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DURATION OF THE ARCHIMEDES SPIRAL AFTEREFFECT
UNDER VARIED STIMULUS CONDITIONS

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DURATION OF THE ARCHIMEDES SPIRAL AFTEREFFECT
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CHAPTER I

INTRODUCTION

Spiral aftereffects were first studied by Plateau in 1850 (Boring, 1942) who found that an impression of contraction or expansion was experienced when a subject viewed a rotating spiral under conditions of clockwise or counterclockwise movement. When rotation of the spiral was halted, the impression of expansion or contraction directly opposite to that given during rotation was experienced.

The spiral aftereffect phenomenon was further studied by Oppel in 1859, Dvorak in 1870, Bowditch and Hall in 1881, and Szily in 1905 (Boring, 1942; Wohlgemuth, 1911). At the turn of the century Wohlgemuth (1911) published his comprehensive monograph which surveyed all of the previous work and included his own studies dealing with spiral aftereffects. He studied spiral aftereffects as related to a number of stimulus variables such as: different speeds of rotation, levels of illumination, and varied colored spirals on a black background. He reported that the aftereffect can be experienced for any speed of stimulation up to the point where fusion appears to take place. He concluded that the aftereffect of movement is most pronounced in a brightly illuminated field.

Wohlgemuth's experimentation was considered classical for his day and helped set the stage for further research on this phenomena. However, a major shortcoming of his work was that his experiments employed only two or three subjects.

Since the publication of Wohlgemuth's study, few articles have appeared dealing with the perception of the spiral aftereffect. Those articles which were published tended to deal with stimulus variables already delineated by him. For example, Granit (1928) studied viewing distance. He concluded that viewing distance enhanced the perception of the aftereffect. Later, Grindley and Wilkinson (1953) had the spiral viewed through a telescope and found that subjects reported the usual aftereffect under such conditions.

Since 1949 most experiments utilizing the spiral aftereffect have been conducted in the clinical field. The most common type of spiral used has been the Archimedes spiral. This is a spiral of 920° with two and one-half turns radiating from the center. A subject typically views this spiral in rotation for a specified period of time and during this period of rotation the spiral appears either to expand or contract, depending on the direction of rotation. When the spiral is stopped a reverse aftereffect of either contraction or expansion is experienced.

A representative review of the studies utilizing the Archimedes spiral in a clinical situation would begin with the investigation of Freeman and Josey (1949). They reported a study in which the performance of 85 hospitalized psychiatric subjects and 50 normal subjects were compared as to their perception of the spiral aftereffect. They concluded that most of the patients with memory impairment did not report the aftereffect, while those with little or no memory loss perceived the effect as often as did normal subjects.

Standlee (1953) tested 25 psychotic patients and 16 normals with the Archimedes spiral. All of the psychotics and normals reported the aftereffect for a single clockwise and counterclockwise rotation. Standlee concluded there was no relationship between memory impairment and perception of the aftereffect. In a follow up study, Standlee (1954) tested 25 psychotics following electroshock therapy. All but two of the 25 patients reported the aftereffect. These results, he felt, confirmed his previous findings.

Price and Deabler (1955) reasoned that failure to perceive the spiral aftereffect might be related to brain damage and that the spiral could be fruitfully utilized to arrive at a differential diagnosis of brain damage. They compared 120 patients with known brain damage to 40 normals and 40 functional psychiatric patients. Using four trials (two with clockwise rotation and two with counterclockwise rotation) they found that 95% of the normal and functional psychiatric patients reported the aftereffect on all four trials, while only 2% of the brain damaged patients did so. The stimulus conditions which they used in their study consisted of 78-100 rpm rotation speed, 920° spiral, and a 30 second exposure period.

Page, Rakita, Kaplan, and Smith (1957) compared the results of the spiral aftereffect for 20 brain damaged patients and 20 functional psychiatric patients. These investigators, like Price and Deabler (1955), concluded that the brain damaged group reported significantly fewer aftereffects.

Later investigators (Davids, Goldenberg, & Laufer, 1957; Garrett, Price, & Deabler, 1957; Goldberg & Smith, 1958; Spivack & Levine, 1957) found that the spiral aftereffect was reported more often by normal than by brain damaged subjects.

More recently, Blau and Schaffer (1960) reported that children exhibiting abnormal EEGs did not report the aftereffect as frequently as children with normal EEGs. Other investigators (McDonough, 1960; Schein, 1960; Sindberg, 1962; Whitmyre & Kurtzke, 1962) found that patients with known brain damage reported significantly fewer aftereffects than functional psychiatric patients and normals. Thus, their general conclusion was that the spiral aftereffect was a valid clinical instrument for detecting the presence of brain damage.

Some investigators have found little or no support for Price and Deabler's (1955) contention that individuals with brain damage report significantly fewer spiral aftereffects than nonbrain damaged individuals.

Gilberstadt, Schein, and Rosen (1958) after administering the spiral to 87 admissions of a Psychiatry Service and 140 admissions to a Neurology Service of a VA hospital concluded that the spiral aftereffect had limited usefulness for diagnosing brain damaged from normal subjects. An even more striking finding was reported by Holland and Beech (1958) who found that only one of 21 known brain damaged subjects which they tested failed to report the aftereffect.

Other investigators (Aaronson, 1958; Berger, Everson, Rutledge, & Koskoff, 1958; Philbrick, 1959; Spivack & Levine, 1959) likewise found there was little or no difference between normals and brain damaged patients in regard to their report of the spiral aftereffect.

Several investigators have contended that there is no real impairment of perception in persons with brain damage but rather an impairment of the ability to give a verbal report of the spiral aftereffect.

London and Bryan (1960) using 22 normals and 44 brain damaged patients found that when instructions were varied from structured to unstructured the brain damaged group perceived the aftereffect as frequently as the normals. This finding was supported by Mayer and Coons (1960) who likewise found that brain damaged and schizophrenic subjects varied in their frequency of experiencing the aftereffect under conditions of neutral and anxiety-producing instructions.

From this survey of the literature concerning the clinical use of the Archimedes spiral in detecting brain damage, the varied findings do not unequivocally support the diagnostic value of the aftereffect as first reported by Price and Deabler (1955). However, it is not unreasonable to infer from the experimental findings that brain damaged subjects do not report the spiral aftereffect as frequently as normals.

The majority of investigators relied on the presence or absence of a spiral aftereffect report as the criterion for differentiating brain damaged from nonbrain damaged subjects. Such a method was questioned by Gallese (1956) who noted that when brain damaged subjects reported experiencing the spiral aftereffect their perception of the phenomenon was of shorter duration than was that of normal subjects. Thus, by means of demonstrating differences in duration of experience of the spiral aftereffect, rather than relying on gross all-or-none differences such as those reported in the previously mentioned clinical studies, the value of the spiral as a diagnostic instrument might be increased.

Several studies have been conducted to investigate the role of spiral aftereffect duration as a means of diagnosing brain damage. Gallese (1956), as mentioned above, reported that when brain damaged subjects experience the spiral aftereffect it was of shorter duration than was the aftereffects reported by normals.

Holland and Beech (1958) after evaluating the duration of the aftereffect by brain damaged and normal subjects concluded that a finer discrimination between the two groups could be made by comparing the duration of the spiral aftereffect. They further concluded that the brain damaged group had significantly shorter aftereffects than the normals.

Philbrick (1959) administered the spiral to 81 consecutive admissions to the Neurology Ward of a general hospital. After the diagnosis of brain damage was established, there was no significant difference between the brain damaged and nonbrain damaged groups in regard to their report of the spiral aftereffect. However, it was noted that the brain damaged patients saw the spiral aftereffect for a shorter period of time than did those without brain damage.

Spivack and Levine (1957) administered the spiral to 32 brain damaged adolescent boys and 35 emotionally disturbed adolescent boys. They reported that the brain damaged group reported significantly fewer aftereffects than the emotionally disturbed group. In addition, they reported that when the brain damaged group experienced the spiral aftereffect it was of longer duration than the experience of the aftereffect by the emotionally disturbed group. In a follow up study, Spivack and Levine (1959) administered the spiral to 24 brain damaged females and 20 normal females. Again, they reported the brain damaged group had longer durations of the spiral aftereffect than the normal group.

Page et al. (1957) found no differences in the duration of the spiral aftereffect between brain damaged and schizophrenic patients. The investigators concluded that differentiation of brain damaged from nonbrain damaged individuals could not be accomplished by considering the reported length of the aftereffect.

Truss and Allen (1959) administered the spiral to 17 brain damaged and 8 normal subjects. They reported that the duration of the aftereffect was not significantly different for the two groups. Likewise, Schein (1960) after administering the spiral to 81 admissions to the Neurology Service and 40 admissions to the Psychiatry Service of a VA hospital concluded that there were no significant differences between the groups in their experience of the duration of the spiral aftereffect.

Costello (1961) attempted to account for differences reported by previous investigators in regard to the duration of the spiral aftereffect. He reported that those investigators finding shorter aftereffects for the brain damaged (Gallese, 1956; Holland & Beech, 1959; Philbrick, 1959) used the contraction aftereffect (counterclockwise rotation) whereas those reporting longer aftereffects (Spivack & Levine, 1957; 1959) had used the expansion aftereffect (clockwise rotation). In view of these stimulus conditions, Costello predicted that brain damage results in an increase of the expansion spiral aftereffect and a decrease in the contraction spiral aftereffect.

In order to test his hypothesis, i.e., satiation produced by brain damage results in an increase in the expansion aftereffect and a decrease in the contraction aftereffect, Costello assumed that massed trials of the spiral would produce satiation in normal subjects similar to that found in brain damaged individuals. Using 40 normals, assigned to either an "expansion group" or "contraction group," each subject was given six massed trials on the spiral with each trial consisting of 60 seconds of stimulation. Under these conditions he found that the over-all duration of the contraction spiral aftereffect tended to be shorter than the expansion aftereffect. Thus he felt that his hypothesis was confirmed. Findings similar to those of Costello have more recently been reported by Eysenck, Willett, and Slater (1962).

The conflicting results obtained in regard to the measurement of the duration of the spiral aftereffect in brain damaged and normals could possibly be attributed to the variability of the stimulus conditions. For example, Gallese (1956) used a rotation speed of 90 rpm and an inspection period of 30 seconds. Holland and Beech (1958) used a rotation speed of 78 rpm and an exposure time of 30 seconds in their study. Philbrick (1959) used a rotation speed of 100 rpm and a 30 second exposure period. Spivack and Levine (1957; 1959) used a rotation speed of 78 rpm and a 30 second exposure period. In addition, the previously mentioned investigators used only the expansion aftereffect (clockwise rotation) as a measure of duration. Page et al. (1957) used a rotation speed of 100 rpm and a 30 second stimulation. In addition, these investigators dealt with only the contraction aftereffect (counterclockwise rotation) as a measure of duration. Truss and Allen (1959) used a rotation speed of 64 rpm with inspection periods of 10 and 30 seconds. They, too, used only the expansion aftereffect for measuring the duration of the aftereffect. Schein (1960) used a rotation speed of 100 rpm and exposure times of 15 and 30 seconds. He used both the expanding and contracting aftereffects as measures of the duration. Holland and Beech (1958), Costello (1961), and Eysenck et al. (1962) used a completely different spiral (one with 180° or four throws) from that used by other investigators.

The subject variable has likewise fluctuated considerably from one study to another. Gallese (1956) used 41 schizophrenics, 97 brain damaged, 12 lobotomized schizophrenics, and 30 normals. Holland and Beech (1958) used 21 brain damaged and 17 normals. Philbrick (1959) used 81 patients admitted to the Neurology Service of a general hospital. Spivack and Levine (1957) used 32 adolescent boys with brain damage and 35 adolescent boys with the diagnosis of emotional disorders. In their later study (1959) they used 24 females with brain damage and 20 females with no evidence of brain damage. Page et al. (1957) used 20 patients with known brain damage and 20 patients suffering from emotional disturbances. Truss and Allen (1959) used 17 subjects suffering from cerebral palsy as their brain damaged group and eight subjects with no brain damage as their control group. Schein (1960) used 81 admissions to the Neurology Service and 40 admissions to the Psychiatry Service of a VA hospital. The former group constituted his brain damaged subjects and the latter group his nonbrain damaged patients. Finally, Costello (1961) used 40 industrial apprentices and made the assumption that massed trials would induce satiation similar to that found in brain damaged patients.

In view of the variability of both stimulus conditions and samples used in order to study the duration of the spiral aftereffect, it was concluded that a systematic investigation of the influence of certain stimulus variables on the duration of the aftereffect was warranted. By utilizing a nonbrain damaged population a better evaluation of the relevant stimulus variables can be ascertained. Such an investigation would isolate some of the relevant variables of the spiral aftereffect on a normal sample and give some conception of their influence. Such research seems to be pertinent if the spiral is to be used as a research method in the investigation of brain damage.

Despite all of the clinically oriented research with the spiral there is a paucity of theoretical statements concerning the perceptual mechanisms underlying the spiral aftereffect phenomenon. The two most prominent theories of aftereffects, the Kohler and Wallach (1944) and the Osgood and Heyer (1952), apparently fall short in accounting for the phenomenon of visual movement aftereffects.

Kohler and Wallach (1944) state that displacement of perceived figures occurs when a new pattern of stimulation impinges on cortical tissue which has been already satiated by prior stimulation. For example, a subject is asked to fixate on a figure for a specific period of time, then a second figure is presented. This second figure appears to be displaced away from the area previously occupied by the first figure. Kohler and Wallach reason that the first figure builds up neural satiation within the cortical tissue which prevents further figural currents in that tissue. Thus when the second figure is presented it will give the impression of moving away from the satiated area. Kohler (1951) accounts for this effect of displacement in terms of differential nerve stimulation. He continues by stating that electrochemical processes are responsible for the basic mechanisms of perception and changes in these neurophysiological processes are responsible for figural aftereffects. However, Kohler (1958) specifically stated that the theory of aftereffects formulated by him and Wallach may not be adequate to account for visual aftereffects. In this regard Kohler states:

> Our theory of figural after-effects is mainly concerned with anaelectrotonic action . . . when perception begins to be stable, catelectrotonic attraction will soon be overcome by anaelectrotonic repulsion. We all know perceptual facts which only arise under the conditions favorable to catelectrotonic effects. I am referring to the various forms of apparent movement (Kohler, 1958, p. 154).

Osgood and Heyer (1952) drawing from the work of Marshall and Talbot (1940) as well as the Kohler-Wallach (1944) theory, proposed a statistical theory to account for figural aftereffects. Briefly stated, Osgood and Heyer assumed that when an individual views a figure consisting of contours, a spatial distribution of excitation will be established due to the resultant projection in the nervous system. When the individual is then presented with an inspection figure the contours of this figure will leave the individual neurones in unequal states of recovery. This state of the neurones is then supposed to shift the zone of maximum excitation. During the period of shift in excitation it is assumed that the resultant zone of maximum excitation will give rise to the experience of an aftereffect. Smith (1952) offered six criticisms of the Osgood-Heyer position and concluded that their theory could not adequately explain visual aftereffects. Osgood (1953) replied to Smith's criticisms as follows:

> These theories (Kohler-Wallach and Osgood-Heyer) also do not explain contrast phenomena or the effect of values and motives upon perceived size . . . they are not required to cover all phenomena in the field of perception (Osgood, 1953, p. 211).

George (1953) proposed a theory to specifically account for spiral aftereffects. Using the model proposed by Osgood-Heyer (1952), he postulated the arousal of an asymmetrical gradient on the cortical tissue during the initial rotation of the spiral. When rotation was halted and the subject viewed a stationary spiral, the differential excitability established by the static spiral would be symmetrical about the neurological projection of the lines about the spiral. The position of the previous inspection curve (established during rotation) and the present test curve (established by the static spiral) should give the displacement effect. Spitz (1958) pointed out that according to George a test surface with contours is essential to his theory and since the aftereffect can be observed on a test surface devoid of spiral contours his theory does not give a satisfactory explanation of aftereffects.

Deutsch (1956) presents a theory of shape-recognition in combination with the theories of Kohler-Wallach (1944) and of Osgood-Heyer (1952) in an attempt to explain movement aftereffects. He reasons that when an individual views the rotating spiral the contours of the spiral generate impulses in the cortical tissue and a wave front in the direction of the spiral contour takes place. At the same time, a wave front in the opposite direction is established, but is reduced since it has to pass over areas of cortical tissue which have already been stimulated. This reduction of the wave front in the opposite direction causes a difference in the rate of the wave fronts propagated backwards and forwards. When the spiral stops, this difference in rate of travel reverses itself, since the forced speeding up in a particular direction leads to a change in direction of the wave front. This reversal of wave front movement gives rise to an aftereffect. Griffith and Spitz (1959) point out that Deutsch's theory like George's (1953) is dependent upon the presence of contours on the static spiral in order for the aftereffect to be observed. Since it has been shown that subjects experience movement aftereffects by viewing plain surfaces after the spiral has halted, thus the theory presented by Deutsch appears questionable in its explanation of movement aftereffects.

Several theories have been formulated from which predictions can be made concerning the duration of aftereffect movement. Such theories include those of Klein and Krech (1952), Saucer (1953; 1954; 1956), Shaprio (1954), Wertheimer (1954; 1955), and Eysenck (1955; 1957).

Klein and Krech (1952) drawing from the model offered by Kohler-Wallach (1944) postulate that any neural activity will induce heightened resistance to additional activity in a previously stimulated area. They further state that there are individual differences in basal levels of cortical conductivity and predict that individuals with high basal cortical conductivity will react differently than individuals with low basal cortical conductivity to such variables as satiation rate, degree of satiability, and dissipation of satiation. Following this line of reasoning they concluded that one of the consequences of injury to cortical tissue is reduced conductivity. Since conductivity is reduced, neural activity will likewise be more resistant to stimulation. They thus predicted that for longer exposure periods the duration of the aftereffect in brain damaged individuals would be significantly shorter than those of nonbrain damaged individuals.

Saucer (1953; 1954) and Saucer and Deabler (1956) postulated a matrix theory of perception to account for aftereffects. Saucer and Deabler proposed that the entire cerebral cortex be viewed as a single matrix. By this they meant that motion perception is based on a matrix synthesis of perceptual organizations which are related to stimulus detail and to the temporal aspects of the stimulus configuration. The ability for perceiving apparent motion is further dependent upon the functional efficiency of the entire cerebral cortex. Following this line of reasoning, Saucer and Deabler proposed that any damage to the cerebral cortex would result in impaired perception. Such an impairment was due to the fact that the cerebral cortex was postulated to have as one of its major functions the integration of information received through the sensory channels. Thus, any injury to the cerebral cortex would result in inferior sense organ functioning. Individuals with brain damage would demonstrate damage to the perceptive mechanisms regardless of the type of cortical damage since sense organ functioning would be disrupted. In line with this theorizing, Saucer and Deabler concluded:

> It may be inferred that perception is a global process of the entire cortex and that by measuring the amount of organizational force available to the individual for use in perceptual processes such as perception of apparent motion, the functional efficiency of the individual may be measured and presence or absence of pathology determined (Saucer and Deabler, 1956, pp. 388-389).

Shaprio (1954) hypothesized that visual stimulation is followed by the irradiation of excitatory effects within the brain from the point of stimulation. If stimulation to another part of the brain follows previous stimulation, the irradiation effect of the second point of stimulation combines with the irradiation effect of the first stimulation in some manner so as to produce visual perception. Shaprio further reasoned that one of the effects of brain damage is the increase of inhibitory effects in the injured area. Thus, the brain damaged individual would not experience apparent motion or have such an experience reduced because the irradiation effects would be inhibited. In essence, Shaprio's theory postulated an exaggeration of inhibitory effects in the brain damaged person. These effects weakened the irradiation of the excitatory processes which were believed to be the basis for the perception of apparent motion.

Wertheimer (1954; 1955) advanced a theory of metabolic efficiency as the basis of individual differences in the perception of figural aftereffects. He hypothesized that stimulation produces a modification in localized areas of the cortex and these changes are related to an alteration in the chemical and electrical properties of the neural tissue involved. He stated that brain damaged individuals will manifest reduced metabolic efficiency which would be related to a reduced cortical modifiability. He suggested that such reduced modifiability could be measured by utilizing perceptual tasks with both brain damaged and nonbrain damaged individuals. He thus predicted that brain damaged individuals would manifest a decrease in perceptual functions due to their lower metabolism which in turn reduces their cortical modifiability.

Eysenck (1955; 1957) drawing from his hysteric-dysthymic dimension extended his findings to include predictions concerning the duration of spiral aftereffects. He assumed that individuals who are prone to the development of hysterical symptoms have a strong reactive inhibition which is generated rapidly and dissipated slowly. Conversely, individuals who are disposed to dysthymic disorders have a weak reactive inhibition which develops slowly and dissipates quickly. He further reasoned from his experimental studies that the pattern of symptoms manifested by the hysteric are similar to those symptoms of brain damaged individuals. He predicted that the brain damaged individual would build up considerable inhibition when viewing a rotating spiral and should have a shorter duration of the aftereffect than the nonbrain damaged individual. This prediction was supported by Eysenck, Holland, and Trouton (1957). The investigators made the assumption that depressant drugs would lead to an increase in inhibitory potentials in the brain of normal subjects similar to that manifested by brain damaged individuals. If such an assumption were valid, then normal subjects under the influence of a depressant drug would manifest shorter aftereffects than subjects not exposed to the drug. Using six normal subjects under both conditions, first under drug conditions then under placebo conditions, the investigators found results in accordance with their hypothesis.

CHAPTER II

PROBLEM

In view of the recent experimental and theoretical literature dealing with spiral aftereffects, and in particular in regard to the duration of the spiral aftereffect, it is felt that a further evaluation of the stimulus conditions giving rise to the spiral aftereffect should be more carefully evaluated. Such variables as speed of rotation, inspection time, and direction of rotation have rarely been consistent from one study to another. In addition, some investigators have used a spiral of 920° while others used a spiral of 180° or four throws. To date, there is no evidence to suggest that these spirals give comparable results.

Since the principal interest of this investigation is centered on the duration of the spiral aftereffect it was decided to utilize a nonbrain damaged population. Normals were selected for a number of reasons. First, there is a decided absence of experimental work with the spiral aftereffect on a normal population. This would provide information for better evaluation of the role of certain stimulus variables on subjects free of brain damage. Secondly, since this study is primarily concerned with the role of stimulus variables in relation to the duration of the aftereffect many of the problems encountered with brain damaged individuals will be avoided. For example, brain damaged individuals frequently do not report the aftereffect, thus this problem will theoretically be avoided. Thirdly, normal subjects will be more apt to understand and comply with the procedure and thus a finer evaluation of the effects of the stimulus variables can be made. Finally, experimental work with the spiral on a nonbrain damaged population will be of assistance in interpreting data derived from the studies using brain damaged individuals.

As noted previously some investigators have found spiral aftereffects of a shorter duration in brain damaged individuals (Gallese, 1956; Holland & Beech, 1958; Philbrick, 1959). Other investigators have reported longer spiral aftereffect durations (Spivack & Levine, 1957; 1959) and still others have reported no significant differences (Page et al., 1957; Schein, 1960; Truss & Allen, 1959). In view of these contradictory findings, it is reasonable to infer that evidence regarding the duration of the spiral aftereffect in brain damaged and nonbrain damaged individuals is equivocal.

As previously mentioned it is felt that differences in the stimulus variables utilized in the different studies may account for the inconsistencies in the duration of the spiral aftereffect. An evaluation of the stimulus variables (type of spiral used, direction of rotation, speed of rotation, and period of stimulation) generates many questions concerning stimulus conditions and theoretical issues.

Many investigators (Gallese, 1956; Page et al., 1957; Philbrick, 1959; Schein, 1960; Spivack & Levine, 1957; 1959) used an Archimedes spiral of 920° or two and one-half turns about its center. While others (Costello, 1960; 1961; Eysenck et al., 1962; Holland & Beech, 1958) used a spiral of 180° or four throws. To date, there is no evidence to suggest that the two spirals render similar aftereffects as far as duration is concerned.

A problem closely related to the type of spiral concerns the duration of the aftereffect following clockwise or counterclockwise rotation. Berger et al. (1958), Costello (1960), and Eysenck et al. (1962) reported that the duration of the contraction aftereffect was seen for a shorter period of time than was the duration for the expansion aftereffect. However, Pickersgill and Jeeves (1958) using 20 normal subjects found no significant differences between clockwise and counterclockwise rotation as far as aftereffect duration is concerned. Since Costello, Eysenck et al., and Pickersgill and Jeeves used a different type of spiral (180° type) and in view of the fact that there is limited evidence to suggest that the duration of the aftereffect is closely related for the two different types of spirals further evaluation of this variable seems to be pertinent.

Speed of rotation has ranged from 64 rpm to 100 rpm. Truss and Allen (1959) used a rotation speed of 64 rpm, Spivack and Levine (1957; 1959) and Holland and Beech (1958) used a rotation speed of 78 rpm, Gallese (1956) used a rotation speed of 90 rpm, and, finally, a speed of 100 rpm was used by Page et al. (1957), Philbrick (1959), Schein (1960), Costello (1960; 1961), and Eysenck et al. (1962). In view of their conflicting findings it may be that rotation speed was a relevant variable in regard to the duration of the spiral aftereffect.

Duration of stimulation appears to be a pertinent variable for experiencing the duration of the aftereffect (Holland, 1958; Holland & Eysenck, 1960; Pickersgill & Jeeves, 1958). Most investigators have utilized a stimulation period of 30 seconds (Gallese, 1956; Holland & Beech, 1958; Page et al., 1957; Philbrick, 1959; Spivack & Levine, 1957; 1959). Truss and Allen (1959) used 10 and 30 second inspection periods. They reported that the duration of the aftereffect was significantly increased for the 30 second exposure period. Schein (1960) used stimulation times of 15 and 30 seconds. He, too, reported that the aftereffect duration following 30 seconds of stimulation was longer than the aftereffect following the 15 second stimulation period. Holland (1958) indicated that a stimulation period of 90 seconds led to a longer persistence of the spiral aftereffect than did stimulation periods of 15, 30, and 60 seconds. In a later study Holland and Eysenck (1960) reported that the relationship of aftereffect duration to stimulation time was curvilinear and that the asymptote was not attained even after stimulation periods of 100 seconds. It would thus seem pertinent to obtain further evidence to determine the relationship of stimulation time and aftereffect duration.

The present author proposed and conducted a research study in which each of these variables were adjusted to two of the most frequently utilized stimulus conditions reported by previous investigators. This was done in the hope of adding some clarity to the practical and theoretical issues relevant to the Archimedes spiral aftereffect.

CHAPTER III

METHOD

Stimulus Conditions

An Archimedes spiral of 920° or two and one-half turns about its center was used. As previously mentioned the majority of investigators have used a spiral arrangement of this type. In addition, a spiral of 180° or four throws was likewise used. The reason for incorporating a second type of spiral is that a number of investigators such as Holland and Beech (1958), Holland and Eysenck (1960), and Costello (1960; 1961) have exclusively used this type of spiral. Since there is no evidence to suggest that the different spirals yield comparable results it seems to be pertinent to compare the duration of the spiral aftereffect for the two different types of spirals to determine if it is advisable to generalize the findings from one kind of spiral presentation to the other.

The duration of the aftereffect was measured for both clockwise and counterclockwise presentations of both spirals. This was done in order to further evaluate the findings of Berger et al. (1958), Costello (1960), and Eysenck et al.

(1962) in which they found the duration of the contraction aftereffect (which follows clockwise rotation) to be seen for significantly shorter periods of time than the expansion aftereffect (which follows counterclockwise rotation).

Two rotation speeds were utilized. First, a speed of 78 rpm was used since Spivack and Levine (1957; 1959), Berger et al. (1958), and Holland and Beech (1958) considered this speed to give the most differentiating results between brain damaged and normal subjects. Secondly, a speed of 100 rpm was used in order to compare the findings of Page et al. (1957), Philbrick (1959), Schein (1960), Costello (1960; 1961), and Eysenck et al. (1962) who utilized this speed of rotation.

Time of stimulation was likewise varied in two ways. A 30 second exposure period was used in view of the fact that the majority of investigators adhered to this stimulation period (Berger et al., 1958; Gallese, 1956; Holland & Beech, 1958; Page et al., 1957; Philbrick, 1959; Spivack & Levine, 1957; 1959). A second exposure period of 100 seconds was used in order to evaluate the contention of Holland (1958; 1962), Holland and Eysenck (1960), and Schein (1960) that the spiral aftereffect duration is a function of stimulation time.

Subjects

The sample consisted of 160 nonbrain damaged individuals. The subjects were selected from the general college population at the University of Oklahoma. It would seem to be a reasonable conclusion, unless otherwise indicated, that students actively engaged in academic course work would be free of any brain damage.

The sample consisted of 80 males with an age range from 18 to 44 years with a mean age of 22.65 years. An equal number of females were selected with an age range from 18 to 44 years with a mean age of 22.15 years. In regard to the age and sex variables a number of studies (Berger et al., 1958; Gallese, 1956; Page et al., 1957; Schein, 1960) have reported there was no relationship between age and duration of the reported aftereffect. The variable of sex difference has not been extensively studied and investigators have reported mixed findings in regard to the influence of this variable. For example, Gallese (1956) and Page et al. (1957) concluded that the duration of the aftereffect was unrelated to sex. However, Spitz and Lipman (1959) reported significant differences between sexes as far as the aftereffect duration is concerned. In view of these results it was decided to evaluate within the context of this experiment whether or not differences exist between male and female subjects in regard to the duration of the spiral aftereffect.

Apparatus

A Lafayette spiral rotor with a range of 10 to 130 revolutions per minute was used. This instrument had an electrodynamic brake which was controlled by the operator. In addition, there was a push button which the subject could compress at the time he saw the spiral aftereffect terminate. A Standard Electric timer was connected so that the apparent aftereffect was precisely measured from the time of its onset until its termination. A stop watch was used to time the duration of the stimulus presentation.

Procedure

Five male and five female subjects were randomly assigned to each of the stimulus conditions listed in Table 1. Each subject was seated eight feet from the apparatus as has been the customary procedure in the majority of studies reported in the literature. The subject was in a well illuminated room and the illumination level was periodically checked. In regard to this variable, the literature indicates that illumination level appears to have little effect upon the proposed response variable. For example, Holland (1958) as well as Pickersgill and Jeeves (1958) reported that the illumination level was not significantly related to the duration of the aftereffect. Finally, the spiral was placed on a table so that it was 35 inches above the floor. A background of medium gray mat board extending approximately 24 inches out from the center was placed behind the rotating spiral.

Table 1

Stimulus Conditions
($\underline{N}$ for each condition 10)

Stimulus Condition	Spiral (type)	Direction	Speed (rpm)	Time (sec.)
1.	920	CW	78	30
2.	920	CW	100	30
3.	920	CW	78	100
4.	920	CW	100	100
5.	920	CCW	78	30
6.	920	CCW	100	30
7.	920	CCW	78	100
8.	920	CCW	100	100
9.	180	CW	78	30
10.	180	CW	100	30
11.	180	CW	78	100
12.	180	CW	100	100
13.	180	CCW	78	30
14.	180	CCW	100	30
15.	180	CCW	78	100
16.	180	CCW	100	100

Key:
CW - clockwise rotation
CCW - counterclockwise rotation

The subjects were given directions similar to those used by Price and Deabler (1955) with certain modifications. Standard directions are presented in Table 5 of the Appendix.

Each subject was given ten trials under one of the stimulus conditions presented in Table 1. The intertrial interval was maintained at 30 seconds as was the procedure in the majority of studies previously reported. During the intertrial period the subject was told to look away from the spiral and at the end of 30 seconds was told to look again at the center of the spiral. The 30 second intertrial interval and the duration of the stimulus presentation (30 sec. or 100 sec.) was measured by means of a stop watch which began when the spiral started moving. The subject's reported duration of the spiral aftereffect was recorded on a Standard Electric timer (.01 sec.) from which the reading for each of the ten trials was taken. The order of the stimulus presentations for the males is given in Table 6 of the Appendix and the order of stimulus presentations for the females is given in Table 7 of the Appendix.

CHAPTER IV

RESULTS

The data were evaluated by a Bartlett's test for homogeneity of variance. The Chi Square value was 14.49, which was not significant at the .05 level of confidence.

A 2 x 2 x 2 x 2 x 2 analysis of variance was performed to determine if the treatment means were significantly different. The results of this analysis are presented in Table 2.

From the results presented in Table 2 it is evident that the treatment means differ significantly. Analysis was then performed to test for significant differences among the major treatment conditions. Results of this analysis are presented in Table 3.

Results presented in Table 3 reveal that three of the five main effects (direction of rotation, speed of rotation, and inspection time) were significant with probabilities less than the .01 level of confidence. The remaining two treatment effects (type of spiral and sex) were not significant.

The over-all effects of the four major treatment

Table 2

Analysis of Variance for Treatment Sum of Squares and Within Treatment Sum of Squares

Source	Sum of Squares	Degrees of Freedom	Mean Square	*F*	*P*
Treatments	77126.270	15	5141.751	29.143	.01
Within treatments	2822.943	16	176.434		
Total	79949.213	31			

Table 3

Analysis of Variance for Major Treatment Conditions

Source		Sum of Squares	Degrees of Freedom	Mean Square	*F*	*P*
A:	Spiral	131.114	1	131.114	.743	n.s.
B:	Direction	4429.834	1	4429.834	25.107	.01
C:	Speed	2089.404	1	2089.404	11.842	.01
D:	Inspection	60568.900	1	60568.900	343.295	.01
E:	Sex	17.036	1	17.036	.096	n.s.
	Error	2822.943	16	176.434		

conditions, namely, period of inspection, speed of rotation, type of spiral, and direction of rotation, are graphically presented in Figure 1.

Variation in type of spiral which was used, either the 920° or 180° type, apparently had little effect as a main variable as far as fluctuations in the duration of the aftereffect was concerned. The aftereffect scores for the two types of spirals under varied stimulus conditions (direction of rotation, speed of rotation, and time of stimulation) are graphically represented in Figure 2.

Direction of rotation, clockwise or counterclockwise, appeared to be a highly significant variable. The over-all results indicated that clockwise rotation which was followed by the expansion aftereffect was reported as being seen for a significantly longer period of time than was the contraction aftereffect which followed counterclockwise rotation. The aftereffect scores for the two directions of rotation under the varied stimulus conditions (type of spiral, speed of rotation, and time of stimulation) are graphically presented in Figure 3.

Speed of rotation appeared to be a more important variable than previous investigators believed. In terms of the present experiment, a rotation speed of 78 rpm gave a significantly longer aftereffect than did a rotation speed of 100 rpm. The aftereffect scores for the two speeds of rotation under the varied stimulus conditions (type of

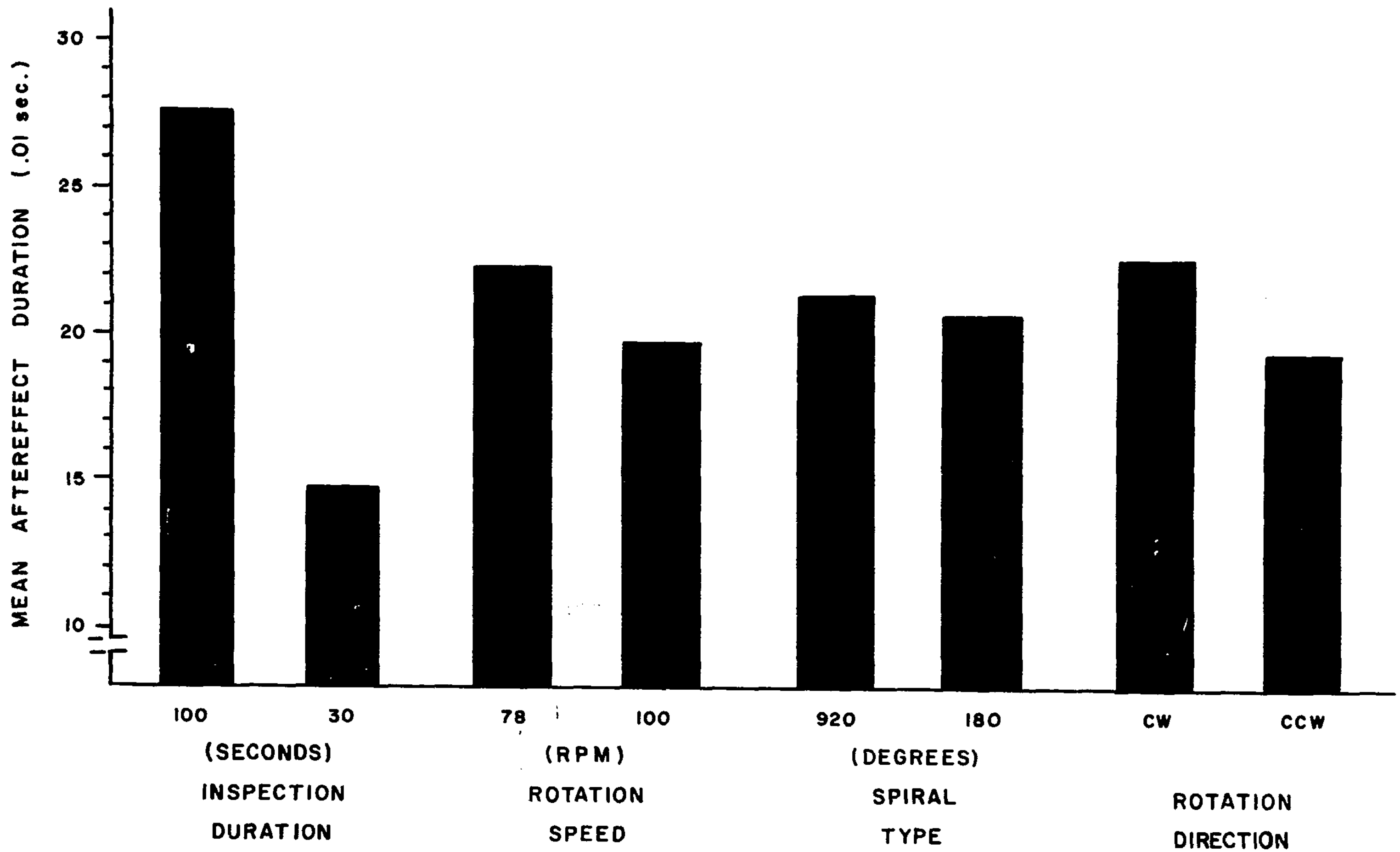

Figure 1. Duration of aftereffect for major treatment conditions.

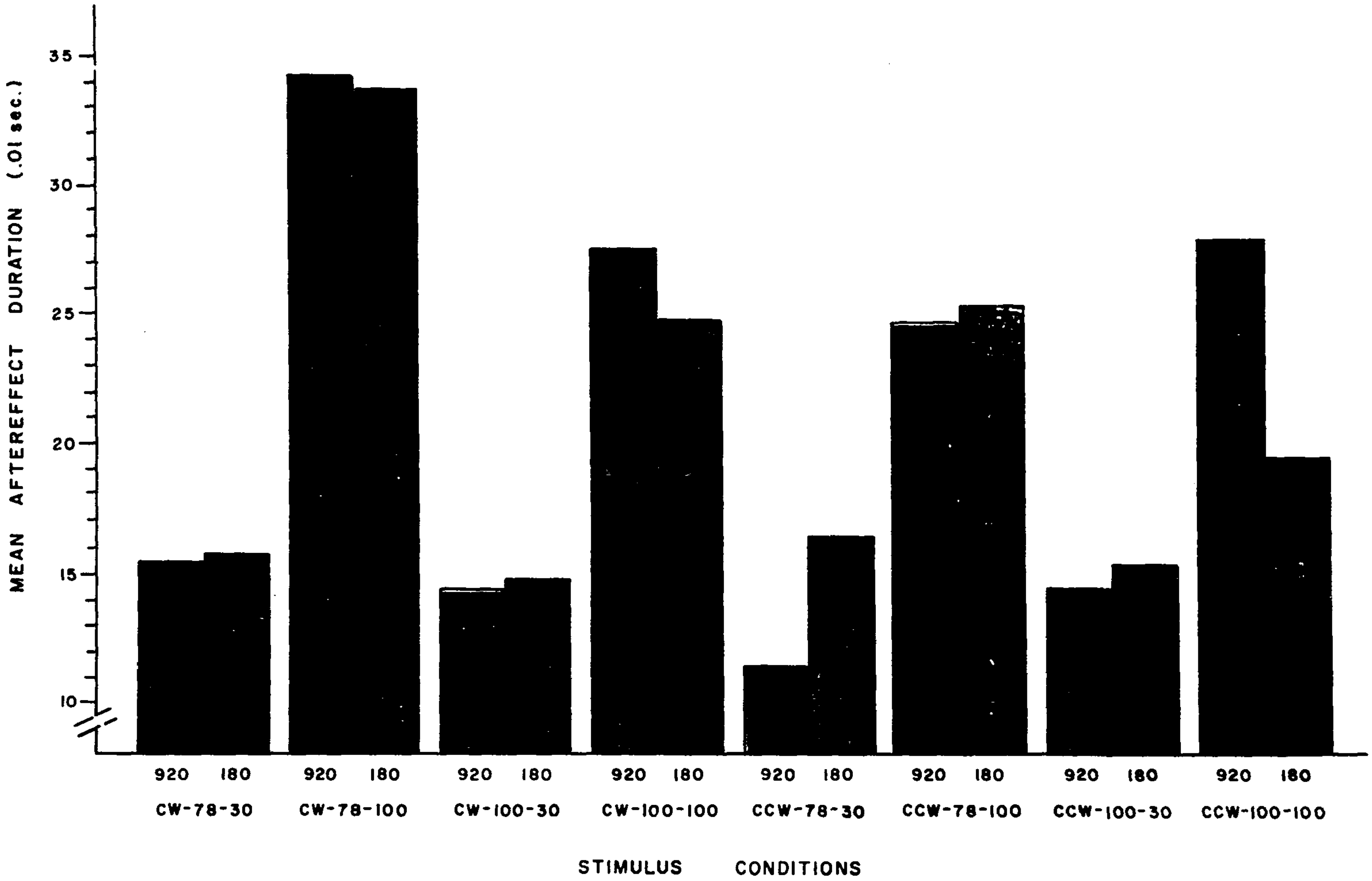

Figure 2. Duration of aftereffect for the two types of spirals under varied stimulus conditions.

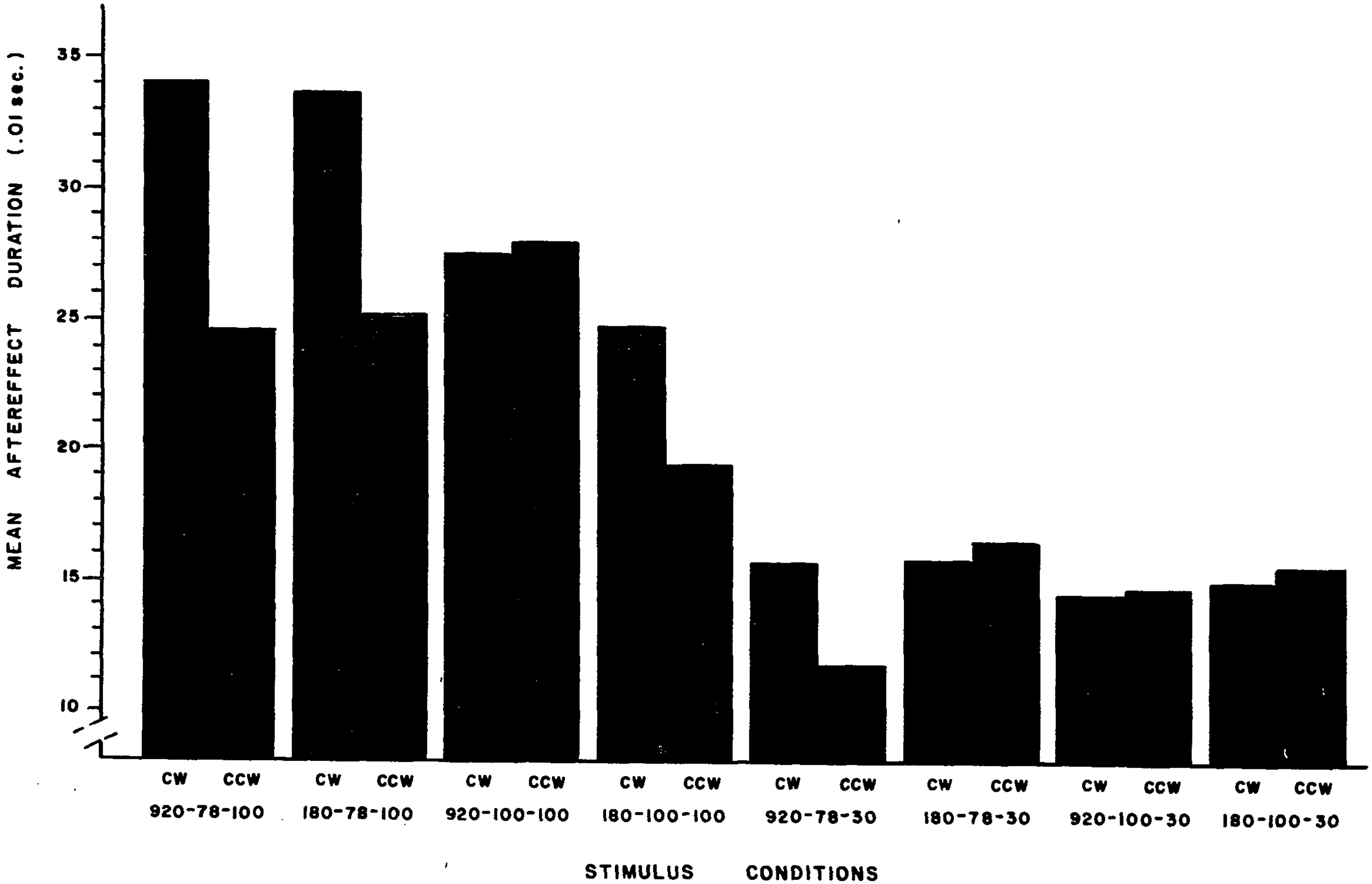

Figure 3. Duration of aftereffect for the two directions of rotation under varied stimulus conditions.

spiral, direction of rotation, and time of stimulation) are presented in Figure 4.

Time of stimulation appeared to be the most highly significant variable. An inspection period of 100 seconds resulted in a significantly longer spiral aftereffect than did an inspection period of 30 seconds. The aftereffect scores for the two inspection periods under the varied stimulus conditions (type of spiral, speed of rotation, and direction of rotation) are presented in Figure 5.

Finally, the sex variable was found to be a non-significant factor as far as aftereffect duration was concerned.

Results of the interaction effects are presented in Table 4. Only the results for first order interactions are presented since none of the other orders of interaction were significant.

The interaction between speed of rotation and type of spiral is presented in Figure 6. This figure indicates that, although the duration of the aftereffect decreases as speed of rotation increases, this decrease is greater for the 180° spiral.

The interaction effect for period of inspection and type of spiral is represented in Figure 7. This figure indicates that as the period of inspection is increased, the duration of the aftereffect increases. However, the increase in duration is greater for the 920° spiral than for the 180°

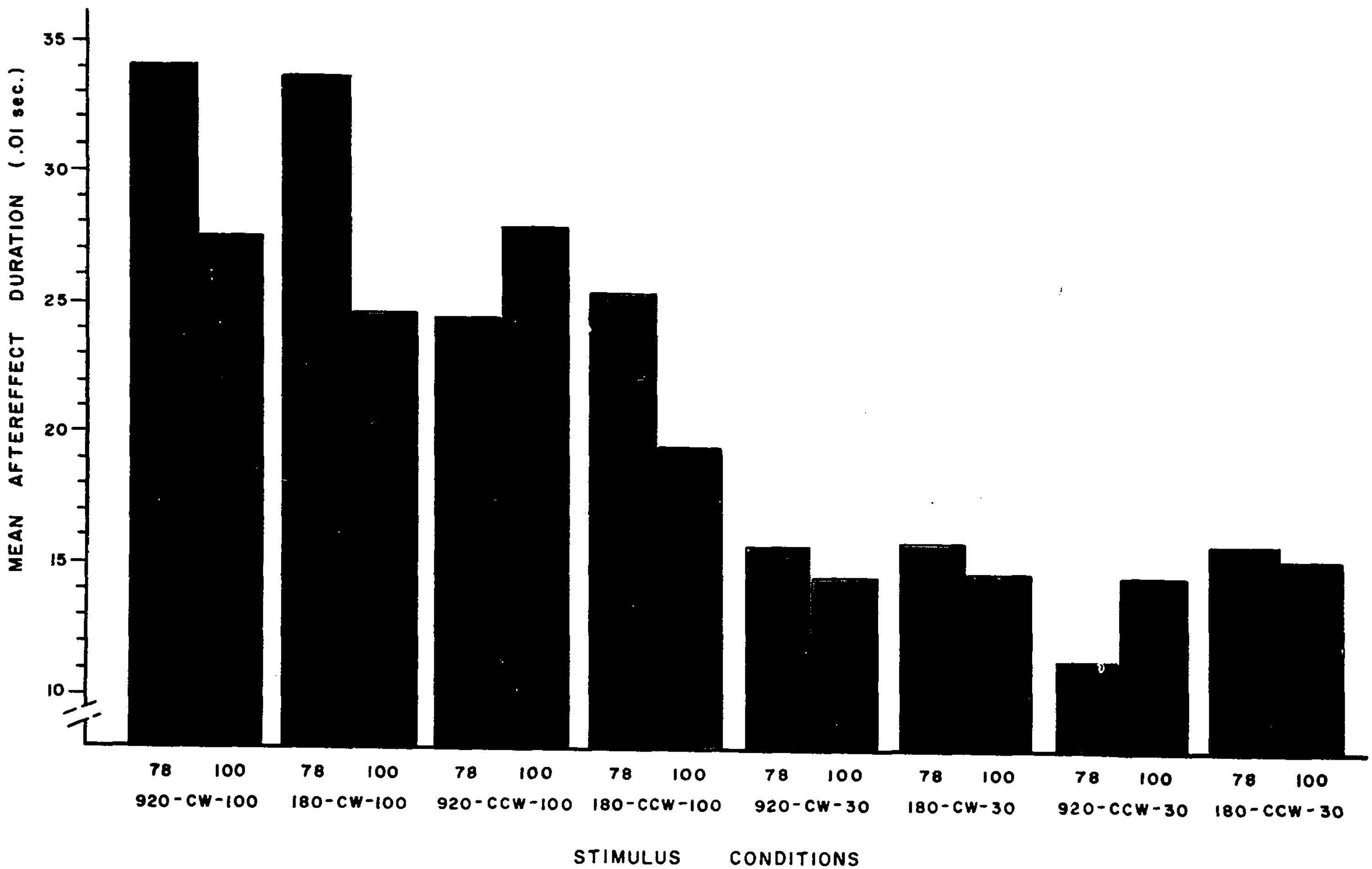

Figure 4. Duration of aftereffect for two speeds of rotation under varied stimulus conditions.

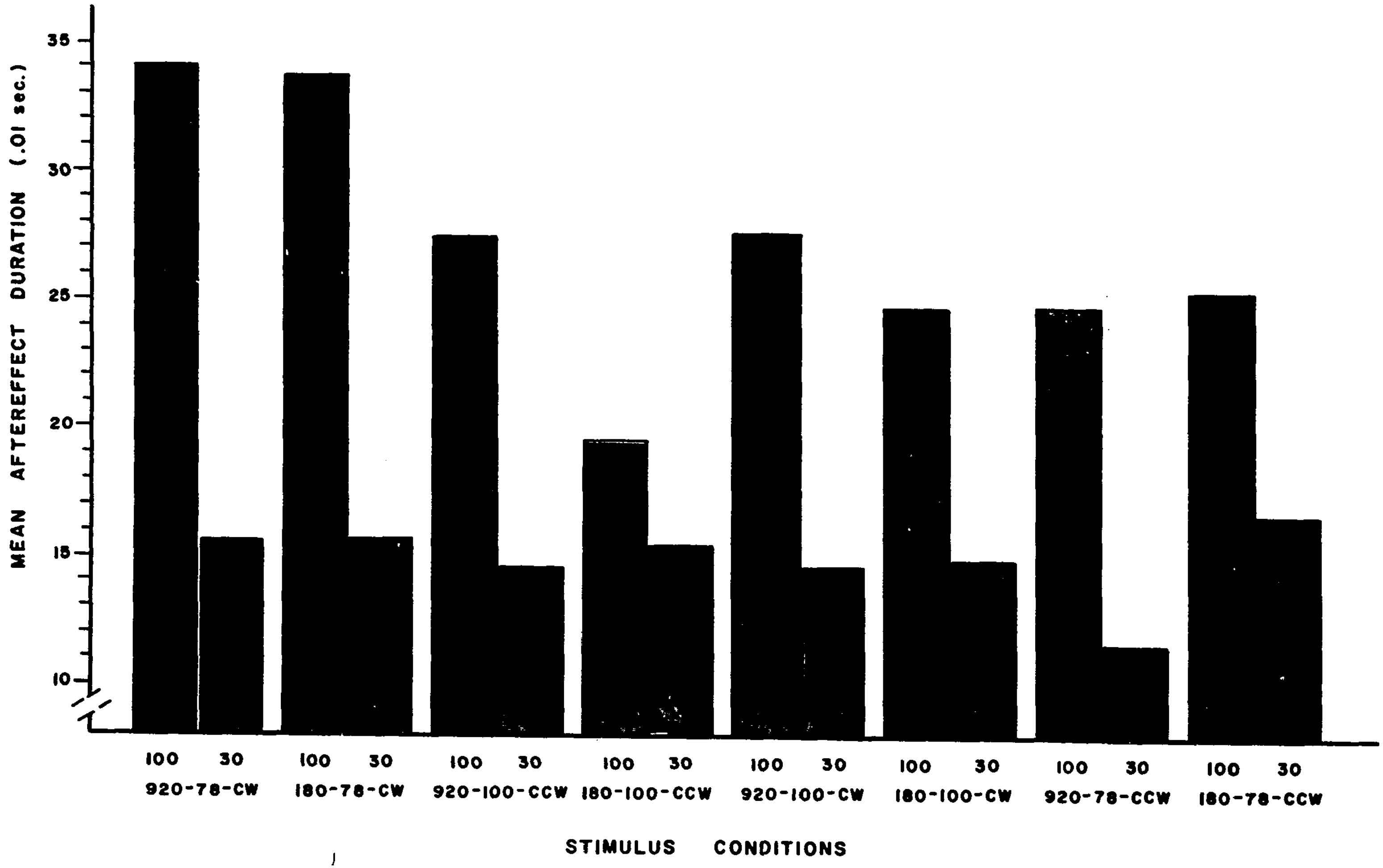

Figure 5. Duration of aftereffect for the two inspection periods under varied stimulus conditions.

Table 4

First-Order Interactions for the Factorial Experiment

Source	Sum of Squares	Degrees of Freedom	Mean Square	*F*	*P*
Sex x Spiral	121.022	1	121.022	.686	n.s.
Direction x Spiral	.504	1	.504	.003	n.s.
Speed x Spiral	1527.051	1	1527.051	8.655	.01
Inspection x Spiral	1855.542	1	1855.542	10.516	.01
Sex x Direction	7.179	1	7.179	.040	n.s.
Speed x Direction	1817.572	1	1817.572	10.301	.01
Inspection x Direction	2499.750	1	2499.750	14.168	.01
Sex x Speed	.269	1	.269	.002	n.s.
Inspection x Speed	2039.922	1	2039.922	11.562	.01
Inspection x Sex	21.169	1	21.169	.012	n.s.
Error	2822.943	16	176.434		

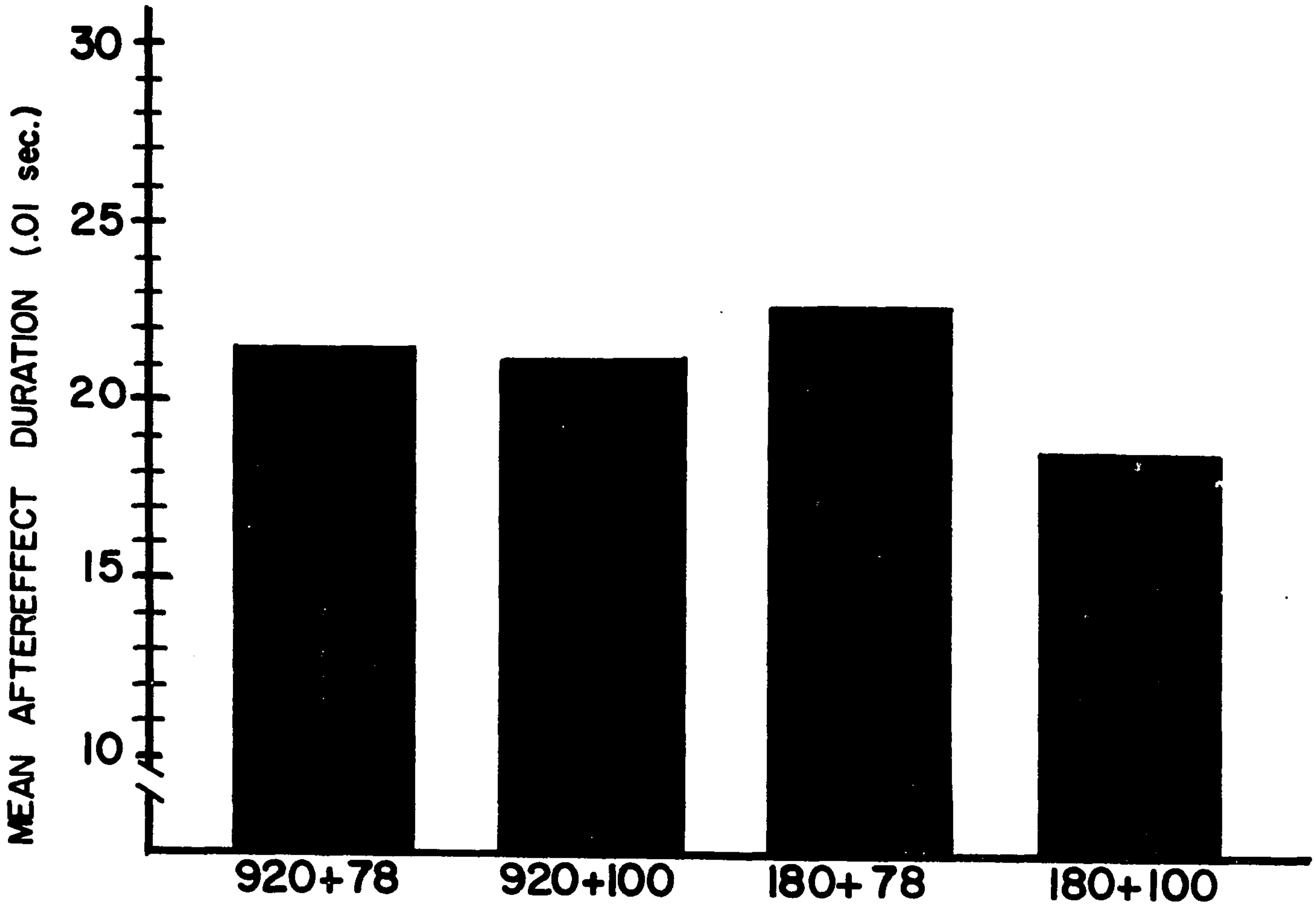

Figure 6. Interaction effect for speed of rotation and type of spiral.

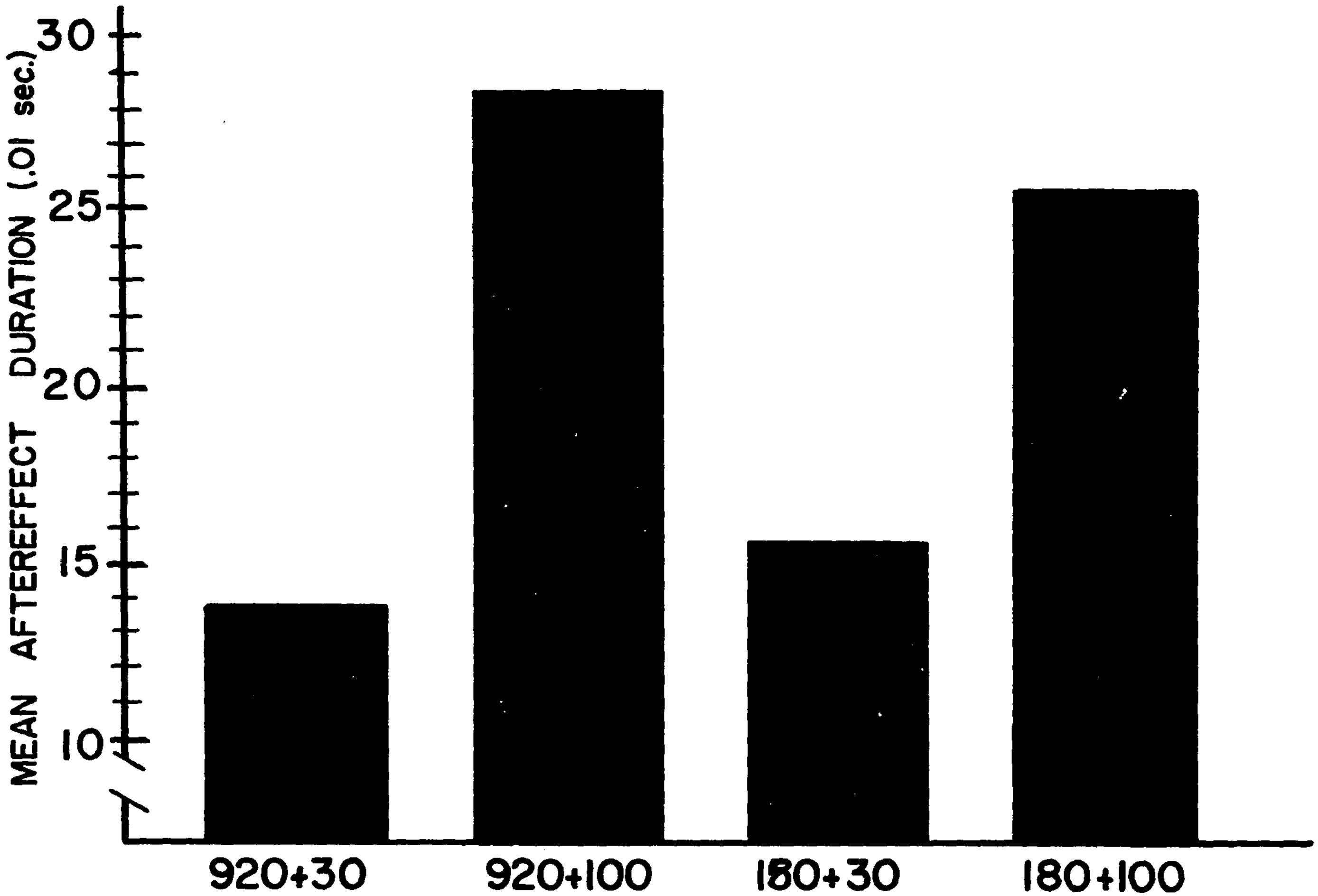

Figure 7. Interaction effect for period of inspection and type of spiral.

spiral.

The interaction effect for speed of rotation and direction of rotation is presented in Figure 8. For clockwise rotation a change in rotation speed from 78 rpm to 100 rpm results in a decrease of the aftereffect duration. However, for counterclockwise rotation a change from 78 rpm to 100 rpm rotation speed results in no change in the duration of the aftereffect.

The interaction effect for period of inspection and direction of rotation is presented in Figure 9. It is noted that for both the 30 second and 100 second inspection period there is a decrease in the duration of the aftereffect when a change is made from clockwise to counterclockwise direction of rotation. However, the decrease in duration is more apparent for the 100 second stimulation period.

The interaction effect for speed of rotation and inspection time is presented in Figure 10. This graph indicates that when speed of rotation is changed from 78 rpm to 100 rpm under the 30 second inspection period there is no difference in the aftereffect duration. However, when speed of rotation is changed from 78 rpm to 100 rpm under the 100 second period of inspection there is a marked decrease in the aftereffect duration.

The nonsignificant interactions provided additional useful information. It is of importance to note that sex differences were unrelated to such variables as speed of ro-

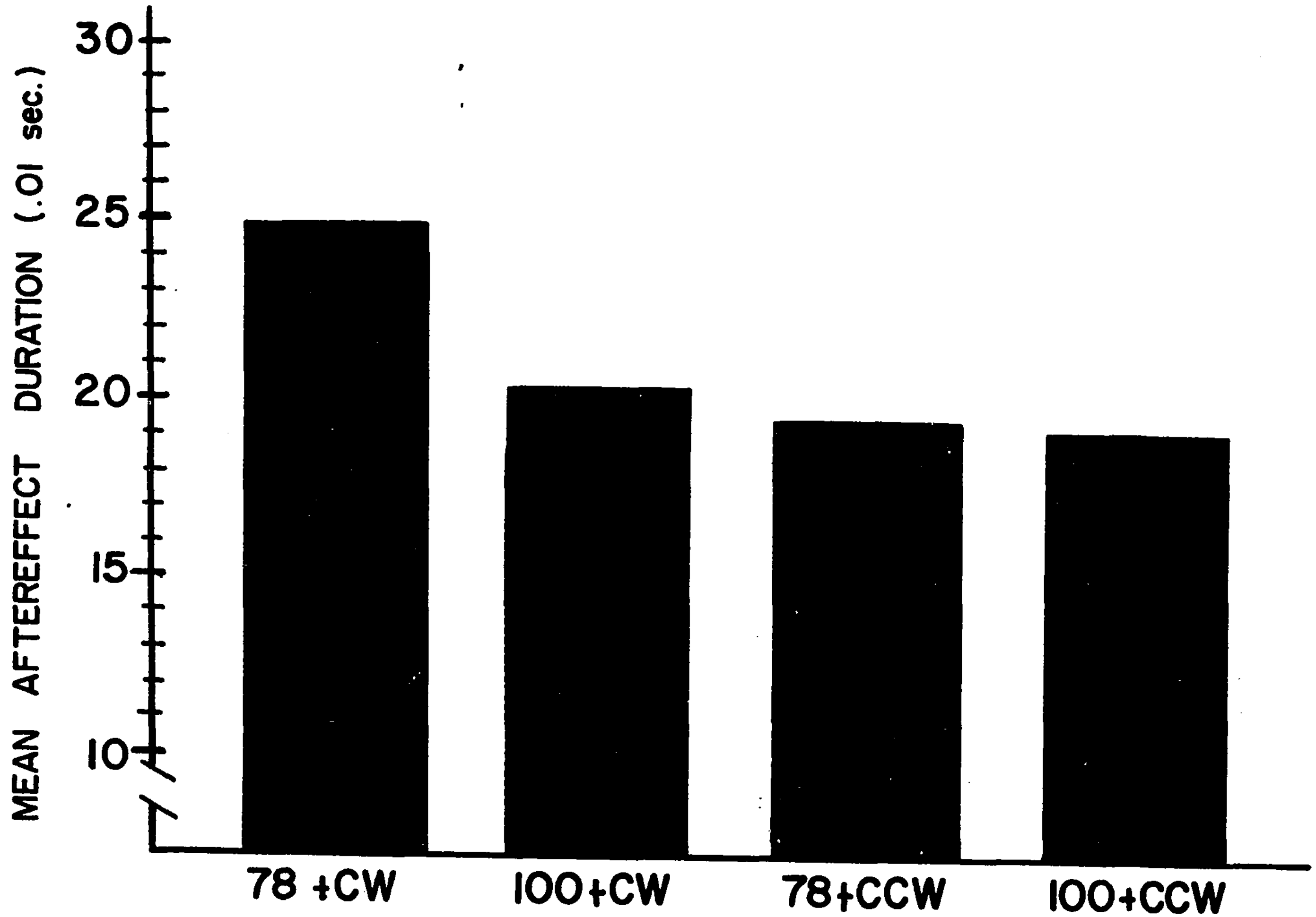

Figure 8. Interaction effect for speed of rotation and direction of rotation.

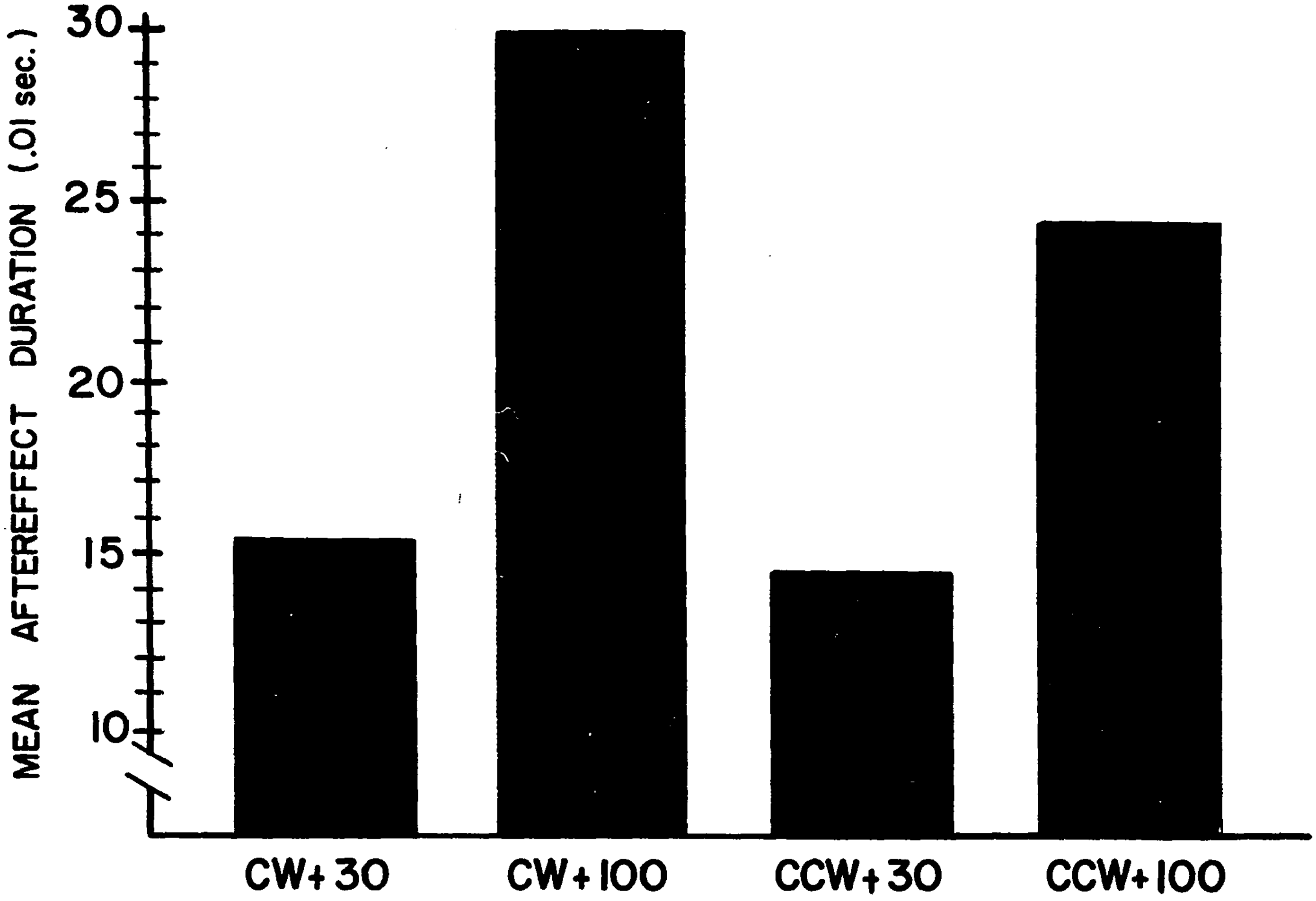

Figure 9. Interaction effect for period of inspection and direction of rotation.

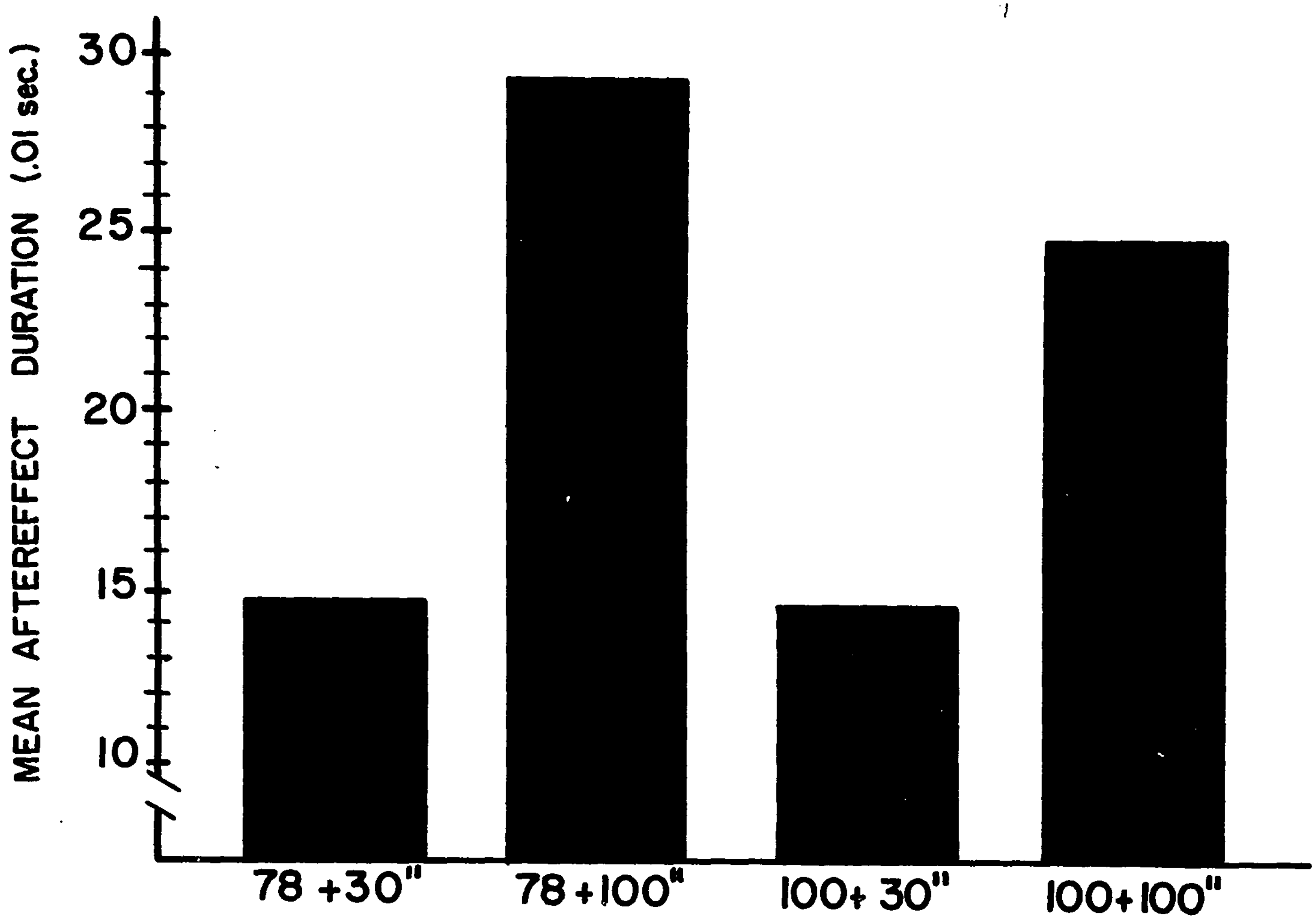

Figure 10. Interaction effect for speed of rotation and inspection period.

tation, type of spiral, and time of stimulation. Such findings give additional support to the contention that males and females manifest no differences in regard to the duration of their aftereffects under the various stimulus conditions.

The mean duration aftereffect scores for all subjects under each of the stimulus conditions are reported in Table 8 of the Appendix.

CHAPTER V

DISCUSSION

In evaluating the effects of the stimulus conditions which were varied in this study, it is clear that certain stimulus conditions elicit different reports as to the duration of the spiral aftereffect. In general, direction of rotation, speed of rotation, and inspection time were significant variables in determining the length of the aftereffect duration. Variation in the other two main variables under investigation, sex of the subject and type of spiral, appeared to have little effect on the duration of the aftereffect, although the type of spiral did have some differential effects in relation to other variables.

Many investigators (Gallese, 1956; Philbrick, 1959; Schein, 1960; Spivack & Levine, 1957; 1959) used an Archimedes spiral of 920°. Others (Costello, 1960; 1961; Holland, 1958; 1962; Holland & Beech, 1958) used a spiral of 180°. It has been thought that the differences these investigators reported in duration of the aftereffect might have been attributed to the variation in the type of spiral. In view of the over-all results of this study, a spiral of 920° tended to give an aftereffect duration comparable to the duration given by the 180° spiral. However, in view of the significant interactions involving type of spiral it would appear that for certain combinations of variables the type of spiral does influence the duration of the aftereffect. For example, a change in rotation speed from 78 rpm to 100 rpm resulted in a decrease in the aftereffect duration for the 180° spiral. However, the 920° spiral evidenced no apparent change in the duration of the aftereffect when the rotation speed was altered from 78 rpm to 100 rpm. In addition, the significant interaction between type of spiral and period of inspection suggests that when the inspection period is increased from 30 seconds to 100 seconds there is an apparent increase in the duration of the aftereffect for both types of spirals. However, the increase appears to be greater for the 920° spiral than for the 180° spiral.

Speed of rotation was found to be a more important variable than previous investigators had reported. Holland (1958; 1962), for example, indicated that on the basis of his investigations, speed of rotation was unrelated to the length of the reported aftereffect. The results of this investigation demonstrated that a rotation speed of 78 rpm gave rise to a significantly longer aftereffect than did a rotation speed of 100 rpm. It is possible that variations in rotation speed which were used by previous investigators may have accounted in part for the discrepancies which they reported in regard to the duration of the aftereffect. For example, Holland and Beech (1958) using the stimulus condition, 180° spiral, counterclockwise rotation, 78 rpm rotation speed, and a 30 second inspection period, reported a mean duration aftereffect of 19.7 seconds for their group. Eysenck et al. (1962) indicated that for approximately the same stimulus condition with the exception of rotation speed which was 100 rpm, resulted in an aftereffect duration of 14.7 seconds for their normal group. This difference is in the same direction as the differences found in the present study. Aside from the main effects of rotation speed, the interactions between speed of rotation and other variables may provide additional clarity. For example, as speed of rotation is increased from 78 rpm to 100 rpm under the 30 second stimulation period there is no apparent change in the duration of the aftereffect. However, when speed of rotation is increased from 78 rpm to 100 rpm under the 100 second inspection period a rotation speed of 78 rpm gives a longer aftereffect than does a rotation speed of 100 rpm.

Clockwise rotation (followed by an expansion aftereffect) resulted in an aftereffect of longer duration than did counterclockwise rotation (followed by a contraction aftereffect). This finding was clearly in support of the conclusions reported by Berger et al. (1958), Costello (1960), and Eysenck et al. (1962). Such a finding may well account for some discrepancies reported in the literature where such differences in direction of rotation were ignored. For example, Spivack and Levine (1959) reported that for the stimulus condition, 920° spiral, clockwise rotation, 78 rpm rotation speed, and 30 second inspection period, their normal group had a mean aftereffect duration of 16.5 seconds. The results of the present experiment indicated that the same stimulus conditions resulted in a mean aftereffect duration of 15.5 seconds. In addition, similar stimulus conditions with counterclockwise instead of clockwise rotation resulted in a mean duration aftereffect of 11.3 seconds. Unfortunately, investigators using only counterclockwise rotations (Gallese, 1956; Philbrick, 1959) did not report the mean aftereffect scores for their control group since the primary objective of their investigation was to determine the presence or absence of the spiral aftereffect. They simply reported as an incidental finding of their research that brain damaged subjects exhibited shorter aftereffect durations than did normals.

The significant interactions involving direction of rotation may give further clarity to the influence of this variable. The interaction between speed of rotation and direction of rotation indicates that when a change is made from a rotation speed of 78 rpm to 100 rpm under conditions of counterclockwise rotation there is no significant change in the duration of the aftereffect. However, when a change is made from 78 rpm to 100 rpm under conditions of clockwise rotation, the duration of the aftereffect is longer for a rotation speed of 78 rpm. The significant interaction between direction of rotation and inspection period indicates that a change from clockwise to counterclockwise rotation under a 30 second stimulation period results in no apparent change in the duration of the aftereffect. However, a change from clockwise to counterclockwise rotation under a 100 second stimulation period results in a significantly longer aftereffect duration for clockwise rotation.

Duration of stimulation appears to have been a highly significant variable in determining the duration of the spiral aftereffect. The size of the sum of squares associated with inspection time suggests that this variable contributed most to the length of the aftereffect experience. A stimulation period of 100 seconds resulted in significantly longer aftereffect durations than did a stimulation period of 30 seconds. These results are in accordance with the findings of Holland (1958; 1962), Holland and Eysenck (1960), and Schein (1960) who reported that duration of the aftereffect increased with prolonged periods of stimulation. It is highly probable that this variable accounts for much of the variability reported in the literature concerning the duration of the aftereffect. For example, Spivack and Levine (1957; 1959) using a 30 second inspection period reported mean aftereffect durations of 14.8 and 16.5 seconds for their control group. In addition, Truss and Allen (1959) using a

30 second inspection period found a mean aftereffect duration of 12 seconds for their control group. Holland (1958) using a 90 second inspection period reported a mean aftereffect duration of 25 seconds for his group of normals. Costello (1960) used a 60 second inspection period and reported a mean aftereffect duration of 20.2 seconds. Thus, the findings from this study question the advisability of comparing the results of investigators using varied periods of stimulation. In addition, the importance of the inspection period was also emphasized by the previously noted interactions between period of inspection and type of spiral, direction of rotation, and speed of rotation.

It is rather difficult to compare this study to those reported by investigators using only brain damaged subjects since the objective of the present investigation was to evaluate the role of certain stimulus conditions on the duration of the aftereffect with a normal population. However, the contradictory findings reported for the duration of the aftereffect in brain damaged and other comparison populations may have been a function of variations in certain stimulus conditions.

Although numerous studies have been made utilizing the spiral aftereffect phenomenon, there is a decided absence of adequate theorizing to explain the development of the aftereffect. Spivack and Levine (1959) after reviewing the current theories of aftereffects concluded, "the neurological mechanism underlying the effects [spiral aftereffect movement] is a complete mystery" (Spivack & Levine, 1959, p. 211).

The theoretical positions advanced by Saucer (1953; 1954; 1956), Shaprio (1954), and Wertheimer (1954; 1955) are considered to be general theories of brain functioning which use aftereffect data as support for their hypotheses. None of these theories accounts for the development of an aftereffect and each appears to be uniquely confined to the effects of brain injury. For example, Saucer and Deabler (1956) considered the arousal of visual aftereffects to be a global effort of the entire cortex. In regard to the mechanisms underlying the aftereffect, they stated, "Evidently perception cannot be fractionated into visual or other components but is a global effort of the entire cortex" (Saucer & Deabler, 1956, p. 388). Shaprio (1954) stated that irradiation effects from one part of the brain combines in some manner with irradiation effects produced in another part of the brain to give an aftereffect experience. Finally, Wertheimer (1955) reported that differences in the duration of figural aftereffects reflect differences in the ease with which modifications in cortical conductivity take place.

Several investigators have utilized the position presented by Kohler and Wallach (1944) as a model in attempting to account for visual aftereffects. Osgood and

Heyer (1952), Klein and Krech (1952), George (1953), and Deutsch (1956) have presented such theories. However, none of these theories appears to give an adequate explanation of visual aftereffects. Smith (1952) specifically cited that the spiral aftereffect phenomenon cannot be accounted for by the theories of Osgood-Heyer and Klein and Krech. Smith further stated that neither theory can explain the apparent movement of the spiral when rotation is halted. Spitz (1958) pointed out that George's explanation does not account for the contraction or expansion aftereffects. Finally, Griffith and Spitz (1958) reported that Deutsch's theory fails to account for the fact that the aftereffect can be seen on a test surface devoid of contours.

Eysenck (1955) explains the persistence of spiral aftereffects as being related to one of the parameters of the extroversion-introversion dimensions of personality. According to Eysenck, the introvert is characterized by low inhibitory potential and high excitation. The extrovert is characterized by high inhibition and low excitation. The introvert would experience long aftereffect durations because excessive excitation would be developed by the rotating spiral. The extrovert would experience short aftereffects because excessive inhibition would prevent the build up of excitation produced by the rotating spiral. Pickersgill and Jeeves (1958), Schein (1960), and Holland (1962) reported that the results of their investigations indicated no significant differences between the duration of the after-effects in introverts and extroverts. The current study did not explore the possible relationship of these variables. However, it is difficult to find any possible relevance of Eysenck's theorizing in application to the data obtained in the present study.

The results of the present investigation cannot at this time be interpreted in any meaningful manner by the current theories of visual aftereffects. An adequate theory of visual aftereffects should account for the differences in duration of the aftereffect as being related to time of stimulation, rotation speed, and direction of rotation. A satisfactory explanation of the spiral aftereffect will probably depend upon future investigations of the pertinent physiological variables involved and general methodological advances in this type of research.

The major contribution of this study would seem to be the systematic investigation of what appeared to this researcher to be some of the major stimulus conditions and their relationship to the duration of the aftereffect. The major significance of the present study would then appear to be empirical in nature. The reported findings of this investigation should facilitate the identification of certain stimulus conditions pertinent to the duration of the spiral aftereffect. Once the more critical stimulus conditions have been systematically explored, future research with spiral aftereffects when oriented toward its diagnostic and other applications should result in more meaningful relationships. For example, much of the contradictory evidence on the value of the spiral aftereffect in diagnosing brain damage may be clarified by more rigorous control of the previously ignored stimulus variations.

CHAPTER VI

SUMMARY

The study was designed to investigate the effects of certain stimulus variables upon the duration of the spiral aftereffect. The major stimulus variables which were manipulated in two ways included: type of spiral (920° or 180°), speed of rotation (78 or 100 rpm), direction of rotation (clockwise or counterclockwise), and time of stimulation (30 or 100 seconds). The study further evaluated the influence of sex differences as related to the duration of the aftereffect.

Since the primary objective of this investigation was to evaluate certain varied stimulus conditions and their relationship to the aftereffect duration, only nonbrain damaged subjects were used in this study. The sample consisted of 80 male and 80 female subjects selected from the general college population. An equal number of male and female subjects were randomly assigned to each of sixteen stimulus conditions representing the various combinations of the major stimulus variables.

The over-all results of the investigation revealed that the duration of the aftereffect was significantly influenced by three of the five manipulated variables. Specifically, variations in speed of rotation, direction of rotation, and time of stimulation, resulted in significant differences in aftereffect duration. A rotation speed of 78 rpm gave significantly longer aftereffects than did a rotation speed of 100 rpm. Clockwise rotation of the spiral resulted in longer aftereffects than did counterclockwise rotations. And, finally, a stimulation period of 100 seconds resulted in longer aftereffects than did a stimulation period of 30 seconds. As a major variable the type of spiral appeared to have no significant effect on the duration of the aftereffect. However, the type of spiral did have significant interaction effects in relation to speed of rotation and inspection period. In regard to the final major variable, there were no significant differences in duration of the aftereffect as function of sex differences.

There were five significant first order interaction effects between variables. These included, speed and spiral, speed and direction, inspection and direction, and, finally, inspection and spiral.

The findings of this investigation were related to the results reported by previous investigators in an attempt to add some clarity to the discrepancies noted in the literature concerning the duration of the spiral aftereffect.

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APPENDIX

Table 5

Standard Instructions

"This is a visual test. Look at the center (pointing) of the spiral and do not look away until I tell you." Then a 65 second rotation of the spiral began (type of spiral and direction of rotation is the same as for the subject's experimental condition) and rotated at a speed of 90 rpm. At the end of 30 seconds the subject was asked, "What does the black line (s) appear to be doing?" This is done in order to ascertain whether or not the subject is attending to the stimulus and can report his experience. At the end of 65 seconds the spiral was stopped and the subject was asked, "Now what appears to be happening to the spiral?" This is done in order to be sure the subject is capable of reporting the aftereffect. If a subject failed to report either the contractive or expansive aftereffect on the first pre-test trial he was then given a second pre-test trial under those conditions for which he failed to experience the aftereffect. Failure on the second pre-test trial results in the subject being eliminated from the experiment. He was thanked for his co-operation and the next subject was run. Assuming the subject reported the aftereffect experience, he was asked to look away from the spiral and was told, "What you just saw is called an aftereffect, the spiral appeared to be (expanding or contracting) in a direction opposite to

Table 6

Order of Stimulus Presentation for Males

Subject	Spiral	Direction	Speed	Time (sec.)
1.	180	CW	78	100
2.	920	CCW	100	30
3.	920	CW	100	100
4.	180	CW	100	100
5.	180	CW	100	30
6.	180	CW	78	100
7.	180	CW	78	30
8.	920	CCW	78	30
9.	920	CW	100	30
10.	180	CW	100	100
11.	180	CW	100	100
12.	920	CW	100	100
13.	920	CCW	100	30
14.	920	CW	100	30
15.	180	CW	78	100
16.	920	CCW	100	100
17.	180	CCW	100	30
18.	920	CW	78	30
19.	920	CCW	100	30
20.	920	CCW	100	100
21.	180	CCW	78	100
22.	180	CW	100	30
23.	180	CCW	78	100
24.	180	CCW	100	100
25.	920	CCW	100	100
26.	180	CW	78	100
27.	180	CCW	78	30
28.	180	CW	78	30
29.	180	CCW	78	30
30.	920	CW	100	30
31.	920	CW	78	30
32.	180	CW	100	100
33.	180	CW	78	100
34.	180	CCW	100	30
35.	920	CW	100	30
36.	920	CCW	78	100
37.	920	CW	100	100
38.	920	CW	78	100
39.	920	CCW	100	100
40.	180	CCW	78	30

Table 6 (Continued)

Subject	Spiral	Direction	Speed	Time (sec.)
41.	180	CW	100	30
42.	180	CCW	78	30
43.	180	CCW	100	30
44.	180	CW	78	30
45.	920	CCW	100	30
46.	920	CCW	78	30
47.	180	CW	78	30
48.	920	CCW	78	30
49.	920	CW	78	100
50.	180	CW	78	30
51.	180	CCW	78	100
52.	180	CCW	100	30
53.	920	CCW	78	100
54.	920	CCW	100	30
55.	920	CW	78	30
56.	920	CW	100	30
57.	920	CW	78	30
58.	180	CCW	100	100
59.	180	CW	100	100
60.	180	CW	100	30
61.	920	CCW	78	100
62.	920	CW	78	30
63.	920	CW	78	100
64.	180	CCW	78	100
65.	920	CW	78	100
66.	180	CCW	100	100
67.	920	CW	100	100
68.	920	CCW	100	100
69.	920	CCW	78	30
70.	920	CCW	78	100
71.	180	CCW	100	100
72.	920	CW	78	100
73.	180	CCW	78	100
74.	180	CCW	78	30
75.	180	CW	100	30
76.	920	CCW	78	30
77.	180	CCW	100	100
78.	920	CW	100	100
79.	920	CCW	78	100
80.	180	CCW	100	30

Table 7

Order of Stimulus Presentation for Females

Subject	Spiral	Direction	Speed	Time (sec.)
1.	180	CW	78	30
2.	180	CCW	100	30
3.	920	CCW	78	100
4.	180	CW	100	30
5.	920	CCW	78	30
6.	920	CCW	78	100
7.	180	CCW	78	30
8.	920	CW	78	30
9.	180	CW	78	100
10.	920	CCW	78	100
11.	920	CW	78	30
12.	920	CCW	100	30
13.	920	CCW	78	100
14.	180	CW	100	100
15.	180	CW	78	100
16.	920	CCW	100	30
17.	180	CW	78	30
18.	920	CW	100	100
19.	920	CCW	100	100
20.	180	CW	100	30
21.	180	CW	78	100
22.	920	CW	100	30
23.	180	CW	100	100
24.	180	CCW	100	100
25.	180	CW	100	30
26.	920	CCW	100	30
27.	920	CW	78	100
28.	180	CCW	100	100
29.	180	CW	100	30
30.	920	CCW	100	30
31.	920	CCW	78	30
32.	180	CW	78	100
33.	180	CCW	100	30
34.	920	CCW	78	30
35.	920	CW	100	30
36.	180	CCW	78	100
37.	920	CCW	78	30
38.	180	CCW	100	100
39.	920	CCW	100	100
40.	180	CCW	100	100

Table 7 (Continued)

Subject	Spiral	Direction	Speed	Time (sec.)
41.	180	CW	100	100
42.	920	CW	78	100
43.	180	CCW	78	30
44.	920	CW	100	30
45.	920	CCW	100	100
46.	920	CW	100	100
47.	180	CW	78	30
48.	180	CW	100	100
49.	920	CW	100	100
50.	180	CCW	78	100
51.	920	CW	100	30
52.	180	CCW	100	30
53.	920	CCW	100	30
54.	180	CCW	78	100
55.	920	CW	100	30
56.	920	CCW	100	100
57.	920	CW	78	30
58.	180	CW	100	30
59.	180	CCW	78	30
60.	920	CW	78	100
61.	920	CW	100	100
62.	180	CW	78	30
63.	180	CW	100	100
64.	920	CCW	100	100
65.	920	CW	78	100
66.	180	CCW	78	30
67.	180	CCW	100	30
68.	920	CW	100	100
69.	180	CCW	78	30
70.	180	CCW	78	100
71.	180	CCW	100	100
72.	920	CW	78	100
73.	920	CW	78	30
74.	180	CW	78	100
75.	180	CW	78	30
76.	920	CCW	78	100
77.	920	CW	78	30
78.	180	CCW	78	100
79.	920	CCW	78	30
80.	180	CCW	100	30

Table 8

Mean Scores (sec.) for Subjects Exposed to Each Stimulus Condition

Stimulus condition: 920-CW-78-30"

Subject	Age	Sex	Mean Score (sec.)
1.	20	M	14.63
2.	23	M	14.50
3.	21	M	17.83
4.	24	M	15.72
5.	24	M	16.81
6.	22	F	16.97
7.	21	F	14.47
8.	32	F	12.85
9.	18	F	16.43
10.	21	F	15.39

Stimulus condition: 920-CW-78-100"

Subject	Age	Sex	Mean Score (sec.)
1.	21	M	31.87
2.	21	M	30.45
3.	22	M	38.04
4.	19	M	37.52
5.	18	M	32.65
6.	32	F	35.33
7.	34	F	35.96
8.	21	F	32.55
9.	19	F	33.25
10.	18	F	32.52

Table 8 (Continued)

Stimulus condition: 920-CW-100-30"

Subject	Age	Sex	Mean Score (sec.)
1.	27	M	13.61
2.	22	M	12.43
3.	22	M	14.22
4.	24	M	15.69
5.	20	M	12.76
6.	20	F	16.27
7.	19	F	16.02
8.	22	F	14.91
9.	44	F	14.22
10.	19	F	14.61

Stimulus condition: 920-CW-100-100"

Subject	Age	Sex	Mean Score (sec.)
1.	22	M	26.09
2.	24	M	25.43
3.	27	M	26.94
4.	23	M	32.65
5.	22	M	29.56
6.	20	F	27.32
7.	19	F	26.55
8.	27	F	25.62
9.	21	F	26.03
10.	20	F	27.71

Table 8 (Continued)

Stimulus condition: 920-CCW-78-30"

Subject	Age	Sex	Mean Score (sec.)
1.	25	M	13.56
2.	27	M	12.37
3.	18	M	12.57
4.	21	M	10.91
5.	22	M	12.10
6.	22	F	12.90
7.	19	F	10.28
8.	24	F	9.76
9.	20	F	10.06
10.	20	F	9.31

Stimulus condition: 920-CCW-78-100"

Subject	Age	Sex	Mean Score (sec.)
1.	23	M	24.23
2.	18	M	23.50
3.	18	M	24.65
4.	21	M	24.18
5.	23	M	26.02
6.	23	F	25.20
7.	22	F	22.46
8.	20	F	22.67
9.	21	F	25.59
10.	20	F	27.12

Table 8 (Continued)

Stimulus condition: 920-CCW-100-30"

Subject	Age	Sex	Mean Score (sec.)
1.	39	M	13.26
2.	21	M	16.67
3.	21	M	13.87
4.	18	M	13.18
5.	24	M	13.60
6.	21	F	17.67
7.	26	F	13.23
8.	19	F	14.58
9.	20	F	14.38
10.	20	F	14.75

Stimulus condition: 920-CCW-100-100"

Subject	Age	Sex	Mean Score (sec.)
1.	20	M	28.97
2.	26	M	27.03
3.	19	M	30.06
4.	22	M	29.89
5.	21	M	25.39
6.	25	F	28.03
7.	21	F	28.02
8.	22	F	27.09
9.	22	F	27.53
10.	20	F	26.04

Table 8 (Continued)

Stimulus condition: 180-CW-78-30"			
Subject	Age	Sex	Mean Score (sec.)
1.	21	M	12.06
2.	21	M	15.33
3.	23	M	15.82
4.	21	M	16.93
5.	21	M	17.03
6.	21	F	18.81
7.	19	F	14.90
8.	20	F	14.46
9.	20	F	16.85
10.	21	F	16.34

Stimulus condition: 180-CW-78-100"			
Subject	Age	Sex	Mean Score (sec.)
1.	27	M	30.50
2.	21	M	32.58
3.	20	M	33.30
4.	22	M	34.07
5.	21	M	35.46
6.	18	F	37.22
7.	19	F	31.15
8.	23	F	32.85
9.	19	F	35.25
10.	19	F	35.14

Table 8 (Continued)

Stimulus condition: 180-CW-100-30"

Subject	Age	Sex	Mean Score (sec.)
1.	21	M	15.56
2.	23	M	14.17
3.	21	M	13.92
4.	19	M	13.48
5.	21	M	12.80
6.	18	F	16.37
7.	21	F	14.44
8.	21	F	14.71
9.	20	F	14.93
10.	21	F	18.10

Stimulus condition: 180-CW-100-100"

Subject	Age	Sex	Mean Score (sec.)
1.	22	M	23.86
2.	18	M	27.28
3.	32	M	25.51
4.	22	M	25.21
5.	21	M	28.04
6.	20	F	23.89
7.	19	F	24.26
8.	20	F	24.95
9.	23	F	24.17
10.	20	F	21.11

Table 8 (Continued)

Stimulus condition: 180-CCW-78-30"

Subject	Age	Sex	Mean Score (sec.)
1.	21	M	15.68
2.	23	M	15.05
3.	21	M	17.96
4.	24	M	16.05
5.	21	M	17.15
6.	21	F	16.99
7.	26	F	14.38
8.	25	F	18.49
9.	21	F	15.20
10.	20	F	16.42

Stimulus condition: 180-CCW-78-100"

Subject	Age	Sex	Mean Score (sec.)
1.	19	M	25.00
2.	26	M	24.54
3.	20	M	23.09
4.	19	M	21.12
5.	21	M	25.35
6.	19	F	26.42
7.	23	F	28.01
8.	22	F	24.15
9.	19	F	29.76
10.	32	F	23.39

Table 8 (Continued)

Stimulus condition: 180-CCW-100-30"

Subject	Age	Sex	Mean Score (sec.)
1.	21	M	12.91
2.	20	M	13.38
3.	30	M	14.69
4.	20	M	15.52
5.	33	M	16.48
6.	36	F	17.41
7.	24	F	17.34
8.	22	F	13.60
9.	19	F	15.43
10.	28	F	15.28

Stimulus condition: 180-CCW-100-100"

Subject	Age	Sex	Mean Score (sec.)
1.	24	M	18.88
2.	22	M	17.33
3.	44	M	17.72
4.	22	M	16.26
5.	30	M	23.56
6.	25	F	18.03
7.	24	F	17.99
8.	24	F	20.82
9.	22	F	19.30
10.	22	F	22.27