given forced reaching by Suess would tend to take fewer non-preferred reaches in the post-operational situation than true ambidexters.

(2) The only factorial analysis which could be made on all twenty-four rats was in terms of fifty pre-operational reaches compared to fifty post-operational reaches. If the influence of the drugs did not begin until after fifty post-operational reaches had been taken it would not be shown in this design. More post-operational reaches were treated in the modified design, using only twelve rats. In these analyses, however, because of the few cases involved, the degrees of freedom were greatly reduced and the remainder term vanished, leaving only the interactions to test the influence of treatments.

(3) Only a few of the rats used in the design show



reasons for this:

(1) Guess did not designate which of his rats had been given forced teaching. Some of his rats included in this study may have been from the forced-teaching group. Guess says that these rats are for all intents and purposes as good as natural ambidexters. This is not necessarily the case, however. It has not been proven that the ambidexterity of single-handed rats given forced teaching is equivalent to that of natural ambidexters. Thus those rats which had been given forced teaching by Guess would tend to take fewer non-preferred reaches in the post-operational situation than true ambidexters.

(2) The only factorial analysis which could be made on all twenty-four rats was in terms of fifty pre-operational reaches compared to fifty post-operational reaches. If the influence of the drugs did not begin until after fifty post-operational reaches had been taken it would not be shown in this design. More post-operational reaches were treated in the modified design, using only twelve rats. In these analyses, however, because of the few cases involved, the degrees of freedom were greatly reduced and the remainder term vanished, leaving only the interactions to test the influence of treatments.

(3) Only a few of the rats used in the design show



consistent reaching with the non-preferred hand. Some took many non-preferred reaches in the first few periods and then reverted to virtual single-handedness before the operation. Some rats switched their handedness preference after the first few periods of observation and continued until they took practically all of their reaches with the previously non-preferred hand.

For the reasons given above any influence that the drugs had might have been masked by the inconsistencies in the day to day reaching of the rats used in the design. These were the best ambidexters that could be found in a two semester period, not counting the time spent by Suess in collecting his ambidexters. With the facilities available it is likely that it would take a period of years to find enough good ambidexters to fill out an experimental design. Since Peterson found that only two out of 108 single-handed rats were influenced by the application of Ach the possible success in using such rats seems remote, unless more effective combinations of drugs can be found. Baker used a method of forced reaching in investigating the influence of Ach.<sup>39</sup> An Ach and a control group (using

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<sup>39</sup>C. A. Baker, "Transfer in Handedness in the Rat Induced by Acetylcholine and Forced Practice," (Unpublished Master's Thesis, The University of New Mexico, Albuquerque, 1950.



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<sup>39</sup>C. A. Baker, "Transfer in Handedness in the Rat Induced by Acetylcholine and Forced Practice," (Unpublished Master's Thesis, The University of New Mexico, Albuquerque, 1950.)



water) were given equal amounts of forced reaching with the non-preferred hand and then the drugs were applied. Any differences in post-operation non-preferred reaching in a free-reaching situation could then be attributed to the influence of the cortical applications. However, he selected an unfortunate amount of forced practice and very few animals in either group were influenced. The same difficulty is encountered to a degree in this approach as is encountered in the use of ambidexters. The amount of transfer of handedness resulting from a given number of forced reaches varies considerably from rat to rat.

Further investigation by this method at a more critical level of forced practice, however, may prove more fruitful than the investigations already done with ambidextrous rats.

Summary and Conclusions. Twenty-four ambidextrous rats were used in a factorial design to ascertain the influence of acetylcholine and the two forms of glutamic acid on handedness. The combinations of drugs were applied to the handedness area of the motor cortex which controlled the non-preferred hand. Twelve rats were used in a modification of the factorial design which had the same purposes and utilized the same methods as the first design. Statistical analysis of the data by means of analysis of variance



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showed no significant influence for any of the combinations of drugs. It was felt that the inconsistency of the non-preferred reaching of the rats involved negated any influence which the drugs might actually have had. It was suggested that further attack of the problem might be done by using a method of forced reaching already employed by Baker.



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TABLE I

FACTORIAL DESIGN AND THE DIFFERENCE BETWEEN THE LAST PRE-OPERATIONAL PERIOD AND THE FIRST POST-OPERATIONAL PERIOD

Combinations	Rats	Reaches with Pre-operation	Non-preferred Hand Post-operation	D
ABR	1F	24	11	-13
	3M*	34	3	-31
ABr	2F	1	3	2
	1M*	4	0	-4
AB'R	3F	13	7	-6
	4M*	20	10	-10
AB'r	4M	14	0	-14
	5M	22	15	-7
AbR	6F	26	20	-6
	18F*	9	0	-9
Abr	7F	0	0	0
	17M*	3	0	-3
aBR	8M	0	0	0
	21F*	26	9	-17
aBr	9F	4	2	-2
	10M	32	27	-5
aB'R	11F	11	7	-4
	22M*	25	4	-21
aB'r	12M	14	9	-5
	13F	10	6	-4
abR	14F	3	1	-2
	24M*	9	0	-9
abr	15F	5	19	14
	16F	2	0	-2

\* Cases taken from Suess

\*\* In all of the tables "F" indicates a female rat and "M" indicates a male rat.



TABLE I

FACTORIAL DESIGN AND THE DIFFERENCE BETWEEN THE LAST PRE-OPERATIONAL PERIOD AND THE FIRST POST-OPERATIONAL PERIOD

Combi- nations	Rate	Research with pre-operation	Non-preferred hand post-operation	n
ABR	1P	2P	11	-13
	3M*	3P	3	-31
ABV	2P	1	3	5
	1M*	4	0	-4
AB'R	3P	13	7	-6
	4M*	20	10	-10
AB'T	4M	14	0	-14
	2M	22	12	-7
ABR	6P	26	20	-6
	10P*	9	0	-9
ABV	7P	0	0	0
	17M*	3	0	-3
ABR	8M	0	0	0
	21P*	26	9	-12
ABV	9P	4	2	-2
	10M	32	27	-5
AB'R	11P	11	7	-4
	22M*	27	4	-31
AB'T	12M	14	9	-5
	13P	10	0	-4
ABR	14P	3	1	-2
	24M*	0	0	-9
ABV	15P	2	19	14
	16P	2	0	-2

\* Cases taken from Series  
 \*\* In all of the tables "P" indicates a female rat and  
 "M" indicates a male rat.



TABLE II

ANALYSIS OF VARIANCE OF THE REACHING DIFFERENCES  
SHOWN IN TABLE I

Treatments	Degrees of Freedom	Sum of Squares	Mean Squares
Total	23	1718	
Acetylcholine (A)	1	81	81
Glutamic Acid (B)	2	239	119.5
Hemispheres (R)	1	400	400
(Interactions)			
AxB	2	25.5	12.75
AxR	1	0	0
BxR	2	106	53
AxBxR	2	198.5	99.25
Estimate of Error	12	1901.5	158.46



TABLE II

ANALYSIS OF VARIANCE OF THE BROWNS DISEASE

SHOWN IN TABLE I

Treatments	Number of Plots	Sum of Squares	Mean Square
Total	23	1713	
Acetylcholine (A)	1	81	81
Dinitro Acid (B)	2	230	115.5
Hemipheras (R)	1	400	400
(Interactions)			
AxB	2	12.22	6.11
AxB	1	0	0
BxB	2	120	60
AxBxB	2	208.2	104.1
Estimate of Error	16	1201.5	75.09



TABLE III

FACTORIAL DESIGN AND THE DIFFERENCE BETWEEN THE LAST PRE-  
OPERATIONAL PERIOD AND THE FIRST POST-OPERATIONAL PERIOD  
WITH THE DESIGN INCLUDING ONLY TWELVE RATS

Combi- nations	Rats	Reaches with Pre-operation	Non-preferred Hand Post-operation	D
ABR	1F	24	11	-13
ABr	2F	1	3	2
AB'R	3F	13	7	-6
AB'r	4M	14	0	-14
AbR	6F	26	20	-6
Abr	7F	0	0	0
aBR	8M	0	0	0
aBr	10M	32	27	-5
AB'R	11F	11	7	-4
AB'r	12M	14	9	-5
abR	14F	3	1	-2
abr	16F	2	0	-2



TABLE III

FACTORIAL DESIGN AND THE DIFFERENCE BETWEEN THE LAST PRE-  
 OPERATIONAL PERIOD AND THE FIRST POST-OPERATIONAL PERIOD  
 WITH THE DESIGN INCLUDING ONLY TWELVE RATS

Combi- nations	Rate	Rats with Pre-operation	Non-operated Rats Post-operation	D
ABR	1F	24	11	-0.3
ABr	2F	1	3	3
AB'R	3F	13	7	-8
AB'r	4F	14	0	-14
ABR	6F	26	20	-6
ABr	7F	6	0	0
ABR	8F	0	0	0
ABr	10F	32	27	-5
AB'R	11F	11	7	-4
AB'r	12F	14	12	2
ABR	14F	3	1	2
ABr	15F	5	0	5

EFFICIENCY  
 ERASE BOND



TABLE IV  
ANALYSIS OF VARIANCE OF THE REACHING DIFFERENCES  
SHOWN IN TABLE III

Treatments	Degrees of Freedom	Sum of Squares	Mean Squares
Total	11	265	
Acetylcholine (A)	1	32	32
Glutamic Acid (B)	2	49	24.5
Hemisphere (R)	1	6	6
(Interactions)			
AxB	2	9	4.5
AxR	1	28	28
BxR	2	59	29.5
AxBxR	2	82	41



TABLE IV

ANALYSIS OF VARIANCE OF THE READING DIFFERENCES  
SHOWN IN TABLE III

Treatments	Degrees of Freedom	Sum of Squares	Mean Squares
Total	11	262	
Acetylcholine (A)	1	32	32
Glutamic Acid (B)	2	49	24.5
Hemisphere (B)	1	6	6
(Interactions)			
AxB	2	9	4.5
AxB	1	28	28
BxB	2	29	14.5
AxBxB	2	82	41

ENZYMASE BOARD

CONTENT



TABLE V

FACTORIAL DESIGN AND THE DIFFERENCE BETWEEN THE LAST  
THREE PRE-OPERATIONAL PERIODS AND THE FIRST THREE POST-  
OPERATIONAL PERIODS

Combi- nations	Rats	Reaches with Pre-operation	Non-preferred Hand Post-operation	D
ABR	1F	72	12	-60
ABr	2F	10	19	9
AB'R	3F	58	30	-28
AB'r	4M	56	4	-52
AbR	6F	30	52	22
Abr	7F	3	0	-3
aBR	8M	9	0	-9
aBr	10M	60	77	17
aB'R	11F	41	40	-1
aB'r	12M	50	23	-27
abR	14F	14	1	-13
abr	16F	29	0	-29



TABLE V

FACTORIAL DESIGN AND THE DIFFERENCE BETWEEN THE FIRST THREE PRE-OPERATIONAL PERIODS AND THE FIRST THREE POST-OPERATIONAL PERIODS

Combinations	Rata	Readers with Pre-operation	Non-preferred hand Post-operation	D
ABR	18	22	12	-10
ABT	28	10	12	9
AB'R	38	28	30	-28
AB'T	48	24	4	-28
ABR	68	30	22	22
ABT	78	3	0	-3
ABR	88	2	0	-2
ABT	108	60	72	12
AB'R	118	41	40	-1
AB'T	128	20	23	-27
ABR	148	14	1	-13
ABT	168	22	0	-22



TABLE VI  
ANALYSIS OF VARIANCE OF THE REACHING DIFFERENCES  
SHOWN IN TABLE V

Treatments	Degrees of Freedom	Sum of Squares	Mean Squares
Total	11	7249	
Acetylcholine (A)	1	208	208
Glutamic Acid (B)	2	988	494
Hemispheres (R)	1	1	1
(Interactions)			
AxB	2	2268	1134
AxR	1	109	109
BxR	2	3300	1650
AxBxR	2	375	187.5



TABLE VI

ANALYSIS OF VARIANCE OF THE REACHING DISTANCE  
 SHOWN IN TABLE V

Treatments	Degrees of Freedom	Sum of Squares	Mean Squares
Total	11	7249	
acetylcholine (A)	1	208	208
Glyamic Acid (B)	2	1038	519
Hemiparves (R)	1	1	1
(Interactions)			
AxB	2	2268	1134
AxR	1	109	109
BxR	2	3300	1650
AxBxR	2	372	186



TABLE VII

FACTORIAL DESIGN AND THE DIFFERENCE BETWEEN THE SEVEN PRE-OPERATIONAL PERIODS AND THE SEVEN POST-OPERATIONAL PERIODS

Combinations	Rats	Reaches with Pre-operation	Non-preferred Hand Post-operation	D
ABR	1F	191	58	-133
ABr	2F	42	27	-15
AB'R	3F	179	30	-149
AB'r	4M	140	55	-85
AbR	6F	74	105	31
Abr	7F	79	0	-79
aBR	8M	47	0	-47
aBr	10M	125	159	34
aB'R	11F	59	201	142
aB'r	12M	133	105	-25
abR	14F	42	6	-36
abr	16F	97	37	-60



TABLA VII

OPERATIONAL PERIODS AND THE SEVEN POST-OPERATIONAL PERIODS  
 FACTORIAL DESIGN AND THE DIFFERENCE BETWEEN THE SEVEN PRE-

Combi- nations	Rata	Resces with Pre-operation	Non-preferred Hand Post-operation
ABR	1P	191	28
ABr	2P	42	27
AB'R	3P	179	30
AB'r	4P	140	22
AbR	5P	24	102
AbR	6P	29	0
aBR	8P	42	0
aBr	10P	122	129
aB'R	11P	22	201
aB'r	12P	133	102
aBR	14P	42	6
aBr	16P	97	32



TABLE VIII

ANALYSIS OF VARIANCE OF THE REACHING DIFFERENCES  
SHOWN IN TABLE VII

Treatments	Degrees of Freedom	Sum of Squares	Mean Squares
Total	11	68752	
Acetylcholine (A)	1	15987	15987
Glutamic Acid (B)	2	246.5	123.25
Hemispheres (R)	1	121	121
(Interactions)			
AxB	2	19945.5	9972.75
AxR	1	10027	10027
BxR	2	16921.5	8460.75
AxBxR	2	5504.5	2752.25



TABLE VIII

ANALYSIS OF VARIANCE OF THE DEGREE OF BONDING

IN THE POLYMERIZATION OF VINYL MONOMERS

BY THE METHOD OF

Treatments	Degrees of Freedom	Sum of Squares	Mean Squares
Total	11	6875	
Acetylcholine (A)	1	1567	1567
Glutamic Acid (B)	2	246.5	123.25
Hemisphere (H)	1	151	151
(Interactions)			
AxB	2	1997.5	998.75
AxB	1	10027	10027
BxH	2	1621.5	810.75
AxBxH	2	550.5	275.25







REPORT OF THE STATE OF NEW YORK  
UPON THE BOARD OF STATE EDUCATION

Tests and Examinations

IR-ABE	IR-ABE		IR-ABE	IR-ABE		IR-ABE	IR-ABE		IR-ABE	IR-ABE	
	Day	Day		Day	Day		Day	Day		Day	Day
1	11	11	11	11	11	11	11	11	11	11	11
2	12	12	12	12	12	12	12	12	12	12	12
3	13	13	13	13	13	13	13	13	13	13	13
4	14	14	14	14	14	14	14	14	14	14	14
5	15	15	15	15	15	15	15	15	15	15	15
6	16	16	16	16	16	16	16	16	16	16	16
7	17	17	17	17	17	17	17	17	17	17	17
8	18	18	18	18	18	18	18	18	18	18	18
9	19	19	19	19	19	19	19	19	19	19	19
10	20	20	20	20	20	20	20	20	20	20	20
11	21	21	21	21	21	21	21	21	21	21	21
12	22	22	22	22	22	22	22	22	22	22	22
13	23	23	23	23	23	23	23	23	23	23	23
14	24	24	24	24	24	24	24	24	24	24	24
15	25	25	25	25	25	25	25	25	25	25	25
16	26	26	26	26	26	26	26	26	26	26	26
17	27	27	27	27	27	27	27	27	27	27	27
18	28	28	28	28	28	28	28	28	28	28	28
19	29	29	29	29	29	29	29	29	29	29	29
20	30	30	30	30	30	30	30	30	30	30	30

\*\*\* All testing was taken on consecutive days, except where "one week" indicates, and week interval between testing periods.

\*\* examination after brain removal revealed testicular in hardness area

\* cases taken from Green



TABLE IX

## RECORDS OF REACHING (cont.)

Rats and Treatments											
19M-ABr		3F-AB'R		4M*-AB'R		21M**-AB'R		22M-AB*R		20M**AB'R	
Day	R L	Day	R L	Day	R L	Day	R L	Day	R L	Day	R L
1	7 43	1	22 28	1	31 19	1	50 0	1	50 0	1	44 6
	2 48		15 35		26 24		50 0		50 0		45 5
2	3 47	2	19 31	2	32 18	2	47 3	2	50 0	2	41 9
	0 50		23 27		30 20		47 3		50 0		31 19
3	1 49	3	25 25	3	29 21	3	49 1	3	49 1	3	33 17
	0 50		30 20		23 27		50 0		47 3		44 6
4	0 50	4	37 13	4	30 20	4	50 0	4	49 1	4	42 8
	operation		operation		operation		operation		operation		operation
	0 50		43 7		40 10		47 3		49 1		50 0
	0 50		41 9		34 16		50 0		50 0		50 0
	0 50		36 14		43 7		50 0		50 0		50 0
5	0 50	5	50 0		37 13	5	50 0	5	50 0	5	50 0
	0 50		50 0		reop.		50 0		50 0		50 0
6	0 50	6	50 0	5	47 3	6	50 0	6	50 0	6	50 0
	0 50		50 0		50 0		50 0		50 0		50 0
	one week	7	50 0				one week		one week		one week
7	0 50		reop.			7	50 0	7	50 0	7	50 0
	0 50		50 0				50 0		50 0		50 0
	one week		50 0				one week		one week		one week
8	0 50		50 0			8	50 0	8	50 0	8	50 0
	0 50	8	50 0				50 0		50 0		50 0
			50 0								
		9	36 14								
			40 10								
			one week								
		10	42 8								
			44 6								
			one week								
		11	50 0								
			50 0								

\* cases taken from Suess

\*\* examination after brain removal revealed destruction in handedness area



TABLE IX  
RECORDS OF AN OUTPATIENT (cont.)

LOW-ANT		36-AB'H		44-AB'H		51-AB'H		52-AB'H		53-AB'H		54-AB'H		55-AB'H			
Day	Time	Day	Time	Day	Time	Day	Time	Day	Time	Day	Time	Day	Time	Day	Time		
1	7:43	1	22:28	1	31:19	1	40:30	1	50:00	1	59:30	1	68:30	1	77:30	1	86:30
2	2:48	2	15:35	2	24:26	2	33:17	2	42:08	2	50:59	2	59:50	2	68:41	2	77:32
3	3:47	3	19:11	3	28:02	3	36:53	3	45:44	3	54:35	3	63:26	3	72:17	3	81:08
4	0:50	4	23:27	4	32:18	4	41:09	4	50:00	4	58:51	4	67:42	4	76:33	4	85:24
5	0:50	5	27:25	5	36:16	5	45:07	5	53:58	5	62:49	5	71:40	5	80:31	5	89:22
6	0:50	6	31:23	6	40:14	6	49:05	6	57:56	6	66:47	6	75:38	6	84:29	6	93:20
7	0:50	7	35:21	7	44:12	7	53:03	7	61:54	7	70:45	7	79:36	7	88:27	7	97:18
8	0:50	8	39:19	8	48:10	8	57:01	8	65:52	8	74:43	8	83:34	8	92:25	8	101:16
9	0:50	9	43:17	9	52:08	9	60:59	9	69:50	9	78:41	9	87:32	9	96:23	9	105:14
10	0:50	10	47:15	10	56:06	10	64:57	10	73:48	10	82:39	10	91:30	10	100:21	10	109:12
11	0:50	11	51:13	11	60:04	11	68:55	11	77:46	11	86:37	11	95:28	11	104:19	11	113:10
12	0:50	12	55:11	12	64:02	12	72:53	12	81:44	12	90:35	12	99:26	12	108:17	12	117:08

\* cases taken from bus  
 \*\* examination after brain removed (autopsy)  
 In handwriting area







RM. ONIA - W. EXHIBIT 1 (cont.)

Day	Time	Activity	Person	Notes
1	12:30	operation	1	
2	12:30	operation	2	
3	12:30	operation	3	
4	12:30	operation	4	
5	12:30	operation	5	
6	12:30	operation	6	
7	12:30	operation	7	
8	12:30	operation	8	
9	12:30	operation	9	
10	12:30	operation	10	
11	12:30	operation	11	
12	12:30	operation	12	
13	12:30	operation	13	
14	12:30	operation	14	
15	12:30	operation	15	
16	12:30	operation	16	
17	12:30	operation	17	
18	12:30	operation	18	
19	12:30	operation	19	
20	12:30	operation	20	
21	12:30	operation	21	
22	12:30	operation	22	
23	12:30	operation	23	
24	12:30	operation	24	
25	12:30	operation	25	
26	12:30	operation	26	
27	12:30	operation	27	
28	12:30	operation	28	
29	12:30	operation	29	
30	12:30	operation	30	

\*\* examination also given I received destination in handwriting



TABLE IX

## RECORDS OF REACHING (cont.)

Rats and Treatments											
6F-AbR		18F*-AbR		27M-AbR		7F-AbR		17M*-AbR		28M**AbR	
Day	R L	Day	R L	Day	R L	Day	R L	Day	R L	Day	R L
1	34 16	1	0 50	1	49 1	1	30 20	1	40 10	1	21 29
	34 16		2 48		48 2		35 15		32 18		16 34
2	42 8	2	0 50	2	30 20	2	7 43	2	32 18	2	10 40
	46 4		27 23		41 9		4 46		27 23		5 45
3	49 1	3	30 20	3	36 14	3	2 48	3	20 30	3	5 45
	47 3		37 13		30 20		1 49		4 46		3 47
4	24 26	4	41 9	4	16 34	4	0 50	4	3 47	4	0 50
	operation		operation		operation		operation		operation		operation
	30 20		50 0		23 27		0 10		0 50		1 49
	37 13	5	10 0		21 29	5	0 50		0 50		0 50
	31 19		reop.		8 42		0 50		0 50		3 47
5	33 17	6	50 0	5	0 50		0 50		0 50	5	0 50
	36 14				0 50	6	0 50		reop		0 50
6	44 6			6	3 47		0 50	5	1 49	6	0 50
	47 3				0 50		0 40		0 50		0 50
	reop.				one week	7	reop.				one week
	17 33			7	1 49		0 50			7	0 50
	6 44				6 44		0 50				0 50
	12 38				one week		1 49				one week
7	39 11			8	1 49	8	0 50			8	0 50
	49 1				1 49		0 50				0 50
8	46 4			9	3 47	9	0 50			9	0 50
	30 20				0 50		0 50				0 50
	one week			10	0 50		one week			10	0 50
9	35 15				2 48	10	0 50				0 50
	36 14			11	3 47		0 50			11	0 50
	one week				reop.		one week				reop.
10	12 38				2 3	11	0 50				0 50
	17 33			12	0 50		0 50				0 50
					0 50						0 50
				13	1 49					12	0 50
					0 50						0 50
				14	2 48					13	0 50
					1 49						0 50
					one week						one week
				15	0 50					14	0 50
					0 50						0 50

\* cases taken from Suess

\*\* examination after brain removal revealed destruction in handedness area



TABLE 1

Summary of results (continued)

Date and treatment		187-414		187-415		187-416		187-417		187-418	
Day	Time	Day	Time	Day	Time	Day	Time	Day	Time	Day	Time
1	34 16	1	30 20	1	30 20	1	30 20	1	30 20	1	30 20
2	34 16	2	30 20	2	30 20	2	30 20	2	30 20	2	30 20
3	40 1	3	30 20	3	30 20	3	30 20	3	30 20	3	30 20
4	47 3	4	30 20	4	30 20	4	30 20	4	30 20	4	30 20
5	30 20	5	30 20	5	30 20	5	30 20	5	30 20	5	30 20
6	30 20	6	30 20	6	30 20	6	30 20	6	30 20	6	30 20
7	30 20	7	30 20	7	30 20	7	30 20	7	30 20	7	30 20
8	30 20	8	30 20	8	30 20	8	30 20	8	30 20	8	30 20
9	30 20	9	30 20	9	30 20	9	30 20	9	30 20	9	30 20
10	30 20	10	30 20	10	30 20	10	30 20	10	30 20	10	30 20
11	30 20	11	30 20	11	30 20	11	30 20	11	30 20	11	30 20
12	30 20	12	30 20	12	30 20	12	30 20	12	30 20	12	30 20
13	30 20	13	30 20	13	30 20	13	30 20	13	30 20	13	30 20
14	30 20	14	30 20	14	30 20	14	30 20	14	30 20	14	30 20
15	30 20	15	30 20	15	30 20	15	30 20	15	30 20	15	30 20

EFFICIENT  
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\* cases taken from local examination after brain removed  
 \*\* in parentheses are



TABLE IX

## RECORDS OF REACHING (cont.)

Rats and Treatments											
29F-Abr		8M-aBr		21F*-aBR		30M-aBR		31M-aBR		9F-aBr	
Day	R	L	Day	R	L	Day	R	L	Day	R	L
1	10	40	1	20	30	1	38	12	1	44	6
	1	49		46	4		36	14		45	5
2	9	41	2	46	4	2	44	6	2	47	3
	0	50		50	0		48	2		47	3
3	5	45	3	46	4	3	48	2	3	46	4
	7	43		45	5		41	9		48	2
4	8	42	4	50	0	4	24	26	4	50	0
	operation		operation			operation			operation		
	4	46		50	0		32	9		wouldn't	
	6	44		50	0	5	8	0	5	50	0
	6	44		50	0	6	46	4		50	0
5	0	50	5	50	0	7	49	1	6	50	0
	1	49		50	0					50	0
6	4	46	6	50	0				one week		
	4	46		50	0				7	50	0
7	0	50	7	50	0					50	0
	reop.		one week						one week		
	0	50	8	50	0				8	50	0
	0	50		50	0					50	0
8	0	50									
	0	50									
9	0	50									
	0	50									
	one week										
10	0	50									
	0	50									
	one week										
11	0	50									
	0	50									

\* cases taken from Suess



INDEX OF SUBJECTS (cont.)

Page	Subject	Page	Subject	Page	Subject	Page	Subject
1	10 40	1	20 20	1	30 20	1	40 20
2	1 40	2	2 40	2	3 40	2	4 40
3	0 20	3	1 20	3	2 20	3	3 20
4	8 40	4	7 40	4	6 40	4	5 40
5	4 40	5	3 40	5	2 40	5	1 40
6	4 40	6	3 40	6	2 40	6	1 40
7	0 20	7	0 20	7	0 20	7	0 20
8	0 20	8	0 20	8	0 20	8	0 20
9	0 20	9	0 20	9	0 20	9	0 20
10	0 20	10	0 20	10	0 20	10	0 20
11	0 20	11	0 20	11	0 20	11	0 20

\* cases taken from these



TABLE IX

## RECORDS OF REACHING (cont.)

Rats and Treatments											
10M-aBr		32M-aBr		33F**aBr		34M-aBr		35M-aBr		11F-aB'R	
Day	R L	Day	R L	Day	R L	Day	R L	Day	R L	Day	R L
1	3 47	1	0 50	1	35 15	1	10 40	1	5 45	1	49 1
	17 33		1 49		24 26		7 43		6 44		45 5
2	23 27	2	0 50	2	33 17	2	8 42	2	0 50	2	46 4
	23 28		0 50		6 44		3 47		1 49		42 8
3	12 38	3	0 50	3	21 29	3	4 46	3	2 48	3	43 7
	16 34		2 48		15 35		2 48		2 48		27 23
4	32 18	4	0 50	4	6 44	4	1 49	4	1 49	4	39 11
	operation		operation		operation		operation		operation		operation
	27 23		0 50		0 50		0 50		1 49		43 7
	21 29		0 50		3 47		0 50		1 49		40 10
	29 21		0 50		0 50		0 50		0 50		27 23
5	35 15	5	0 50	5	6 44	5	0 50	5	0 50	5	23 27
	24 26		0 50		1 49		0 50		0 50		7 43
6	5 45	6	0 50	6	2 48	6	0 50	6	0 50	6	7 43
	18 32		0 50		1 49		0 50		0 50		2 48
	one week		one week		reop.		one week		one week		one week
7	30 20	7	1 49		0 50	7	4 46	7	0 50	7	14 36
	31 19		0 50		0 50		0 50		0 50		7 43
	one week		one week		0 50		one week		one week		one week
8	27 23	8	0 50	7	2 48	8	0 50	8	0 50	8	10 40
	33 17		0 50		4 46		0 50		0 50		4 46
				8	1 49						
					0 50						
					one week						
				9	0 50						
					0 50						
					one week						
				10	0 50						
					0 50						

\*\* examination after removal of brain revealed destruction in handedness area



TABLE II  
RESULTS OF READING (Cont.)

Rate and Frequency

ION-ABR	25M-ABR	25R-ABR	25K-ABR	25M-ABR	25R-ABR	25K-ABR
Day 1	Day 1	Day 1	Day 1	Day 1	Day 1	Day 1
1	3.47	1	0.50	1	3.47	1
2	17.33	1	1.43	1	24.38	1
3	23.27	2	0.50	2	30.17	2
4	23.28	2	0.50	2	30.17	2
5	13.38	3	0.50	3	21.66	3
6	16.24	3	0.50	3	15.74	3
7	32.18	4	0.50	4	24.38	4
8	27.23	4	0.50	4	24.38	4
9	21.30	5	0.50	5	17.33	5
10	20.21	5	0.50	5	17.33	5
11	34.16	6	0.50	6	24.38	6
12	24.26	6	0.50	6	17.33	6
13	5.45	7	0.50	7	17.33	7
14	18.32	7	0.50	7	17.33	7
15	one week	one week	one week	one week	one week	one week
16	30.50	7	1.43	7	24.38	7
17	31.19	8	0.50	8	24.38	8
18	one week	one week	one week	one week	one week	one week
19	27.23	8	0.50	8	24.38	8
20	33.17	8	0.50	8	24.38	8
21	one week	one week	one week	one week	one week	one week
22	one week	one week	one week	one week	one week	one week
23	one week	one week	one week	one week	one week	one week
24	one week	one week	one week	one week	one week	one week
25	one week	one week	one week	one week	one week	one week
26	one week	one week	one week	one week	one week	one week
27	one week	one week	one week	one week	one week	one week
28	one week	one week	one week	one week	one week	one week
29	one week	one week	one week	one week	one week	one week
30	one week	one week	one week	one week	one week	one week
31	one week	one week	one week	one week	one week	one week
32	one week	one week	one week	one week	one week	one week
33	one week	one week	one week	one week	one week	one week
34	one week	one week	one week	one week	one week	one week
35	one week	one week	one week	one week	one week	one week
36	one week	one week	one week	one week	one week	one week
37	one week	one week	one week	one week	one week	one week
38	one week	one week	one week	one week	one week	one week
39	one week	one week	one week	one week	one week	one week
40	one week	one week	one week	one week	one week	one week
41	one week	one week	one week	one week	one week	one week
42	one week	one week	one week	one week	one week	one week
43	one week	one week	one week	one week	one week	one week
44	one week	one week	one week	one week	one week	one week
45	one week	one week	one week	one week	one week	one week
46	one week	one week	one week	one week	one week	one week
47	one week	one week	one week	one week	one week	one week
48	one week	one week	one week	one week	one week	one week
49	one week	one week	one week	one week	one week	one week
50	one week	one week	one week	one week	one week	one week

\*\* examination after removal of brain revealed destruction in indicated areas



TABLE IX

## RECORDS OF REACHING (cont.)

Rats and Treatments											
22M*-aB'R		36M**aB'R		37M-aB'R		13F-aB'r		12M-aB'r		14F-abR	
Day	R L	Day	R L	Day	R L	Day	R L	Day	R L	Day	R L
1	1 49	1 49	1 49	1 42 8	1 50 0	1 29 21	1 45 5				
	47 3	48 2	44 6		31 19	20 30	38 12				
2	37 13	2 50 0	2 49 1	2 10 40	2 17 33	2 49 1					
	38 12	50 0	50 0		2 48	17 33	40 10				
3	43 7	3 49 1	3 50 0	3 4 46	3 25 25	3 47 3					
	27 23	50 0	50 0		3 47	11 39	42 8				
4	25 25	4 50 0	4 50 0	4 10 40	4 14 36	4 47 3					
	operation	operation	operation	operation	operation	operation	operation				
	18 1	50 0	50 0	6 44	9 41	49 1					
	28 3	50 0	50 0	2 48	7 43	50 0					
	43 0	50 0	50 0	1 49	7 43	50 0					
5	42 8	5 50 0	5 50 0	5 2 48	5 21 29	5 50 0					
	49 1	50 0	50 0	0 50	28 22	48 2					
		6 50 0	6 50 0	6 0 50	6 19 31	6 50 0					
		50 0	50 0	0 50	14 36	47 3					
		one week	one week	7 2 48	one week	7 50 0					
		7 50 0	7 50 0	reop.	7 1 49	reop.					
		50 0	50 0	2 48	13 37	41 9					
		one week	one week	1 49	one week	16 34					
		8 50 0	8 50 0	0 50	8 8 42	24 26					
		50 0	50 0	8 0 50	2 48	8 47 2					
				0 50	9 7 43	31 19					
				9 0 50	6 44	9 15 35					
				0 50	10 1 49	0 50					
				one week	reop.	one week					
				10 0 50	0 50	10 30 20					
				0 50	0 50	35 15					
				one week	0 50	one week					
				11 0 50	11 1 49	11 44 6					
				0 50	0 50	13 37					
					12 1 49						
					6 34						
					one week						
					13 1 49						
					3 47						

\* cases taken from Suess

\*\* examination after brain removal revealed destruction in handedness area.







TABLE IX

## RECORDS OF REACHING (cont.)

Rats and Treatments						
24M*-abR		15F-abr		16F-abr		
Day	R L	Day	R L	Day	R L	
1	5 45	1	18 32	1	21 29	
	29 21		34 16		17 33	
2	32 18	2	16 34	2	15 35	
	40 10		21 29		29 21	
3	46 4	3	5 45	3	9 41	
	48 2		8 42		11 39	
4	41 9	4	5 45	4	2 48	
	operation		operation		operation	
	50 0		19 31		0 50	
	50 0		5 45		0 50	
5	20 30		7 43		0 50	
	43 7	5	0 50	5	0 50	
	30 20		0 50		1 49	
	21 29	6	1 49	6	0 50	
			2 48		0 50	
		7	3 47	7	0 50	
			reop.		reop.	
			12 38		0 50	
			45 5		0 50	
			42 8		0 50	
		8	11 39	8	0 50	
			13 37		0 50	
		9	7 43	9	1 49	
			22 28		0 50	
			one week		one week	
		10	32 18	10	0 50	
			44 6		0 50	
			one week		one week	
		11	44 6	11	0 50	
			50 0		0 50	

\* cases taken from Suess



TABLE IX

RESULTS OF ANALYSIS (cont.)

Day	1st-2nd		3rd-4th		5th-6th		7th-8th		9th-10th		11th-12th	
	1	2	1	2	1	2	1	2	1	2	1	2
1	18.32	17.32	18.32	17.32	18.32	17.32	18.32	17.32	18.32	17.32	18.32	17.32
2	32.18	31.18	32.18	31.18	32.18	31.18	32.18	31.18	32.18	31.18	32.18	31.18
3	46.4	45.4	46.4	45.4	46.4	45.4	46.4	45.4	46.4	45.4	46.4	45.4
4	48.2	47.2	48.2	47.2	48.2	47.2	48.2	47.2	48.2	47.2	48.2	47.2
5	50.0	49.0	50.0	49.0	50.0	49.0	50.0	49.0	50.0	49.0	50.0	49.0
6	51.28	50.28	51.28	50.28	51.28	50.28	51.28	50.28	51.28	50.28	51.28	50.28
7	53.47	52.47	53.47	52.47	53.47	52.47	53.47	52.47	53.47	52.47	53.47	52.47
8	55.37	54.37	55.37	54.37	55.37	54.37	55.37	54.37	55.37	54.37	55.37	54.37
9	57.14	56.14	57.14	56.14	57.14	56.14	57.14	56.14	57.14	56.14	57.14	56.14
10	58.18	57.18	58.18	57.18	58.18	57.18	58.18	57.18	58.18	57.18	58.18	57.18
11	59.11	58.11	59.11	58.11	59.11	58.11	59.11	58.11	59.11	58.11	59.11	58.11
12	60.0	59.0	60.0	59.0	60.0	59.0	60.0	59.0	60.0	59.0	60.0	59.0

\* Cases taken from cases



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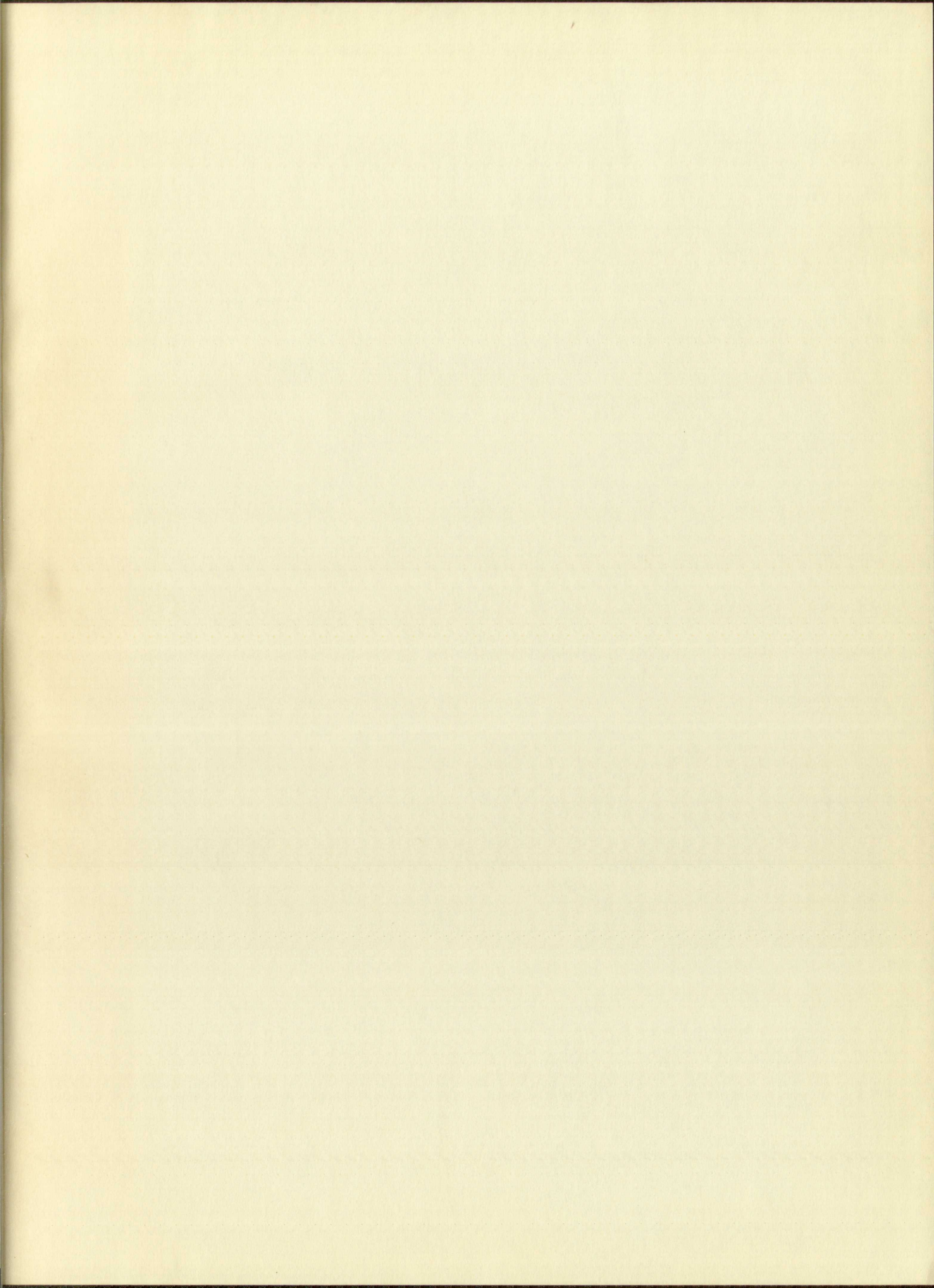
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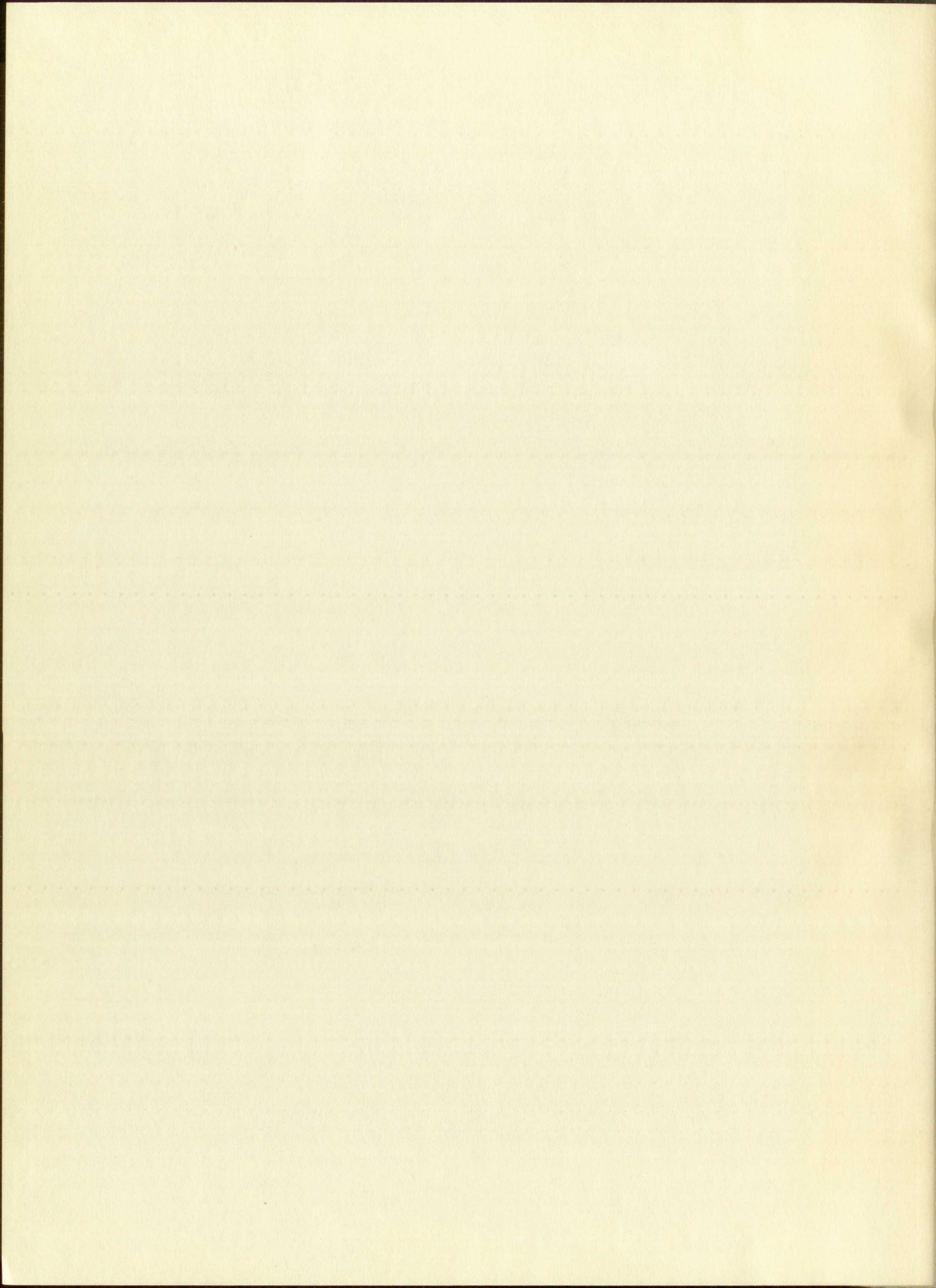
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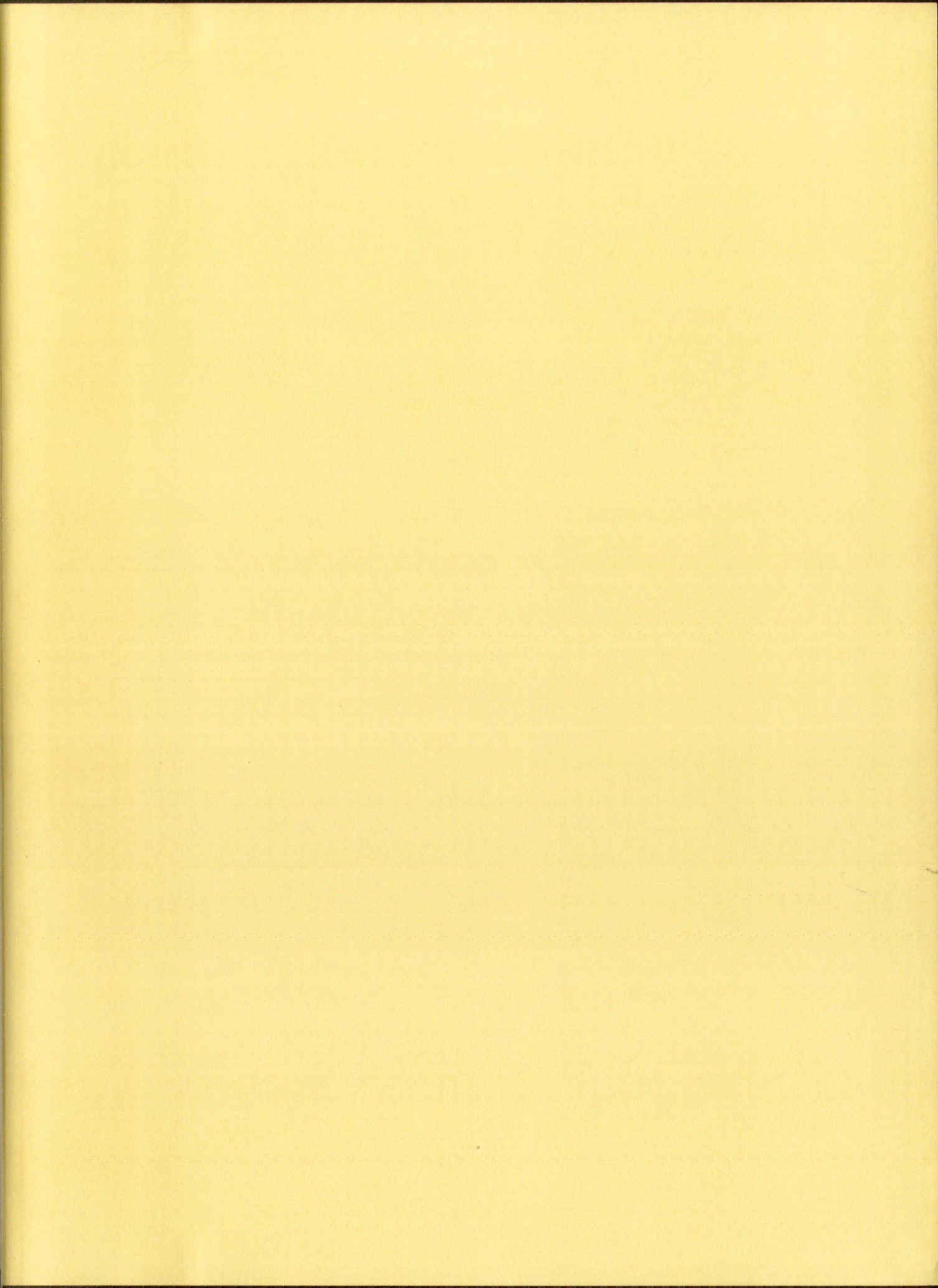














## **IMPORTANT!**

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