EXPERIMENTS IN THE CONTROL OF BINOCULAR RIVALRY

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TABLE OF CONTENTS

SUMMARY

If the eyes receive dissimilar stimulation, a perceptual alternation of the two stimuli occurs known as binocular rivalry (BR). The rate of alternation or predominance of one stimulus may be influenced by a voluntary effort known as the control of BR. In the late nineteenth and early twentieth centuries the field of attention was considered to be of major importance to perception; and BR was accepted by Helmholtz, Titchener, James, and others to be a paradigm of the attention process. Although the field of attention is receiving renewed interest following a period of neglect, few recent psychologists have recognized the potential importance of BR to the study of attention or of BR control to the study of the voluntary properties of attention. To help fill this gap the thesis presents several experiments that investigate the nature of BR control.

The first series of experiments found that the measure of control increased with practice but did not increase with uncontrolled or passive viewing of rivalry. Spaced practice was more effective than massed and the use of knowledge of results of practice was much more effective than no knowledge.

An objective measure of control using tachistoscopic recognition was developed and showed that the duration but not the magnitude of rivalry suppression was altered by voluntary control. The objective measure was correlated with the subjective measure based on rivalry rates and both measures showed an increase as a result of practice. An analysis based on signal detection theory indicated that voluntary control produces a change of signal strength but no change in confidence criteria.

Accommodation, pupillary activity, and blinking were found to be of little or no importance in the control exerted by unpracticed and well-practiced subjects. The increased control from practice was mostly retained and unpracticed control was hardly affected by the use of rivaling afterimages. It was concluded that if peripheral mechanisms play any real part in the degree of control they are only of minor importance.

BR stimulation during induction periods did not affect the subsequent strength of a negative afterimage but did markedly reduce the strength of a movement aftereffect. Because afterimages are retinal phenomena but movement aftereffects are probably nonretinal in origin, it was concluded that the interference of rivalry stimulation occurs on a more central level than the retina. It was also found that the strength of the movement aftereffect was determined by the intensity of rivalry stimulation but not by the amount of phenomenal suppression. It was concluded that control of rivalry was mediated by cortical neural levels higher than those which produce the movement aftereffect.

A recently developed model of binocular rivalry was extended to propose that BR control is effected by inhibiting or exciting a separate switching mechanism of rivalry rather than by inhibiting or exciting either of the retinal inputs. When one eye is selected for attention its dominance phase is lengthened and suppression phase is shortened but the magnitude of inhibition of the suppression phase, when it does occur, is unchanged. The model suggests that selective attention in general is a biased "all-or-some" switching rather than an all-or-none switching or a constant attenuation of unwanted stimuli.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University and, to the best of my knowledge and belief contains no material previously published or written by another person except when due reference is made in the text of the thesis.

Signed.

L.C. Lack

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CHAPTER I.

INTRODUCTION.

Early Theories of Selective Attention

In the late nineteenth and early twentieth centuries attention was considered to be a central issue of psychology. Indeed, Titchener states that "...the doctrine of attention is the nerve of the whole psychological system, ...as men judge of it, so shall they be judged before the general tribunal of psychology (1908, p.173)."

The effects of attention were studied by Wundt, Helmholtz, and Titchener, of the structuralist tradition. The method of introspection was used by the structuralists to investigate the important question of whether attention had the effect of increasing the "clearness" of a sensation or its relative intensity. W.B. Pillsbury, a student of Titchener's, presented a comprehensive review and examination of the effects of attention in his book Attention (1908). Pillsbury felt that it was difficult to specify what is meant by sensory "clearness", and preferred a somewhat more behavioural approach. "All mental processes affect us in some degree, but those to which we attend affect us in a much higher degree than those to which we do not attend (Pillsbury, 1908, p.2)." The "higher degree" of effect from an attended "mental process" resulted, he felt from an increase in its relative intensity. He theorized that attention would either increase the intensity of the attended "process" or decrease the intensity of the non-attended "process". Pillsbury (1908) observed that "...the weight of authority is in favour of regarding the effect of attention as different from the effect of an increased intensity of the external stimulus, but with no convincing proof in favour of that position (p.5)."

Pillsbury also elaborated other major factors of attention still discussed today in slightly different terms. He recognized the apparent fact of our limited capacity to process information: "...the amount of attention is practically constant, and cannot be applied to one object without affecting the clearness of others (Pillsbury, 1908, p.9)." This implies that with two equally strong objects competing for attention if the full "amount of attention" is required for one object, the other object will be relegated to non-attention. However, this state would not last indefinitely since Pillsbury estimates the duration of a single act of attention to be from 3 seconds to 24 seconds and about 5 seconds to 8 seconds on the average. This would result in an alternation between the equally strong sensorial "objects".

Pillsbury was less specific about the mechanism of the control of attention. He did stress the involvement of motor activity as being correlated with attention but not as its initiator or director. "Attention to any stimulus is accompanied by widespread motor phenomena...The bodily processes succeed, or at most accompany, the attention. They do not precede it (p.25)." He suggested that, "the only effect which the contraction of these numerous muscles has upon the efficiency of the attention is that it may slightly increase the adequacy of the attention beyond that which it would have had if the strain sensations were not present (Pillsbury, 1908, pp.61-62)."

At the same time that the Structuralists were investigating the effects of attention, the Functionalist School headed by William James at Chicago was interested in the selective nature of attention and the effect of willful control on mental processes. In his textbook, The Principles of Psychology (1891), James lists three dimensions of attention. The opposite poles of the first category are "sensorial" and "intellectual", of the second category are "immediate" and "derived", and of the third, are passive and voluntary. James felt that although control could definitely be exercised over attention, control was not unlimited. "No one can possibly attend continuously to an object that does not change (James, 1891, p.421)." He also felt that, in general, control of attention was mediated through peripheral and central mechanisms, which he described as "1. The accommodation or adjustment of the sensory organs.

2. The anticipatory preparation from within of the ideational centres concerned with the object to which attention is paid (James, 1891, p.434)."

In summary, attention was a concept central to early psychology. Early theories were concerned with the effects and the control of attention, concerns still relevant today. In what way does attention produce "clearness"? Is it equivalent to an increase of intensity of the attended object or a decrease of intensity of all non-attended objects? Perhaps "clearness" does not have an intensity equivalent but is a result of some other mechanism. To what extent is attention under voluntary control? What is the mechanism of voluntary control? Is it mediated mainly by peripheral motor adjustments, or does it operate mainly on central mechanisms of a higher level?

The role of binocular rivalry in the study of attention

If the two eyes are fixated on dissimilar visual patterns, the observer usually experiences a phenomenal alternation of the two patterns in vision. This phenomenon is known as retinal or binocular rivalry. Because the term "retinal" might presuppose the mechanism or location of rivalry, "binocular" as the more neutral term shall be used throughout this thesis. Binocular rivalry (BR) may be easily demonstrated while looking in a stereoscope in which the right eye and left eye fields of vision are physically separated. With this apparatus the right eye may be fixated, for example, on a pattern of vertical black lines on a white background while the left eye may be fixated on a pattern of horizontal lines. At no time is a complete grid pattern perceived. Instead, if the physical stimulus conditions of the two patterns are equal, an observer will normally see an alternation between the patterns. First the vertical line pattern may predominate by occupying a majority of the visual field or the complete visual field to the exclusion of the horizontal line pattern. The state of BR is never constant, however, and after a short period the vertical pattern will fade and the horizontal pattern will become predominant.

Quite often it is the case with relatively detailed patterns such as those just described that there is not a completely dichotomous alternation. Instead, parts of both patterns may be present in different parts of the visual field at any instant of time. The resultant patchiness of this effect sometimes makes it difficult for an untrained observer to decide which pattern is predominant over the whole visual field. By using simple patterns this problem can be minimized or eliminated. The decision of predominance between a single vertical line in rivalry with a single horizontal line can be made easily by fixating at the expected intersection point of the two lines. Alternatively, a black disk on white background in rivalry with an equally sized and binocularly coincident white disk on black background usually results in unitary dichotomous rivalry.

In addition to being affected by stimulus variables, binocular rivalry has been considered to be affected by voluntary control. By using various methods Helmholtz (1925) was able to maintain the predominance of one rivalry pattern longer than it would normally be observed in passive rivalry. In the rivalry of a horizontal pair of lines with a vertical pair of lines he found that by fixing his "attention on one pair of lines and examining them to see whether there are perhaps some irregularities in them, I can retain the image of one pair or the other according to my fancy (Helmholtz, 1925, p.497)." Other pairs of rivalry stimuli such as a series of parallel lines oriented 90 degrees with respect to a second series of lines he found to be more difficult to control with attention. Counting the lines in one pattern or moving the eyes in the same direction as the lines were both effective methods for retaining the vision of that pattern. If more interesting or attention arousing patterns were used such as a map or photograph in rivalry with a printed page, he could easily read the words or examine the photograph. Although it was more difficult, he could even read the words when the rivaling pattern was relatively much brighter than the printed page. He concluded that "these experiments show that man possesses the faculty of perceiving the images in each eye separately, without being disturbed by those in the other eye, provided it is possible for him, by some of the methods above indicated, to concentrate his whole attention on the objects in this one field (Helmholtz, 1925, p.499)."

The purpose of discussing Helmholtz's experiments here has been to illustrate what is meant by the voluntary control of rivalry. In fact, Helmholtz's confidence in the voluntary control that could be exercised with BR was not shared by all experimenters. The degree of control and mechanisms for effecting control, have been subjects of a continuing controversy which will be elaborated later. Nevertheless, the apparent control of rivalry was accepted by many early experimenters as a significant attribute of BR.

For several reasons binocular rivalry was considered to be an excellent example of the attention process. It is a phenomenon in which two sensations compete for attention because they can not be perceived simultaneously. It displays in a dramatic and vivid way the oscillation of sensory "clearness" or change in relative intensity considered to be the main effect of attention. In addition, it seemed to the early psychologists to be under some degree of voluntary control, an important attribute of attention according to the functionalists. Helmholtz (1925) says of the passive viewing of rivalry that it "is analogous to the careless vacillating, uninterested state of attention, accustomed to flit from one impression to another, until the various objects are gradually passed in review (p.500)." He states that if we do not fix the attention then regular rivalry results and, in this case, stimulus characteristics generally determine predominance. Helmholtz further insists that voluntary control is as much an attribute of BR as it is generally held to be of attention. "Hence the retinal rivalry is not a trial of strength between two sensations, but depends upon fixing or failing to fix the attention (Helmholtz, 1873, pp.294-295)." He wrote of rivalry that "indeed, there is scarcely any phenomenon so well fitted for the study of the causes which are capable of determining the attention (1873, p.295)."

Other experimenters also used BR as an example of the attention process. Breese (1899, p.17) investigated the process of "inhibition of one sensation by another" using rivalry as a paradigm of this process. McDougall (1903, 1906) in his analysis of the physiological factors and more specifically of muscular activity as a factor of the attention process used binocular rivalry along with the phenomena of reversible perspective as examples of sensory attention. Early in his book on attention Pillsbury (1908) states that "one of the most satisfactory ways of studying many of the phenomena of the attention is by means of a simple stereoscope (p.32)." He then goes on to describe binocular rivalry that results from green and red squares that are made to be binocularly coincident in the stereoscope. James (1891) is also very impressed with the relevance of BR to the study of attention and quotes the earlier statement of Helmholtz (1873). In James' classification system, BR would be a particularly good example of sensory as opposed to intellectual, immediate as opposed to derived, and of either passive or voluntary attention. In summary, binocular rivalry served many of the early psychologists as a useful paradigm of the basic aspects of attention.

The decline and revival of interest in attention

The history of attention in psychology is an interesting one. Starting as a core concept of psychology in the nineteenth and early twentieth centuries, it fell into disrepute around 1920 and, except for a few cases, was generally ignored by psychologists for over a quarter of a century. According to Moray (1969) in his recent book on selective attention in vision and hearing, "research on attention disappeared virtually completely from about 1920 onwards", and "not until the 1950's were references to the phenomena [attention] again made explicitly by name (pp.2-3)."

Several recent publications have given a short history of the decline and renewal of interest in attention, (Santos, Farrow & Haines, 1963; Bakan, 1966; Norman, 1969; McGhie, 1969; Moray, 1969; Swets & Kristofferson, 1970). Although they describe the causes of the decline of interest in attention in somewhat different ways, they are in general agreement as to the basic causes. These stem from both methodological and theoretical issues. The rise of behaviorism in the 1920s was partly in reaction to the older psychological schools. Psychology had been embarrassed by the failure of introspection to produce reliable results. In behaviourism, the study of objectively measurable behaviour and strict experimental design, psychology had found a vehicle for the attainment of scientific respectability. Necessarily introspection was precluded, as a tool which yielded only subjective data of low reliability and questionable validity. Introspection, the previous means of studying attention, fell out of practice, but no objective measure of attention took its place. Thus, no means of investigation were available for those who might have still been inclined to study attention.

Besides lacking an acceptable methodology, the topic of attention itself fell into disrepute as a "mentalistic" phenomenon. Either its actual existence was being attacked by the more strict behaviourists, or, by those who might have been interested, it had been indefinitely shelved as too sophisticated a mechanism to be dealt with by a science in its infancy. To study simpler components of behaviour with better experimental control, the use of animals became widespread, resulting in a further drift of interest away from attention. Although behaviourism ascended to a dominant position in psychology other schools were also developing. However, the proponents of gestalt psychology, psychoanalysis, and S-R learning theory were not willing to make a home for the study of attention per se. Thus for both methodological and theoretical reasons attention fell from a position of eminence to virtual oblivion.

Following the Second World War interest in attention revived slowly until today it would be one of the most rapidly expanding topics in psychology. Moray's book on attention (1969) which deals with selective attention rather than other aspects of attention such as vigilance, visual search, arousal level or the physiology of attention, lists a bibliography of over 250 items, over half of which were published since 1961. Before 1947 only occasional years are represented by a publication of direct relevance to selective attention. From 1948 to 1967 the bibliography shows 10, 40, 67 and 108 relevant publications respectively in each five year period.

Various reasons have been advanced recently for this resurgence of interest in attention. In this case there is not such unanimity of opinion as there was for the causes of the decline of interest in attention. Moray (1969) lists three main reasons: 1. the increased ability to objectify the effects of attention, 2. the practical problems dealing with vigilance and information processing tasks that arose during the war and demanded solutions regardless of theoretical biases existing in psychology, and 3. the development of new apparatus such as the tape recorder which increased the ease of experimentation in perception. Norman (1969), McGhie (1969) and Swets & Kristofferson (1970) add the contributing influence of the development of information theory and signal detection theory. Santos et al (1963) point to Rapaport and the work of the psychoanalytic group, the work of Piaget, the neurophysiological investigations of the neural substrates of attention by experimenters such as Hernández-Peón and Galambos, and the theorizing of Hebb and Berlyne. Bakan (1966) also stresses the neurophysiological investigations of attention as an important element in the revival of interest.

The physiologists and medical researchers have not been constrained by the biases of psychology and have taken up the investigation of neural concomitants to attention with enthusiasm. It is difficult to say whether the neurophysiological studies preceded or succeeded the revial of psychological interest in attention, but there is little doubt that they are a contributing factor to the snowballing interest in attention. The physiological investigations lend additional scientific respectability to the study of attention, and have also eliminated any last vestiges of the doubt of the reality of attention.

Further, the revival of interest in attention was probably to some extent a spontaneous phenomenon resulting from a relaxation of the strictures of behaviourism. The very necessary and important points of behaviourism had been made. However, the "mentalistic" phenomena such as attention had not disappeared and were waiting to be considered when technological developments and practical necessities combined to produce a more favourable climate. The hesitancy to study processes associated with attention, indeed even to name it explicitly, seems to have disappeared entirely. The result has been a dramatic acceleration of interest in attention.

The Decline and Revival of Interest in Binocular Rivalry

It is also interesting to note the decline and renewal of interest in binocular rivalry. Its history almost parallels that of attention. The present author's file of publications, not all of which were used in this thesis, included 87 references to publications using or studying binocular rivalry. Except for an anomolous spurt of nine publications between 1933 and 1937 binocular rivalry was not a subject of experimentation between 1909 and 1947. In the following ten years to 1957 there were ten publications; in the six years to 1964 there were twenty; and in the last six years there have been forty-three publications on binocular rivalry.

It would seem that the relative lack of interest in BR was largely a result of the factors which caused a decline of interest in attention. BR is basically a subjective phenomenon for which at that time no objective measure had been devised. It was strongly associated with the method of introspection with the Structuralist and Functionalist schools, and their exhaustive studies of human visual perception, all of which suffered a decline during the ascendance of behaviourism.

Of course the correlation of interest in attention and binocular rivalry over the past century does not indicate any direct causal relationship between the two. The initial renewal of interest in BR was basically not a result of renewed interest in attention. Almost none of the recent studies of BR recognise any relevance of BR to attention. Most of these studies can be classified into categories according to their experimental purposes: the use of BR to illustrate the effects of personality, cultural and conditioned variables; the study of the effects on BR of varying the physical properties of the stimulus such as intensity and movement; the study of the relationship between BR and stereoscopic depth perception; and a miscellaneous group in which BR was used for various other purposes.

The first category consists of studies which were not interested in the phenomenon of binocular rivalry itself. They were primarily concerned with the effects of learning on perception and merely used BR to illustrate these effects. This approach was initiated by Engel (1956) who found that upright faces were perceived more in BR than upside-down faces. This study was replicated by Hastorf & Myro (1959) using tachistoscopically presented faces. Bagby (1957) found culturally meaningful stimuli to be dominant in rivalry. Toch & Schulte (1961) found that short term conditioning of attitudes could affect dominance in BR. Davis (1959) illustrated the effect of word associative strength on BR. van de Castle (1960) used BR to illustrate perceptual defence.

More recently, Ono, Hastorf & Osgood (1966) showed how differences in semantic differential ratings could be used to predict either fusion or rivalry of two different stimuli. Bokander (1966) measured the dominance of a meaningful stimulus pattern over a meaningless pattern in rivalry. Meredith (1967) related personality variables to meaningfulness and BR. Rommetveit, Toch & Svendsen (1968) in a series of studies used BR to compare associative and syntactic meaningfulness of words. Goryo (1969) found that faces predominanted over geometric patterns in relation to the amount of previous exposure of the faces.

A second category of publications is concerned with the effects on binocular rivalry resulting from variation of the physical attributes of the rivalry stimuli such as contour contrast and movement. Alexander (1951), Alexander & Bricker (1952), Mull, Armstrong & Telfer (1956), Kakizaki (1960), Kaplan & Metlay (1964), Whittle (1965), Bokander (1966) and Levelt (1966, 1968) all studied the effects of contour contrast on BR by blurring the contours and varying the illumination. The effects of movement on pattern dominance in BR was studied by Springbett (1961) and Grindley & Townsend (1965, 1966).

Three comparatively recent studies (Triesman, 1962; Hochberg, 1964; Ogle & Wakefield, 1967) investigated the effect of binocular rivalry on perceived depth of stereoscopically viewed patterns containing binocular parallax. The results of these studies suggest that BR does not interfere with perceived depth unless one rivalry pattern is at any time completely suppressed. It is not entirely clear whether depth information penetrates the phenomenal suppression of rivalry or whether the partial retinal disparity that may exist with incomplete BR suppression is enough to give the perception of depth.

Binocular rivalry has also been studied or used for several other purposes. Bárány & Halldén (1947) studied the effects of depressant drugs on BR in the search for a drug that might reduce the suppression effects of strabismic amblyopia. Kakizaki (1960) stressed the importance of BR, but as an example of the rather restricted class of "bivalent" phenomena. Enoksson (1963) induced conflicting optokinetic nystagmus with oppositely moving rivalry patterns in order to devise an objective measure of rivalry and ultimately a measure of ocular dominance. Kaufman (1963) and Hochberg (1964) investigated spreading suppression in the visual system with the use of BR. Aafjes, Hueting & Visser (1966) and Cogan & Goldstein (1967) investigated differences in the rate of rivalry alternation between individuals and over massed and spaced viewing trials. Goldstein (1968) compared the alternations of rivalry with the fading in Troxler's effect and Smith, P. (1968) compared it with image fragmentation of stabilized images and afterimages. Whittle, Bloor & Pocock (1968) compared the effects of coherent or aligned contours with adjacent contours in BR.

The purpose of this brief review of recent publications has been to illustrate the point that the revival of interest in binocular rivalry is not a direct result of the renewed interest in attention. Although the revived interest in attention and BR may be traced to common factors, the large majority of psychologists have not recognized the relevance and potential usefulness of BR to the study of attention.

There have been a few experimenters who have explicitly connected binocular rivalry and attention. However, they have mainly been in the field of physiological psychology. This is understandable since, as Hernández-Peón (1966) and Worden (1966) point out in recent review articles, there has been a rapid increase in the number of neurophysiological investigations of the neural concomitants of the attention process. Many recent investigations have measured the effects of changes in attention in humans on cortical evoked potentials to auditory clicks or flashes of light (Spong, Haider & Lindsley, 1965; Mast & Watson, 1968; Eason, Harter & White, 1969; Kopell, Wittner & Warrick, 1969; and Näätänen, 1970). The main controversy has centred around the question of whether or not selective attention to the clicks or flashes, as opposed to selective attention away from these stimuli, affects the amplitude of the cortical evoked potentials to these stimuli. Binocular rivalry was adopted by several experimenters as a phenomenon with which the question could be investigated. Of these investigators van Balen (1964), Cobb, Ettlinger & Morton (1967), Lawwill & Biersdorf (1968) and Donchin & Cohen (1970) refer to BR as an example of attention.

On the other hand, there are only a few recent psychologists not involved in neurophysiological investigations who have referred to binocular rivalry in the same way as did the early psychologists. Berlyne (1960) who has played a significant role in renewing interest in attention, referred to Breese's study (1899) of BR as an example of the effect of stimulus intensity on attention. He also referred to the studies of Engel (1956) and Bagby (1957) as examples of the effects of familiarity and novelty on attention. To lend further support to his theory of attention Berlyne referred to the Breese findings (1899) that stimulus movement or change predominates over stationary stimuli and that complexity dominates over plainness.

In a rather ambitious series of experiments, Crain (1961) attempted to relate intelligence and the physiological measure of alpha rhythms to binocular rivalry. He refers to BR as an example of attention. "This patchy rivalry would suggest that, while the visual fields may provide the basis for the division of attention, there is also a central (but not voluntary) influence exerted on (or reflected in) the rivalry process (Crain, 1961, p.273)."

Reynolds (1964) developed what is basically a theory of attention based on his concept of the "temporary inhibition of response". He generalized this concept to apply as well to binocular rivalry. For Reynolds BR is not an example of stimulus selection but one of response competition. "If rivalry is learned or subject to the laws of learning then a competing response explanation is not untenable.....even though stimuli are presented simultaneously to the subject, he responds to them successively (p.335)." He concludes that rivalry "reflects a genuine perceptual process which involves a temporary inhibition of response (Reynolds, 1964, p.335)." This is a theoretical issue which will not be discussed here; the main point is that Reynolds seems to accept BR as an example of attention.

Of all recent experimenters Fox (1963) most explicitly recognizes the relevance of binocular rivalry to the study of attention. Speaking of the selection which must take place in rivalry since only one output can result from the two inputs, he says "to the extent that these kinds of selection or control mechanisms are appropriately categorized under the concept of attention, attention is clearly a crucial variable in binocular visual phenomena in general, and is especially relevant to the problem of rivalry in particular (1963, p.14)." He regards his series of experiments on the suppression mechanism in binocular rivalry as part of the recently renewed effort to obtain a better understanding of attention.

Experimenters more directly involved in the study of attention have also recognized BR as an example of attention but have remained doubtful as to its usefulness. Triesman (1969) states that binocular rivalry "may be taken as one limit on divided attention (p.288)." However, she goes on to state that "unlike selection between dichotic auditory inputs, the choice is not normally under voluntary control, and division of attention in vision is usually tested with inputs differing in spacial location (p.288)." Thus, because she assumes that BR is not selective in the same way as dichotic listening, and because most work in visual attention has been concerned with the direction of visual fixation, she does not pursue the discussion of binocular rivalry.

Moray (1969) is in accord with Treisman: as to the ability to control rivalry. "It is generally agreed," he writes, "that binocular rivalry is not under the control of the viewer. The fluctuations come and go, and there is little he can do to determine which shall dominate. The system appears to be one that is tunable but to which the subject cannot pay attention (p.150)." He bases his conclusion of the lack of control of rivalry on the assumption of "general agreement". Since neither Treisman (1969) nor Moray (1969) refer to previous studies, one wonders how "general" the agreement was and what experiments formed the basis of this conclusion. In any case, for Treisman and Moray, BR is not analogous to dichotic listening mainly because it does not seem to be under voluntary control. Therefore, they do not consider BR to be a potentially useful research tool for the study of selective attention.

On the other hand, at the end of his chapter on visual selection, Moray (1969) seems to leave open the possibility that BR is more analogous to dichotic listening than he had previously assumed: "it seems the biggest difference is the degree to which voluntary control over attention can be exercised. However, this may turn out only to be an apparent difference. May there be binaural rivalry for certain classes of signals? The timing of events in the two modalities is certainly very different; perhaps a more fine grained analysis of hearing will reveal that there is auditory rivalry for very short signals (pp.101-2)." Another reason for the distinction made by Moray and

Treisman between BR and dichotic listening was the fact that ear discrimination is made easily, but that eye discrimination is difficult or non-existent. However, Moray refers to a personal communication from Treisman in which she says she found it difficult to discriminate between ears with computer synchronized dichotic pairs of digits. Moray (1969) suggests that "aural rivalry (p.102)" may occur with perfect auditory synchrony.

In his last chapter, Moray (1969) describes a series of experiments in which simple tone bursts of different frequencies were pulsed simultaneously to the two ears. In conclusion, he points out the need for "more information about vision and about intermodal continuous tasks", and the need "to link 'one shot' tasks to continuous tasks (p.193)." This conclusion is consistent with his earlier stated opinion about the effect of the tape recorder in biasing research in attention: "the last decade has perhaps seen too heavy an emphasis on auditory research at the expense of visual work, a balance which is just now beginning to be restored (Moray, 1969, p.5)." Thus, Moray seems to be interested in investigating what essentially would be "binaural rivalry". This may lead him to reconsider the possible similarities of dichotic listening and BR.

To summarize, the vast majority of psychologists who have recently studied or used binocular rivalry have not considered it as an example of attention. Only a few have recognized it as such. At the same time some of the researchers most active in studying auditory attention have previously considered dichotic listening and BR to be different to the extent that BR was of little relevance to selective attention. However, a development of interest in "binaural rivalry (Moray, 1969)", the recent investigations of the neurophysiological effects of BR, and the suggestions of a few psychologists (Berlyne, 1960; Crain, 1961; Fox, 1963; and Reynolds, 1964) may produce a renewed interest in BR for the purposes of studying selective attention.

The Question of the control of Binocular Rivalry

From the preceding review it is clear that one of the main deterrents to the recognition of the relevance of binocular rivalry to attention is the assumption that BR is not normally subject to voluntary control. Like Treisman (1969) and Moray (1969), Bárány and Halldén (1947) expressed the view that "most previous observers agree that attention has no influence on retinal rivalry (p.298)." Bárány and Halldén state that neither of them could, through a conscious effort, influence the rivalry between simple horizontal and vertical bars. They refer to Helmholtz's apparent finding of control (1925) but suggest that his control may have been mediated by eye movements. This view implies that the small degree of control that may sometimes be found is a result of eye movements or some other adjustment of the sense organs and thus, should not be considered a legitimate mechanism of selective attention. Adjustments of the physical structure of the eye such as blinking, eye movements, accommodation and pupillary changes may affect dominance in BR through an effective change of stimulus strength. However, this is very much different than stimulus selection on a more central level which is presumably what occurs in selective dichotic listening. The assumption seems to be that if control of rivalry is found, it is of only a small degree and, in any case, is likely to be effected through trivial mechanisms. If this is the case then BR could not be considered an example of selective attention. At this point it would be appropriate to examine the experiments that have studied the voluntary control of rivalry.

The early work by Helmholtz (1925) has already been mentioned. It is quite clear from his detailed introspections that he finds that he can control rivalry. With simple pairs of vertical and horizontal rivalry stimuli or with a printed page in rivalry with a complicated stimulus he can exert a fair degree of control by attending to one rivalry pattern to the exclusion of the other. Other stereogram pairs, such as series of parallel lines, were more difficult to control. With these he found that by counting the lines, moving his fixation perpendicular to the lines, or by moving his fixation along the lines parallel to their direction he could maintain one pattern in attention. As a result, he concludes that a specific type of eye movement is not necessary for the fixation of attention. In addition he feels that although eye movements may facilitate control, they are not necessary. He states that "...by purely psychic means of concentrating the attention, which are well understood and similar to those instanced above, the variation can be instantly stopped, without producing any noticeable change in the external conditions (such as changing the direction or movement of the eyes, etc.) (p.500)."

However, Helmholtz (1925) believes that like all other examples of selective attention and voluntary processes the control of rivalry is a "mediate, not an immediate, volition (p.500)." He feels that it is not enough merely to intend to concentrate the attention. The "psychic means" he refers to is some mental work or manipulation, some mental activity that is associated with or requires the perception of the rivalry stimuli to which attention is to be directed. Thus Helmholtz does propose a mediating device of attention. However, this is basically a central mediation and would, therefore, not be considered trivial. This level of mediation would probably be qualitatively similar to listening, and all that is probably involved in the process of "listening" to the verbal material in a selective listening experiment. Thus Helmholtz (1873, 1925) would conclude that a high degree of control is possible with rivalry, and that it is exercised in a way similar to other examples of voluntary attention.

Breese (1899) was the first to conduct a reasonably thorough series of quantified experiments with factors affecting binocular rivalry and the control of rivalry. He used as rivalry stimuli a red square on the right eye containing five parallel diagonal lines and which corresponded with a green square on the left eye containing diagonal lines oriented perpendicularly to those of the red square. Nine naive subjects were instructed under different conditions to watch the rivalry without exerting control, to hold the red field by "will power", and to hold the green field. Percentage of time for which each field was seen was recorded on each trial. When the red field was held it was seen an average of 68% of the time; when the green field was held it was seen 63% of the time and the red field was seen 37% of the time. Thus the effect of willful control was an average variation of predominance of about 30% between the "hold red" and "hold green" instructions.

On the other hand, since these instructions to alter the relative predominance did not result in a change in the average number of fluctuations, he concluded that "the number of fluctuations in rivalry could not be controlled (Breese, 1899, p.25)." It must be noted here, however, that Breese's subjects were only instructed to favour one pattern or the other; they were not instructed directly to increase or decrease the number of fluctuations. Since it would seem to be possible for his subjects to follow his instructions either by increasing the separate durations of the held pattern (resulting in a decreased number of fluctuations) or decreasing the durations for which the non-held pattern is seen (resulting in an increased number of fluctuations) conclusions about the rate of rivalry fluctuation may not be warranted from his experiment. The question of the control of the number of fluctuations can be tested directly only with the use of instructions specifically to increase or decrease the rivalry rate.

Breese noted that his subjects seemed to make vigorous eye movements when the instructed pattern was being seen but that these movements ceased each time the non-held pattern was seen. He suspected that eye movements were involved in the attempt to hold the instructed pattern. To test this he used himself as subject and attempted to increase the predominance of either the red or the green field while at the same time carefully maintaining a constant fixation point in the centre of the rivalry patterns. Under these conditions he was unable, through an effort of will power alone, to alter the predominance of either field from that which is obtained during the passive observation of rivalry.

In addition when he reintroduced conscious eye movements perpendicular or parallel to the lines of the pattern to which he wanted to attend, he found, as did Helmholtz (1925), a very significant ability to alter the predominance in rivalry (an average of about 35%).

To account for the change of predominance, Breese (1899) proposed that eye movements had a physiological instead of psychical effect on rivalry. Eye movements when the "held" pattern was in consciousness would maintain a high level of stimulation from that eye. Conversely, the cessation of eye movements when the unwanted pattern was in consciousness would result in a more rapid decline of stimulation from that eye. However, this explanation seems to be vitiated when Breese recognizes that since both eyes move together, both eyes will receive increased stimulation during movement or reduced stimulation without movement. One eye cannot be favoured separately with this scheme. He then proposes the mechanism of fixation as the basis of control. That is, when fixations are made with respect to one pattern, then that pattern will predominate in rivalry regardless of the identical but "aimless" pattern movements in the other eye. Thus when eye movements are directed by the input from one eye, it will be the pattern in that eye which predominates. This implies that the effect of eye movements is "not in terms of the physiological function of the periphery but in terms of the central processes

(Breese, 1899, p.46)." This is as close as Breese gets to the position of Helmholtz. In opposition to Helmholtz, Breese concludes that eye movements are necessary for control and thus rivalry is not a purely psychical function.

A study relevant to the question of eye movements during rivalry was made by Peckham (1936) who observed the eye movements of subjects observing rivalry. He found that the overall number of fluctuations were correlated with the number of eye movements. However, there did not seem to be any causal relation between specific eye movements and specific fluctuations. As many disappearances occurred without eye movements as occurred with eye movements. Eye movements were as likely as not to be followed by disappearances. Based on Breese's hypothesis (1899), fluctuations, or in this case disappearances, should tend to occur when eye movements cease. Yet this was not found to be the case. On the other hand, it may be argued that because Peckham's subjects were passive observers and were not attempting to control the rivalry, Breese's hypothesis should not be expected to apply. Peckham's study does not really resolve the issue of the role of eye movements in the control of rivalry.

Of more direct relevance to this question is an experiment by Washburn & Gillette (1933). They used 35 naive subjects who observed the rivalry of a red square versus a blue square or the rivalry of the afterimages of these stimuli (a green square versus a yellow square). Their subjects were instructed under two conditions to hold one pattern or the other. A percentage difference between these two conditions was used as the measure of control. For the rivalry of the illuminated squares the degree of control ranged from -4.9% to 51.85% with an average of 23.78%. The average control of the afterimage rivalry (13.07%) was significantly ($p = .05$) less than with the illuminated stimuli. At the same time the value of 13.07% was over two and a half times its standard error greater than 0%.

The fact that neither coloured square had any contours specific to itself should have eliminated fixation movements specific to either stimulus. This should, if fixations are necessary for the control of rivalry, have eliminated control. Yet the mean of 23.78% is not very much less than that obtained by Breese using his highly contoured stimuli. In any case fixation movements would have been eliminated entirely in the rivalry of afterimages. The fact that control was reduced in this situation may be considered evidence in support of the fixation hypothesis. However, the relatively reduced intensity of afterimages would be a confounding variable. The fact that subjects had significant control of these coloured squares and also of their afterimages would seem to discount the necessity of fixation movements for the control of rivalry. Indeed, Washburn & Gillette (1933) comment that "eye movements and movement ideas are absent in rivalry control (p.319)."

Interestingly enough Washburn & Gillette (1933) attribute the control of rivalry, afterimage rivalry, Necker cube reversals and cube afterimage reversals to "motor processes". This conclusion is warranted, they feel, by the fact that the control of the Necker cube reversals, with which eye movements and movement ideas seemed associated, was far superior to the control of the other phenomena less associated with movement. The control that does exist with rivalry they attribute to "verbal reactions, since it was derived from the subjects acceptance of verbal instructions (p.318)." Here Washburn & Gillette consider themselves "motor psychologists" as opposed to "certain philosophers and psychologists" who postulate "the existence of mind as a dynamic entity capable of directly controlling its own processes (p.319)." It would seem that "verbal reaction" is only semantically different from the position of Helmholtz. Perhaps this distinction was enough to allow the anomaly described earlier of the isolated spurt of experiments on binocular rivalry to occur during the 1930s. In any case the findings of Washburn & Gillette (1933) would suggest that fixation movements themselves, although they may be facilitative, are not necessary for the control of rivalry.

Eye movements have not been the only motor mechanism with which the control of rivalry has been associated. The sensory organ adjustments of pupillary constriction and accommodation effected by intrinsic eye muscle activity has been implicated in control. McDougall (1903) found that if the intrinsic eye muscles of one eye were paralyzed with atropine, that eye became less favoured in BR. He found this to be especially true when the eyes are made to converge to some extent, thereby increasing the intrinsic muscle activity in the normal eye but not in the paralyzed eye. A voluntary effort to hold the pattern in the normal eye resulted in an average increase in its predominance of 14.5 seconds out of a total of 118 seconds. But a voluntary effort to hold the pattern in the paralyzed eye resulted in an increase compared with the passive condition of 10 seconds. Thus the loss of intrinsic muscle activity seems to reduce the predominance of the effected eye in passive rivalry and to reduce the extent to which it can be favoured in the control of rivalry.

There are a number of methodological problems, however, which make McDougall's conclusions (1903) about the role of the intrinsic eye muscles difficult to accept. Since he does not present figures of relative dominance before atropine is introduced, it is impossible to know to what extent the dominance of the normal eye was the result of the atropine treatment or merely a reflection of a possible pre-existing ocular dominance. The atropine treatment, besides paralyzing the intrinsic ocular muscles, may have resulted in a more intense stimulus because of pupillary dilation. Because accommodation was also lost, the retinal image may have been blurred and out of focus. In any case the ability to favour the atropinized eye by voluntary control seems merely to have been reduced and not abolished. Intrinsic muscle activity therefore seems to be facilitative but not necessary for the control of rivalry.

The effect of paralysis of the intrinsic eye muscles on the control of rivalry was also tested by George (1936). He mentioned the results of a short experiment in which both eyes were paralyzed and voluntary control was tested for reversible perspective, binocular rivalry and the BR of afterimages. This treatment had little effect on the control of reversible perspective but "noticeably decreased (p.58)" the control of BR and the BR of afterimages. Unfortunately he omits a detailed description of the method and results and, thus, it is difficult to assess the degree of the reduction of control. Apparently, as in McDougall's experiment, control of rivalry was not abolished by paralyzing the intrinsic eye muscles.

The most thorough analysis of the role of intrinsic eye muscles in the control of rivalry was conducted by Fry (1936). Having assumed that accommodation provided the basis of the control of rivalry, he proceeded to analyze the exact mechanisms involved. His measure of control was the extent of the difference of rivalry rates when a subject attempted to accelerate and to retard the rate. When both eyes were paralyzed the control of the rate of afterimage rivalry was "practically abolished (p.136)." The "acceleration" and "retardation" condition produced 23 and 13 alternations per minute with eyes normal but produced 15.4 and 13.4 per minute respectively with eyes paralyzed. Since accommodation cannot affect the optical quality of afterimages, Fry suggested the action of intraocular pressure changes or proprioceptive stimulation of the intrinsic eye muscles as the basis of control of afterimage rivalry. Of these two possibilities he favoured the mechanism of pressure changes since he could demonstrate an effect on the afterimages as a result of pressing on the eyeballs.

In the case of rivalry of patterns produced by direct stimulation Fry (1936) found that control was abolished by the use of small artificial pupils with the eyes still normal. With large artificial pupils 3.94 mm in diameter his subject was able to produce 48.6 and 28.4 alternations per minute under the acceleration and retardation conditions respectively. When the artificial pupil diameters were reduced to 2.06 mm the respective rates were 42.6 and 39.6 per minute. He reasoned that since intraocular pressure changes and proprioceptive stimulation would still be present, the abolition of control must have resulted entirely from the use of small artificial pupils. Since the reduction of the diameter of the artificial pupils would reduce the extent of retinal blurring effects, he concluded that accommodation provided the basis of control of rivalry in normal conditions through a mechanism of retinal blurring.

To summarize, McDougall (1903) and George (1936) both found the effects of intrinsic eye muscle paralysis to be a reduction but not abolition of control of rivalry. Fry (1936) found that small artificial pupils or the paralysis of intrinsic eye muscles had the effect of abolishing the control of rivalry. Since each of these experimenters presumably used one subject, a total of two subjects showed some reduction of control and one subject showed an abolition of control with the loss of accommodation. Thus, it is not clear from the previous studies whether accommodation is the only mechanism involved in the control of rivalry or whether it is merely facilitative.

Blinking may be another peripheral mechanism involved in the control of binocular rivalry. If it were shown that blinking were the basis of BR control, it would certainly reduce control to the level of triviality. Washburn & Gillette (1933) state that blinking is a method "available (p.318)" in the control of rivalry. They suggest that blinking may be used to change the phase of rivalry and that prevention of blinking may tend to hold a perceived phase. However, they have no direct data to test this hypothesis. They also note that blinking cannot be used for the control of afterimages since subjects kept their eyes closed. It is difficult to know whether the reduction of control from 23.78% to 13.07% in the afterimage condition is the result of the loss of a blinking mechanism. In any case the control of afterimage rivalry is not dependent on blinking.

Bárány & Halldén (1947) state that blinking may cause a change of state of rivalry but that it has "no influence in the long run (p.298)." They tested this assumption by cocainizing the cornea to avoid blinking and found no difference in the overall rate of rivalry with the condition in which blinking was allowed. Thus, according to Bárány & Halldén blinking would have only a temporary effect on rivalry and could not effectively be used to increase or decrease the rate of rivalry as measured over a sufficiently long period.

More recently Meredith & Meredith (1962) examined the control of rivalry. They had 24 subjects indicate alternations in rivalry under the three instructional conditions "Natural Rate", "Rapid Rate", and "Slow Rate". The resultant mean rivalry rates were 30.86, 50.96 and 18.06 respectively. Meredith & Meredith preferred to attribute these very significant differences to the effects of "Instructional conditions" rather than "employ some central process, such as 'attention', 'set', 'attitude', or 'volition' to control the rate of reversal (p.660)." Referring to these latter concepts they add "...it is apparent that this sort of mentalistic explanation is no longer tenable in modern psychology (p.660)." What is to Meredith & Meredith (1962) an important distinction seems to be rather a preference of terminology which perhaps relates to the historical events in the field of psychology discussed earlier. In any case the important point here is that their subjects had a considerable degree of rivalry control.

With respect to blinking, Meredith & Meredith (1962) stated that they warned subjects not to blink unless it was necessary. They reported further that none of their subjects reported any difference in blink rate between the instructional conditions. However, they mentioned that blink rates were not, in fact, measured, and they cautioned against the reliance on the subjects' recollection of blink rates. Thus, they refrained from discounting the effects of blinking on the control of rivalry.

However, if the subjective reports of subjects with respect to rivalry reversals are accepted as fairly reliable, it seems reasonable to take some note of the subjects judgments of their blink rates. It would seem unlikely that if blinking were the basis of BR control it would go unnoticed by subjects producing an average "Rapid Rate" almost three times the average "Slow Rate". In any case, although blinking does not appear to be necessary for the control of rivalry, more experimental evidence is required to establish the role of blinking, if any, in BR control.

In summary, the control of binocular rivalry does seem to exist to a significant but not always a very appreciable extent. However, it is unclear from past studies to what extent peripheral mechanisms such as blinking, eye movements and accommodation play a part in this control. Blink rates have never actually been measured. Eye movements and fixations in particular seem to facilitate control. On the other hand, Helmholtz (1925) and Washburn & Gillette (1933) found that eye movements were certainly not essential for control. Microsaccadic eye movements which could not be measured by past experimenters can not be excluded as a potentially necessary element of BR control. There have been mixed findings regarding accommodation as the basis of control although all experimenters who have paralyzed the intrinsic eye muscles of subjects have found a reduction of control. The control of afterimage rivalry, although it is reduced in degree compared with normal control, must not be dependent on blinking, fixations, or retinal blurring. Fry (1936) assumes, nevertheless, that accommodation operates in this case through intraocular pressure changes. This assumption has yet to be substantiated. The considerable degree of control exercised by the subjects of Meredith & Meredith (1962) is reminiscent of the degree of control described by Helmholtz. However, the extent to which peripheral mechanisms may have been operating was not determined. Thus the emphasis in the past upon peripheral mechanisms, the paucity of crucial experiments, and the small degree of control found in most experiments would be grounds for a fair scepticism about the relevance of BR control to selective attention.

Current Theories of Attention

The last decade has seen the development of a number of theories of attention. Since recent publications by Moray (1969) and Swets & Kristofferson (1970) have described and compared these theories in detail, only brief summaries of the main theories will be presented here for the purposes of making distinctions of relevance to binocular rivalry and BR control.

Broadbent (1958) proposed what has become known as the "Filter Theory", in which the human is conceived of as an information processor of limited capacity. To protect the processor from an overload of information, a single channel is selected for processing at the expense of all other channels--channels being defined on the basis of sense modalities or physical characteristics. Messages in the rejected channels are filtered out at an early stage in the perceptual process, before any cortical analysis or recognition of the messages occurs. Preceding the filtering process all messages are temporarily stored in a short term memory. A message in a rejected channel would decay in memory and normally be lost within a few seconds. However, whatever remains of a message in a rejected channel may be extracted if the filter is switched to that channel. The filter can switch channels in a minimum time of about .17 seconds, and is biased to switch to sudden, novel or intense stimuli, or to stimuli of a high probability or expectation. The filter may also switch channels spontaneously or as a result of instructions to a subject.

Because of subsequent experimental evidence that seemed to be damaging to the filter theory, Treisman (1969) proposed a modification and elaboration of the theory. The basic change was to drop the notion of the filter as an all-or-none process in which messages in rejected channels were completely lost. She proposed that rejected channels were merely attenuated or reduced to a low level in effective intensity. The selection mechanism may be influenced by transient effects such as instructions to subjects. She also elaborated the process of perceptual analysis, positing a hierarchy of processing levels. Simple physical characteristics would be analyzed at low levels, phonemic characteristics at secondary levels, and semantic characteristics at higher levels. The details of this recognition system are probably more relevant to attention to verbal messages than to selection of sense modalities and will, therefore, not be elaborated here.

Treisman's (1969) paper is important because it recognizes some of the complexities of the process of selective attention, particularly the wide variety of items that may be considered as "channels". She proposes that selection can be made on the basis of four broad categories: 1. on the basis of input selection (sense modalities, physical characteristics, etc.), 2. on the basis of output selection, 3. on the basis of the selection of "analyzers" (single dimensions or properties of stimuli), or 4. on the basis of target selection (specific stimulus combinations including many dimensions). The first category would conform to Broadbent's original definition of channel and would probably be most relevant to binocular rivalry. The second is similar to the theories of Deutsch & Deutsch (1963) and Reynolds (1964). The third type of selection is comparatively the most difficult to control since it is frequently dependent on selection of a single dimension from amongst several stimulus dimensions within the same input. The fourth category is probably most relevant to the process of scanning a large number of stimuli for a specific target as was required in many of the experiments conducted by Neisser (1967).

Despite the classification system outlined above, the theory of attention by Deutsch & Deutsch (1963) and its elaboration by Norman (1969) would be considered a more fully comprehensive one by its proponents than merely one type of attention as suggested by Treisman (1969). The basic departure from the filter theory and attenuation theory is the level proposed for the selection process. The

Deutschs' theory states that all stimuli are fully analyzed or recognized on the cortical level before unwanted or unimportant signals are ignored. Selection then merely determines awareness, motor output, and long term memory storage. The weighting of importance of stimuli is a function of past experience but also of transient effects such as instructional conditions.

The main controversy then seems to centre around the question of the level at which selection takes place. In the final analysis it may be the case that selection takes place on various possible levels, the level being determined by the type of selection in operation. In any case the main testable distinction between the present theories is the extent to which stimuli in a rejected channel are available for recognition responses. The filter theory would suggest that as long as the channel remained rejected the stimuli contained within it would be unavailable for recognition. If the filter did not switch to the rejected channel within a few seconds the stimuli would never be available for recognition. Treisman's attenuation model would suggest that some recognition of non-attended stimuli would exist but that it would be inferior to that for attended stimuli. This statement must however be qualified by a reference to the ways in which the non-attended stimulus differs from the attended stimulus. The theory of Deutsch & Deutsch (1963) would suggest that a full recognition analysis is conducted on all stimuli, and that, thus, all stimuli should be equally available for recognition. Selective attention would only determine which recognition response is presented to awareness, memory or motor response. The limitation of attention capacity is on the output side of the recognition analyzers. There should be no reason why information could not be extracted from a non-attended recognition analyzer. It should merely be a matter of a shift of attention to that analyzer.

Possible Role of the Control of Binocular Rivalry in the Study of Selective Attention

What is apparent from the review of attention theories is the emphasis placed on the effects of attention using verbal messages. This is understandable in view of the early emphasis of experimentation in auditory attention, especially in verbal dichotic listening and "shadowing" tasks in which a subject verbally repeats the message in one ear. It is, perhaps, significant of the confusing results of these early experiments that there seems to be a trend towards the use of simpler acoustical stimuli to enable better quantification of the effects of attention (Moray, 1969).

It also seems to be that theories of attention have not been particularly concerned with the voluntary control of attention. In all cases this is referred to as the effect of instructional conditions and recognized only as another effective variable. However, voluntary control or instructional conditions per se have not yet been thoroughly investigated.

Until recently there has been very little work on selective attention in vision. Most of the work concerned with vision has studied attention as a result of the direction of vision or fixation responses. Visual fixation preferences (Mackworth, 1967), scanning for visual target stimuli (Neisser, 1967), and attention in peripheral vision (Grindley & Townsend, 1970) have been the main categories of experiments in visual attention. The visual modality as a whole or the eyes separately have not recently been considered as attention "channels" except by a few neurophysiologists and one or two psychologists. Thus, BR and BR control have remained relatively unused as tools to investigate selective attention.

However, for a number of reasons the study of binocular rivalry may contribute to a better understanding of attention processes. BR is a comparatively simple phenomenal fluctuation of perception between two stimuli competing for attention. The stimuli can be exactly specified; they may be simple or complex; they may be constant or changing. Technical apparatus such as tachistoscopes, computer controlled cathode ray oscilloscopes, video tape recorders, etc. are now available to allow a tremendous variation of quantifiable stimulus conditions. BR also seems to be susceptible to voluntary control. If this is the case and if control is exercised mainly by central and not peripheral mechanisms then it would possibly allow the investigation of the voluntary control aspects of selective attention.

Finally, if the neurophysiological substrates of attention are sought, the study of attention in BR may prove to be a more productive avenue of investigation than the auditory modality. The visual system in comparison with the auditory system is less complicated and better understood. The fact that in the visual system there are several fewer synaptic junctions from sense organ to cortex, and the fact that the topographic organization is comparatively well understood suggests that it may eventually be easier to understand the neurophysiological effects of attention in vision than in hearing.

Of course the point of this introductory chapter is not to attempt to establish the importance of binocular rivalry and BR control to the study of attention. The importance of BR control is, in the final analysis, an empirical question. The point of this chapter has been only to suggest the possible importance of BR control. The rest of the thesis may provide some support for this suggestion. In any case it is clear that several questions about BR control must first be resolved.

First of all, does control of rivalry really exist? If it does, to what extent can it be exercised? Is it really very different from the degree of control found in dichotic listening? Can the degree of control be increased with practice, and if so, to what extent? If BR control is a perceptual skill then it should be susceptible to conditioning or practice with feedback of results. These questions will be considered in Chapter II.

A very important question is that of the behavioural reality of BR control. Can BR control be measured in an objective way or must it remain a mentalistic phenomenon? If it can be measured, what are the behavioural effects of control? Chapter III will investigate these questions.

If BR control does exist, is it mediated by a peripheral motor mechanism and, thus, of questionable importance to selective attention? To what extent are blinking, eye movements, accommodation and pupillary changes involved in BR control? Are they only minor factors or are they the sole basis of control? How reliable and valid are the reports of observers of the alternations of rivalry? The experiments in Chapter IV will undertake to answer these questions.

A final series of questions are concerned with the level on which binocular rivalry takes place. Is the physiological interaction between the inputs of the two eyes which underlies the phenomenal alternation of rivalry a retinal or a cortical mechanism? If that can be established one may then ask how and where BR control exerts its influence on this physiological mechanism. Is centrifugal control involved? Does BR control exert its influence on a level peripheral to the mechanism underlying rivalry? Or does BR control directly affect the rivalry mechanism? Tentative answers to some of these questions arise from the experiments of Chapters V and VI.

CHAPTER II.

THE EFFECT OF PRACTICE ON THE EXTENT OF VOLUNTARY CONTROL OF BINOCULAR RIVALRY.

Introduction

It is of primary importance to obtain more quantitative data regarding the degree of voluntary control of binocular rivalry. Introspective reports from investigators in the past have ranged from a report of the lack of control (Bárány & Halldén, 1947) to a report of a high degree of control (Helmholtz, 1925). Only a few previous investigations have tested the degree of BR control with groups of naive subjects. Breese (1899) instructed subjects to hold dominant the pattern in one eye for 100 second trials. The difference in the time for which the right eye pattern is seen between the hold right eye and hold left eye instructions may be taken as a percentage measure of the degree of control. This measure applied to Breese's group of 9 subjects produces an average of 29.3%. Using coloured patches without diagonal lines as rivalry patterns Washburn & Gillette (1933) found an average BR control of dominance for 35 subjects of 23.78%. Although Breese (1899) did not test directly the ability to control the rate of fluctuation, he found no change in the rate of fluctuation and concluded that subjects could not control the rate. However, in contrast to Breese, Meredith & Meredith (1962) found the average "rapid rate" of a group of 24 subjects to be almost three times the average "slow rate". They also found considerably more control of rivalry rate than earlier investigators found for control of dominance (assuming they can be compared). Thus, these are two reasons to verify the findings of Meredith & Meredith (1962).

Binocular rivalry has often been considered together with the phenomenon of reversible perspective. Kakizaki (1960, p.94) refers to them both as examples of "bi-valent" situations. Vernon (1962) considers them examples of fluctuations of attention. Dember (1963) uses them to illustrate the instability of perceptual organization that may arise when two equally probable perceptions are available. Other experimenters, while considering them together, have examined the differences between them. Washburn & Gillette (1933) found that Necker Cube reversals were susceptible to a greater degree of voluntary control than BR. They attributed this to the greater availability of "motor processes" because much less control was found using the afterimage of the Necker Cube. George (1936) makes the distinction between reversible perspective and BR as to the level of perception involved. Because reversible perspective is more affected than BR by general stimulant or depressant drugs but reversible perspective is less affected by the paralysis of intrinsic eye muscles, he considers reversible perspective "a higher level function than that involved in binocular rivalry (p.58)." Nevertheless George (1936) considers there to be a common factor underlying BR and reversible perspective.

The factors common to reversible perspective and binocular rivalry may be those contained in the generalizations put forward by Ammons (1954) regarding factors affecting visual recognition responses. Some of these factors, such as practice, distribution of observation periods, and reinforcement have been studied with reversible perspective. Ammons, Ammons, Dubbe, Tschida & Preuninger (1958) using several hundred subjects found that the rate of perspective reversal could be increased with practice. They also found that subjects could learn with practice to reverse parts or the whole of 3-dimensional objects. Ammons, Ulrich & Ammons (1959) gave 10 subjects practice in accelerating the Necker cube reversal rate on ten 15 minute trials. The mean reversal rate for their subjects went from about 35 reversals per 30 second period on Trial 1 to 140 reversals on Trial 9. Further studies by Ammons & Ammons (1965, 1967) found that a practice schedule of 5 minutes of continuous practice, followed by 5 minutes rest, followed by another period of continuous practice, produced the effects of warm-up, work decrement from "reactive inhibition", and reminiscence which are usually found in learning tasks. These experiments have shown that the rate of perspective reversal can be learned and may be increased with practice of instructions to accelerate the reversal rate.

An experiment reported by Peckham (1936) contained an incidental remark to the effect that with practice subjects learned to increase the dominance of one eye in binocular rivalry. However, to the knowledge of the present writer no experimenter has subjected the control of BR to a direct test of the effect of practice. At the same time Moray & Jordan (1966) have evidence to suggest that with practice in a dichotic listening situation subjects can learn to increase their capacity to attend to one channel exclusively or to switch more readily between channels. Moray (1969) supports this suggestion with his personal experience that experimenters and other well-practiced subjects show superior performance to naive subjects in dichotic listening experiments. Moray (1969) states that there is a great need to study the effects of practice: "No one has systematically investigated what happens with observers who have been practiced over many thousands of trials, and it is most important that such work should be undertaken (p.194)." Therefore, in the spirit of that statement and because the effects of practice on BR control are unknown, this chapter will investigate the effects of practice, distribution of practice trials, and knowledge of results of practice on the ability to control binocular rivalry.

Experiment 1

The main purpose of this experiment was to verify the results of Meredith & Meredith (1962). For this reason rivalry stimuli and control instructions used were similar to those of Meredith & Meredith (1962). They used simple rivalry stimuli consisting of a single black vertical bar on the left eye and a single horizontal black bar on the right eye. In the stereoscopic condition these bars bisected each other. They used control instructions to affect the rate of rivalry instead of dominance. Under their "natural rate" instructions subjects were not to exert any control over the rate of rivalry alternations; in the "slow rate" subjects were to reduce the rate of alternations; and in their "rapid rate" subjects were to accelerate the rate of alternation.

The second purpose of the experiment was to examine the effects of spaced practice of the rate control instructions. Ammons, Ulrich & Ammons (1959) found a steady and considerable increase over trials of the rate of Necker cube reversals when subjects were given spaced practice of the instructions to produce a rapid reversal rate. Thus, if BR rate is also subject to learning, then one would predict an increase of BR rate with spaced practice of the rapid rate instructions.

On the other hand, from the Ammons & Ammons work (1965, 1967) it is not clear as to what the prediction would be with regards to practice of the slow rate instructions. Ammons & Ammons were mainly concerned with illustrating the fact that the reversal rate can be learned and did not specifically refer to the increase of reversal rate as an increase in the ability to control the rate of reversal. They did not measure the reversal rate under both rapid and slow instructions at the end of practice sessions to test whether the difference produced by these two instructions (the degree of control) had been increased by practice of the rapid rate instructions alone. It may have been the case that the reversal rate under slow rate instructions increased in proportion to the increase under the rapid rate instructions. If this were so, then it could not be concluded that the practice of the rapid rate instructions produced an increase in the ability to control the reversal rate.

In any case past investigations have shown that the reversal rate of ambiguous figures can be increased or decreased according to the instructions given to subjects. Bruner, Postman & Mosteller (1950) found that three different rates of reversal resulted when the three different instructions to increase the rate, to watch the reversals passively, and to decrease the rate were given to the same group of subjects in different 10 minute periods. Pelton & Solley (1968) found that when one group of subjects were given only the increase rate instructions and another group were given the decrease rate instructions, the same magnitude of difference between the rates was obtained. Pelton & Solley view this difference as the result of "active intentional attitudes" in opposition to a prediction of the dependence of the reversal rate on a pure satiation theory (p.588). One may then predict that the spaced practice of the slow rate instructions would result in a decrease of the BR alternation rate under the slow rate instructions. Thus the practice of both instructions should result in an increasing difference in binocular rivalry rate between the instructional conditions, or in other words, an increase in the degree of BR control.

Method

Subjects

Ten males and ten females with normal or corrected to normal vision were obtained from an introductory psychology class to serve as subjects. All were naive with respect to binocular rivalry and the purpose of the experiment.

Stimuli

The stimuli to serve as fusion contours in the two eyes were identical black rings 1 degree of visual angle in width and with an outer diameter subtending 9.5 degrees of visual angle. The circles were centred in square white fields, each subtending 28 degrees of visual angle. The white fields were surrounded by a black background which provided an additional fusion contour for the left and right visual fields. The rivalry stimuli were provided by a black vertical line 1 degree in width bisecting the right fusion ring and a black horizontal line 1 degree in width bisecting the left fusion ring. The fusion and rivalry stimuli were mounted in a stereocard so that the rings were 58 mm apart from centre to centre. Viewed stereoscopically the rings formed one fused ring and the mutually perpendicular rivalry lines bisected each other at the centre of the fusion ring.

Apparatus and Procedure

The apparatus consisted of a Stereo King Model HN-44 stereoscope in which could be mounted a 4 cm by 10 cm stereocard 5.5 cm from refracting lenses. This provided fixation at infinity for normal vision. The fusion rings and rivalry lines were inked on thin white paper and mounted in the black stereocard. The stimuli were transilluminated by a 75-W, 240-v incandescent lamp placed 80 cm behind the stereocard. The luminance of the black fusion rings and rivalry lines as measured at the lens by an S.E.I. spot photometer was 0.62 foot-Lamberts (ft-L). The white background luminance was a uniform 4.5 ft-L. The black background was a uniform luminance of 0.4 ft-L.

Subjects pressed the button of a hand tally counter to indicate each dominance change in binocular rivalry during timed trials. Although Cogan & Goldstein (1967) noted that there are periods when both patterns seem to be visible, with the present stimuli the contours of one line always predominate over the other at the expected intersection point.

The nondominant line may be absent entirely, or it may be faded out at the intersection point, or it will at least appear to be weaker or behind the dominant line. Since a dichotomous classification was possible at all times, a change of dominance was unambiguous and easily reported.

All subjects were given the general instructions: 1. "at the (ready) signal, look into the stereoscope and fixate at the apparent intersection point of the vertical and horizontal lines"; 2. "after the (start) signal, press the hand tally counter once for each change of rivalry dominance", and 3. "at the (stop) signal, stop tapping and look away". They also received one of three different rivalry rate instructions for any one test trial. The instructions were similar to those used by Meredith & Meredith (1962) of "natural rate", "slow rate", and "rapid rate". The equivalent of their "natural rate" was the "passive rate" instruction.

Passive rate: "You are to look at the pattern in a passive manner. Look at the intersection point of the vertical and horizontal bar. At any instant one of the bars will be dominant in that it is solid or continuous while the other is broken or fades out at the intersection point. This bar will not remain dominant for the dominance will change to the other bar. Do not assist or hold back this change of dominance. Do not try to control the rate of dominance changes. Just relax and with an aloof, passive attitude let the bars alternate at their own natural rate."

Slow rate: "You are to exert control over the rivalry rate by making the dominance of the patterns change as slowly as possible. Look at the intersection point of the vertical and horizontal bars. At any instant one of the bars will be dominant in that it is solid or continuous while the other bar is broken or fades out at the intersection point. Always concentrate on the dominant bar to hold it dominant as long as possible or suppress the nondominant bar to keep it from becoming dominant. If, eventually, the dominance changes, apply the same procedure to maintain the new dominant bar as long as possible. In this way slow down the rate of dominance changes."

Rapid rate: "You are to exert control over the rivalry rate by making the dominance of the patterns change as rapidly as possible. Look at the intersection point of the vertical and horizontal bars. At any instant one of the bars will be dominant in that it is solid or continuous while the other bar is broken or fades out at the intersection point. To make the changes take place rapidly concentrate on or attend to the bar that is not dominant to bring it into dominance, or suppress the dominant bar to make it nondominant. When a change in dominance takes place, apply the same procedure to make the dominance changes take place as rapidly as possible."

All 20 subjects completed the same experimental procedure, consisting of ten 30 second trials on each of ten consecutive days. Intertrial rest periods of 30 seconds allowed the rivalry rate on the previous trial to be recorded and the instructions for the next trial to be given. For the first and tenth trial on each day subjects received the "Passive rate" instructions. On odd numbered test days starting with Day 1 the "slow rate" instructions were given for trials 2, 3, 4 and 5 and the "Rapid rate" instructions were given for trials 6, 7, 8 and 9. This order of rivalry rate instructions was reversed on alternate days so that on even numbered days the "rapid rate" instructions were given for trials 2, 3, 4 and 5 and the "slow rate" instructions were given for trials 6, 7, 8 and 9.

Results and Discussion

Figure 2.1 shows that the effects of practice under the present experimental conditions were quite dramatic. The rapid rate (rivalry rate under the "rapid rate" instructions) increased from a mean of 46.7 dominance changes/min and range of 22 to 82 on Day 1 to a mean of 98.2 and range of 41 to 160 on Day 10. The increase of rapid rate between Day 1 and Day 2 was significant ($t = 5.26$, $df = 19$, $p < .001$). In fact, there were increases of mean rapid rate on every practice day, of which the differences between Day 4 and 5, between Day 6 and 7, and between Day 8 and 9 also were significant to

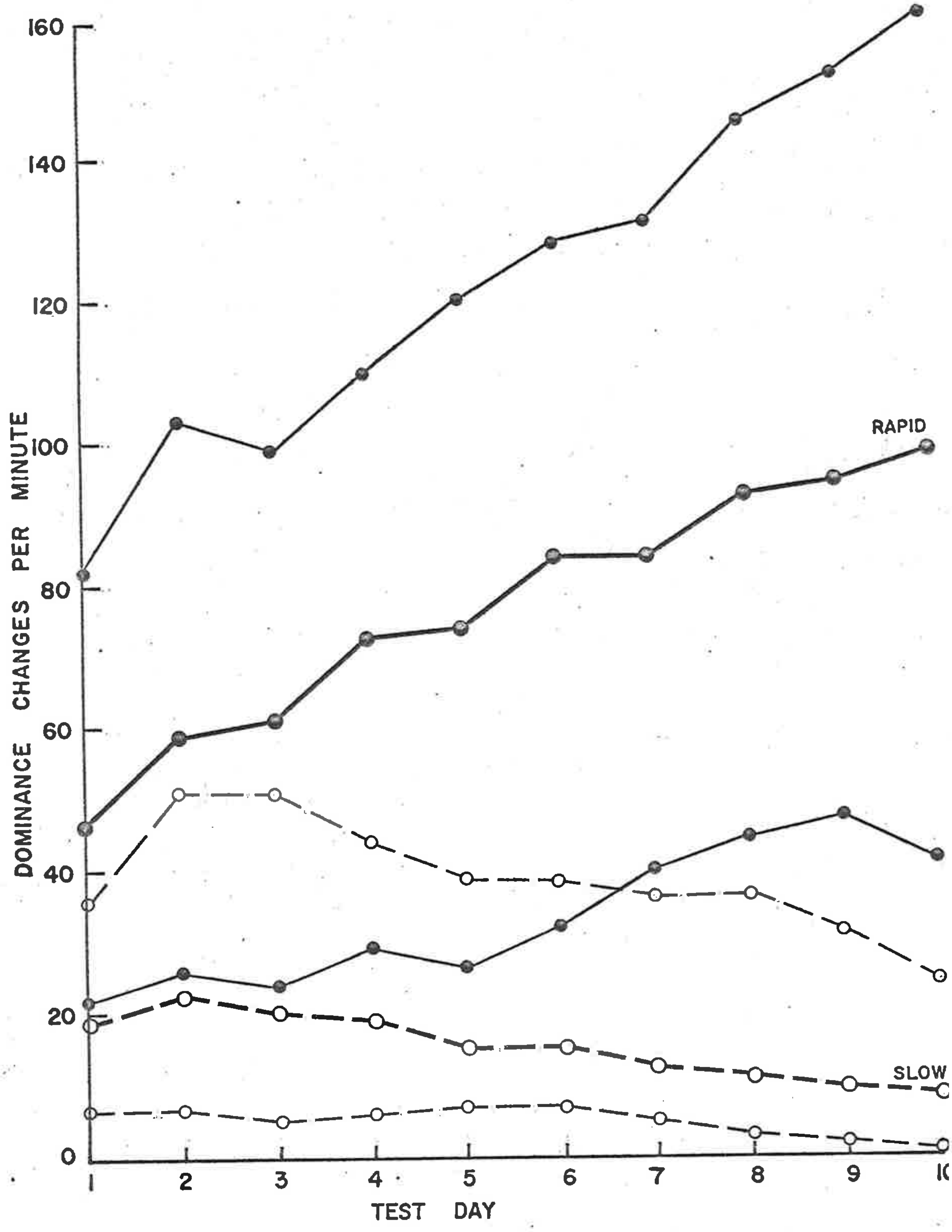


Fig. 2·1. Mean rapid rate with upper and lower values of the range (small filled circles) and mean slow rate with upper and lower range values (small open circles) the ($p = .01$) level. As a result, the difference in rapid rate between Day 1 and Day 10 was significant to a very high level ($t = 18.5$, $df = 19$, $p < .0001$).

The effect of practice on slow rate was somewhat less consistent than that of rapid rate. There was an initial increase of slow rate ($t = 2.76$, $df = 19$, $p < .02$) between Day 1 and 2. However, by Day 5 the slow rate was significantly lower than the slow rate on Day 1 ($t = 4.33$, $df = 19$, $p < .001$). There were significant decreases ($p < .01$) of slow rate between Day 4 and 5, between Day 6 and 7, and between Day 8 and 9. Thus the eventual difference in slow rate between Day 1 and Day 10 was significant to a high level ($t = 8.28$, $df = 19$, $p < .0001$).

From Figure 2.1 it appears that the greatest daily increases of rapid rate occur on even numbered days and that the greatest daily decreases of slow rate occur on odd numbered days. It may be recalled that on even numbered days the "rapid rate" instructions preceded the "slow rate" instructions and that on odd numbered days the "slow rate" instructions were given first. Thus it seems that on any given day whichever control instructions were practiced first produced the greatest change from the previous day's performance. This may be a result of the fact that whichever instruction is first on a given day was also the second control instruction on the previous day, so the first rivalry control instruction each day followed the same instructions from the previous day. On the other hand, the second rivalry control instruction on a given day always followed two successive days or a total of eight trials of the opposite rivalry control instructions. If there is any proactive interference between the two rivalry control instructions then the second on each day will be detrimentally affected by the previous eight trials of practice of the opposite control instructions.

The passive rate (rivalry rate following the "passive rate" instructions) was not included in Figure 2.1 because it was not a dependent variable of major concern. In fact the mean passive rate was remarkably stable across practice days. It was 36.0 dominance changes/min on Day 1 and 36.1 on Day 10. In between it never exceeded 39.2 or fell below 33.4 dominance changes/min.

A measure of the degree of BR control must logically include a comparison of the rapid rate and the slow rate. All subjects had greater rapid than slow rates on Day 1. A direct test of the difference between the mean rapid and slow rate showed a very significant effect of control instructions on Day 1 ($t = 8.9$, $df = 19$, $p < .0001$). The difference between rivalry rates then increased on each successive day so that there was complete separation of the distribution of rapid rates and slow rates by Day 7.

Because there are large differences of passive rate between subjects, the absolute difference of rapid and slow rate may not be a measure of control that is comparable between subjects. A reasonably comparable measure of the degree of BR control would use the difference between the rapid and slow rate in relation to the overall rate for that subject. For instance one subject with a rapid rate of 20, a slow rate of 5 and a difference of 15 should be considered to have more control than a subject with a rapid rate of 60, a slow rate of 40, and a difference of 20. Even though the second subject produced a greater absolute difference between instructions, the difference represented a much smaller difference proportional to his overall rate. Since individual differences in overall rate should not be a function of the degree of BR control they should be cancelled out of the measure of BR control.

A measure of BR control was devised incorporating the difference of the rapid and slow rates in comparison with the overall rate, the sum of rapid and slow rates. The measure was put in the form of a percentage difference by multiplying by 100. The percentage control measure equals (100)(Rapid rate - Slow rate)/(Rapid rate + Slow rate). This measure will produce a value of zero for no difference between rapid and slow rates, a negative value for slow rates greater than rapid rates, and a value of 100% when the difference is as great as the sum (when slow rate equals 0). With this measure the first of the two previously hypothesized subjects would have (100)(20-5)/(20+15) = (100)(15)/(25) = 60%. The second subject would have (100)(60-40)/(60+40) = 20% control. This measure applied to all subjects produced a fairly symmetrical distribution with a mean control of 45.5% and a range of 13.2% to 66.0% on Day 1 and a mean control of 83.0% with a range of 65.5% to 98.5% on Day 10.

The mean rapid and slow rate on Day 1 of the present experiment are very similar to those found by Meredith & Meredith (1962) with their unpracticed subjects. They found a mean rapid rate of 50.96 reversals per minute and mean slow rate of 18.06 reversals per minute resulting in a mean control measure of 47.7%. These are very similar to the respective values in the present experiment of 46.7 dominance changes per minutes, 17.0 dominance changes per minute, and mean control of 45.5%. This suggests that the degree of BR control using the "slow" and "rapid rate" instructions may be a fairly stable value from sample to sample under the same experimental conditions or even between different experimental conditions using somewhat differently worded instructions.

In summary, the effect of "Rapid rate" instructions and "slow rate" instructions is to produce a very significant difference in rivalry rates on Day 1. The respective rivalry rates and degree of control are very similar to that found by

Meredith & Meredith (1962). The effect of successive practice days of these instructions is a monotonic and significant increase of rapid rate and eventually a significant decrease of slow rate. In other words, subjects can exert a significant degree of control over the rate of alternation in binocular rivalry. The degree of BR control then increases monotonically with successive practice days of the rate control instructions.

One question which now arises is to what extent is the increase of BR control a result of the practice of the rivalry control instructions. It may be the case that BR control would increase as a result of only passive viewing of rivalry. The next experiment is concerned mainly with a test of this possibility.

Experiment 2

Investigators have usually found an increase of BR rate with spaced practice but not during massed practice of passive viewing (Aafjes, Hueting & Visser, 1966). Cogan & Goldstein (1967) suggest that "rest periods" during spaced practice provide a motivating factor for subjects to follow unintentionally inferred instructions to increase the BR rate. This would suggest that during spaced "passive rate" viewing subjects may, to some extent, be practicing some internally derived type of "rapid rate" instructions.

It is also not clear from the literature what the effects are of passive viewing on BR control. It could be that "passive rate" viewing increases the familiarity of the subject to both phases of the rivalry stimulus thereby increasing the subject's ability to control the rate. On the other hand, "passive" viewing may increase both the first rapid rate and slow rate when tested and, thus, not affect BR control. Therefore, the purpose of this experiment is to investigate the extent to which the control of binocular rivalry is altered by spaced practice of passive viewing as separate from the effects of the rate control instructions.

Method

Subjects

Sixteen males and sixteen females with normal or corrected to normal vision were selected randomly from an introductory psychology class to serve as subjects. All subjects were naive to the rivalry situation and to the purpose of the experiment.

Stimuli and Apparatus

The fusion and rivalry stimuli were the same as those of Experiment 1. The apparatus was the same as that in Experiment 1 with the exception of a telegraph key to replace the hand tally counter for the purpose of reporting rivalry dominance changes. In this case the subject was given the instruction to tap the telegraph key once with his preferred hand to indicate each dominance change in rivalry during timed trials. In addition a chin rest was adjusted for the subject who sat in a sound deadened and dimly lit room. The subject received instructions through headphones from the experimenter in an adjacent room. A tap of the telegraph key activated a digital counter in the experimenter's room which allowed the rivalry rate to be measured for a timed trial.

Procedure

The general instructions and the three specific rivalry rate instructions were the same as in Experiment 1. The testing schedule also consisted of a total of 10 test days each with ten 30 second timed trials spaced with 30 second intertrial intervals. In this experiment the 32 subjects were divided randomly into 4 groups, each containing 4 males and 4 females. The 4 groups had different amounts of passive viewing and control practice (see Table 2.1). Group A had "slow rate" and "rapid rate" instruction on all 10 test days. Group B had 7 test days of control instruction starting on Test Day 4. Group C had 4 test days of control instruction starting on Test Day 7. Group D had "slow rate" and "rapid rate" instructions only on Test Day 10. Until the first control practice day for Groups B, C and D, all 10 trials on each day were "passive rate" instructions. On all control practice days, the first and tenth trial remained "passive rate" instructions, and the middle eight trials

TABLE 2.1

Experiment 2 Design. S-"Slow Rate" Instruction. R-"Rapid Rate" Instruction.

Group	Control Trials	Test Day 1	2	3	4	5	6	7	8	9	10
A	2,3,4,5	S	R	S	R	S	R	S	R	S	R
	6,7,8,9	R	S	R	S	R	S	R	S	R	S
B	2,3,4,5	"Passive"			R	S	R	S	R	S	R
	6,7,8,9	"Passive"			S	R	S	R	S	R	S
C	2,3,4,5	"Passive"			"Passive"			S	R	S	R
	6,7,8,9	"Passive"			"Passive"			R	S	R	S
D	2,3,4,5	"Passive"			"Passive"			"Passive"			R
	6,7,8,9	"Passive"			"Passive"			"Passive"			S

received the control instructions. The "slow rate" instructions were first (Trials 2, 3, 4, 5) followed by "rapid rate" instructions (Trials 6, 7, 8, 9) on odd-numbered test days, alternating with "rapid rate" followed by "slow rate" on even numbered test days. All subjects remained naive to the "slow rate" and "rapid rate" instructions until their first control practice day.

Results and Discussion

When questioned on the first test day and on subsequent test days, all subjects reported no difficulty in indicating dominance changes. The measure of blink rates by a second experimenter confirmed that subjects were following instructions not to blink excessively. There were no significant differences in blink rates for any subjects between any of the conditions nor any change of blink rate over time.

The control measure applied to the slow and rapid rates of all subjects on the first control test day of each group yielded a mean percentage control for Group A-Day 1 of 42.6, for Group B-Day 4 of 46.3, for Group C-Day 7 of 39.1 and for Group D-Day 10 of 53.2. The overall mean percentage control for all subjects on their first control practice day was 45.3. This agrees closely with the mean percentage control measure of 45.5 on Day 1 of Experiment 1 and the value of 47.7 from the experiment of Meredith & Meredith (1962).

Figure 2.2 shows graphically the rivalry rate for each of the groups under the "slow rate" instructions. The effect of passive viewing on the slow rate can be tested by comparing means of the first "slow rate" practice day of all groups. A simple analysis of variance applied to Group A-Day 1, Group B-Day 4, Group C-Day 7 and Group D-Day 10 found a significant effect ($F = 3.09$, $df = 3/31$, $p < .05$) of passive viewing on slow rate. A trend analysis using "orthogonal polynomials" (McNemar, 1962) showed that the significant difference between groups was produced by a significant linear increase ($F = 8.84$, $df = 1/31$, $p < .02$). The cumulative effect of "slow rate" instructions on slow rate can be tested by applying a treatments by subjects design analysis of variance (Lindquist, 1953) to each group across the practice days of "slow rate". Group A showed a significant difference across Test Days 1 through 10 ($F = 3.79$, $df = 9/63$, $p < .001$). Group B showed a significant difference across Test Days 4 through 10 ($F = 4.44$, $df = 6/55$, $p < .005$). Group C showed a significant difference across Test Days 7 through 10 ($F = 6.96$, $df = 3/31$, $p < .005$). In summary, the effect of "passive rate" instruction alone was to increase the rivalry rate under the first "slow rate" instructions, whereas the effect of subsequent "slow rate" instructions on every group was a decrease of slow rivalry rate over practice days. Since these two instructions have opposite effects on the slow rate, it is not surprising to find a significant

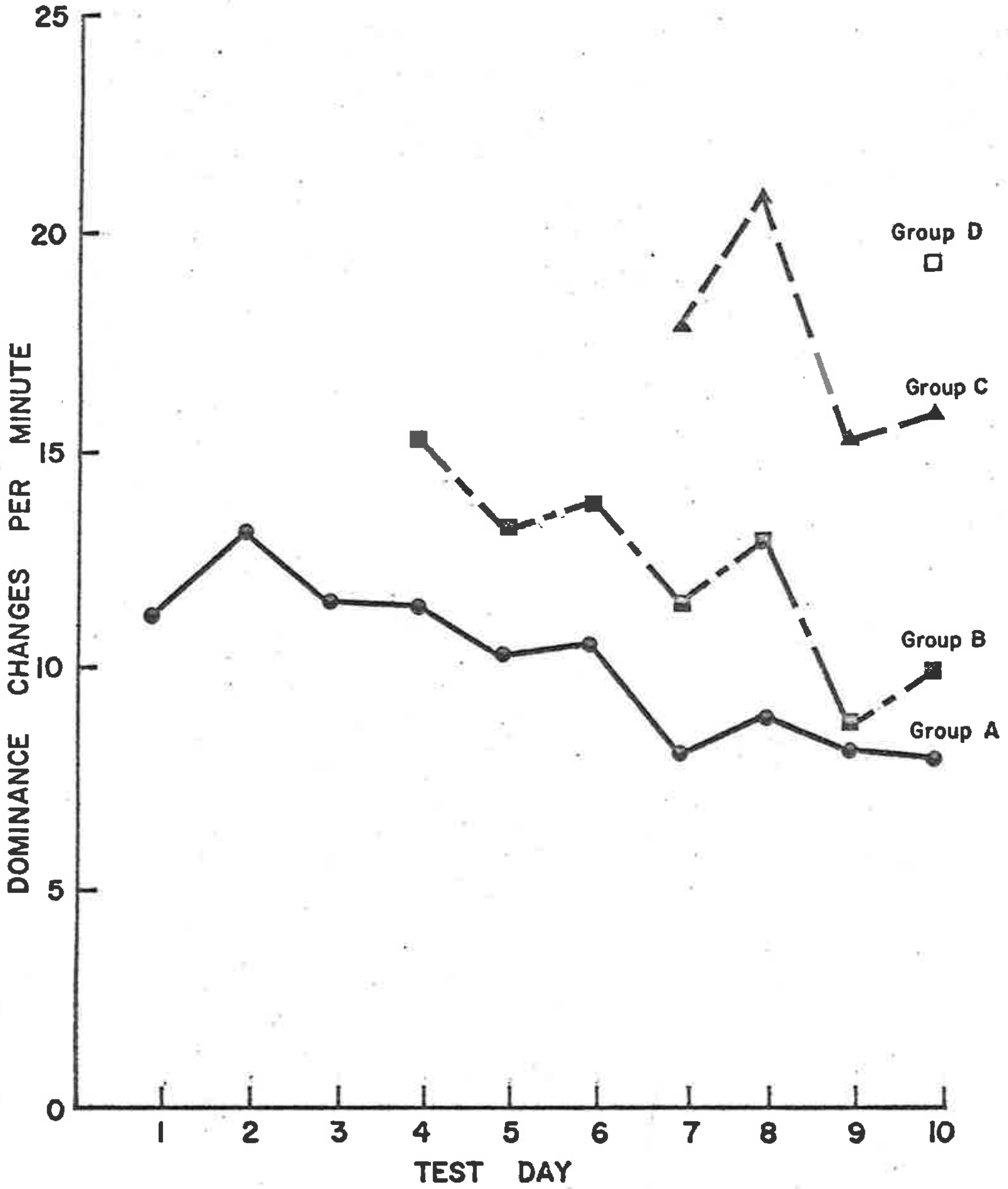


Fig. 2·2. Mean rivalry rate under "slow rate" instruction difference of slow rate between groups on Test Day 10 ($F = 8.43$, $df = 3/31$, $p < .001$).

Figure 2.3 shows graphically the rivalry rates under "rapid rate" instructions for each group. The effect of passive viewing on the first "rapid" rivalry rate can be tested by comparing means of the first "rapid rate" practice day of all groups. A simple analysis of variance applied to Group A-Day 1, Group B-Day 4, Group C-Day 7 and Group D-Day 10 found a significant effect ($F = 4.64$, $df = 3/31$, $p < .01$) of passive viewing on rapid rate. The first "rapid rate" seems to be a linearly increasing function ($F = 12.02$, $df = 1/31$, $p < .01$) of the number of days of "passive rate" only. The cumulative effect of "rapid rate" instructions on rapid rate can be tested by applying a treatments by subjects analysis of variance to each group over the practice trials of "rapid rate". Group A showed a difference across Test Days 1 through 10 ($F = 8.22$, $df = 9/63$, $p < .001$). Group B showed a significant difference across Test Days 4 through 10 ($F = 7.04$, $df = 6/55$, $p < .001$). Group C showed a significant difference across Test Days 7 through 10 ($F = 5.60$, $df = 3/31$, $p < .01$).

Therefore the effect of both "passive rate" and "rapid rate" instructions is to increase the rivalry rate under "rapid rate" instructions.

By testing the difference between groups on Test Day 10, any difference in the magnitude of effect of the two instructions on rapid rate can be compared. If "rapid rate"

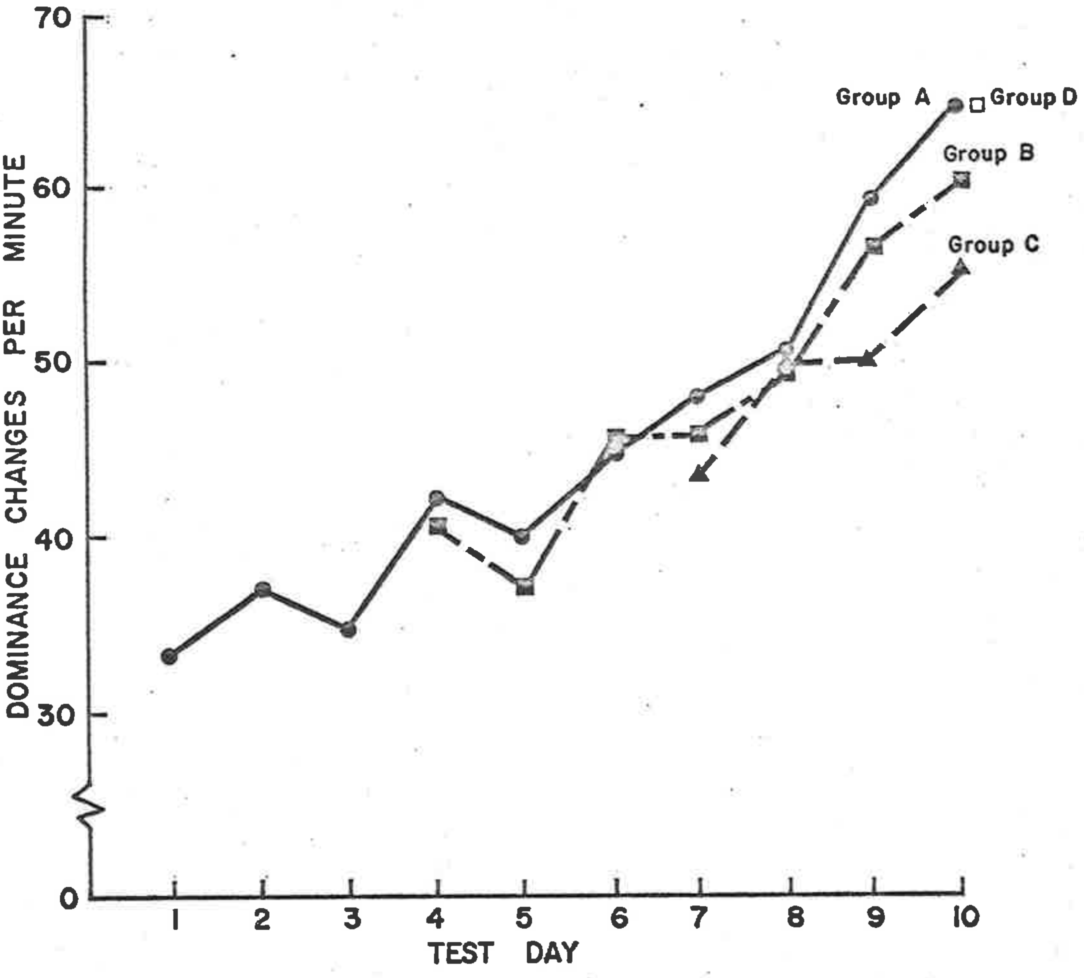


Fig. 2·3. Mean rivalry rate under "rapid rate" instruction.

has more effect than "passive rate" instructions on increasing the rapid rate, there should be a linear increase in rapid rate on Day 10 from Group D to Group A. In other words Group A would show the greatest rapid rate if "rapid rate" instructions were more effective than "passive rate" instructions in increasing the rapid rate. However, there is no significant difference between groups ($F = 0.22$), nor is there any linear trend ($F = 1.0$). Therefore, there is no significant difference between the effects of "passive rate" and "rapid rate" instructions on the increase of rivalry rate over test days as tested under "rapid rate" instructions.

The reason for the increased slow and rapid rates of Groups C and D with prior passive viewing becomes evident when the passive rivalry rates are analyzed in these two groups. A treatment by subjects analysis of variance applied to Group C, Days 1 through 6, shows a significant linear increase ($F = 8.15$, $df = 1/35$, $p < .001$) of passive rivalry rate. The same analysis applied to Group D, Days 1 through 9, also shows a significant linear increase of passive rivalry rate ($F = 18.7$, $df = 1/56$, $p < .001$). Using a Spearman Rank Correlation Test it was found that those subjects who showed the highest passive rate in Group C on Day 6 had the highest slow rate ($r_s = +.90$, $n = 8$, $p < .02$) on Day 7. Those subjects in Group D who showed the highest passive rate on Day 9 had the highest rapid rate ($r_s = +.91$, $n = 8$, $p < .02$)

and tended to have a higher slow rate ($r_s = +.54$, $n = 8$, $p < .10$) on Day 10. In summary, the increased slow and rapid rates of Groups C and D on their first control practice days are due to the general increase of passive rates during days of only "passive rate" instructions.

Figure 2.4 shows graphically the measure of binocular rivalry control ((100)(Rapid - Slow)/(Rapid + Slow)) for each group on test days for which "rapid rate" and "slow rate" instructions were given. The effect of passive viewing on control can be tested by comparing the 4 groups' control values on the first day of "slow rate" and "rapid rate" instructions. A simple analysis of variance was applied to the control measures on the first control instruction days of the 4 groups. There was no significant difference between groups on their first day of control practice ($F = 1.32$, $df = 3/31$, $p > .25$). To test the effect of practicing the "slow rate" and "rapid rate" instructions on the control of binocular rivalry a treatment by subjects analysis of variance was applied across the practice days of each group. Group A showed a significant difference in control across Test Days 1 through 10 ($F = 7.85$, $df = 9/63$, $p < .001$). Group B showed a significant difference across Test Days 4 through 10 ($F = 12.7$, $df = 6/55$, $p < .001$). Group C showed a significant difference across Test Days 7 through 10 ($F = 8.12$, $df = 3/31$, $p < .001$). Since control does not significantly change with

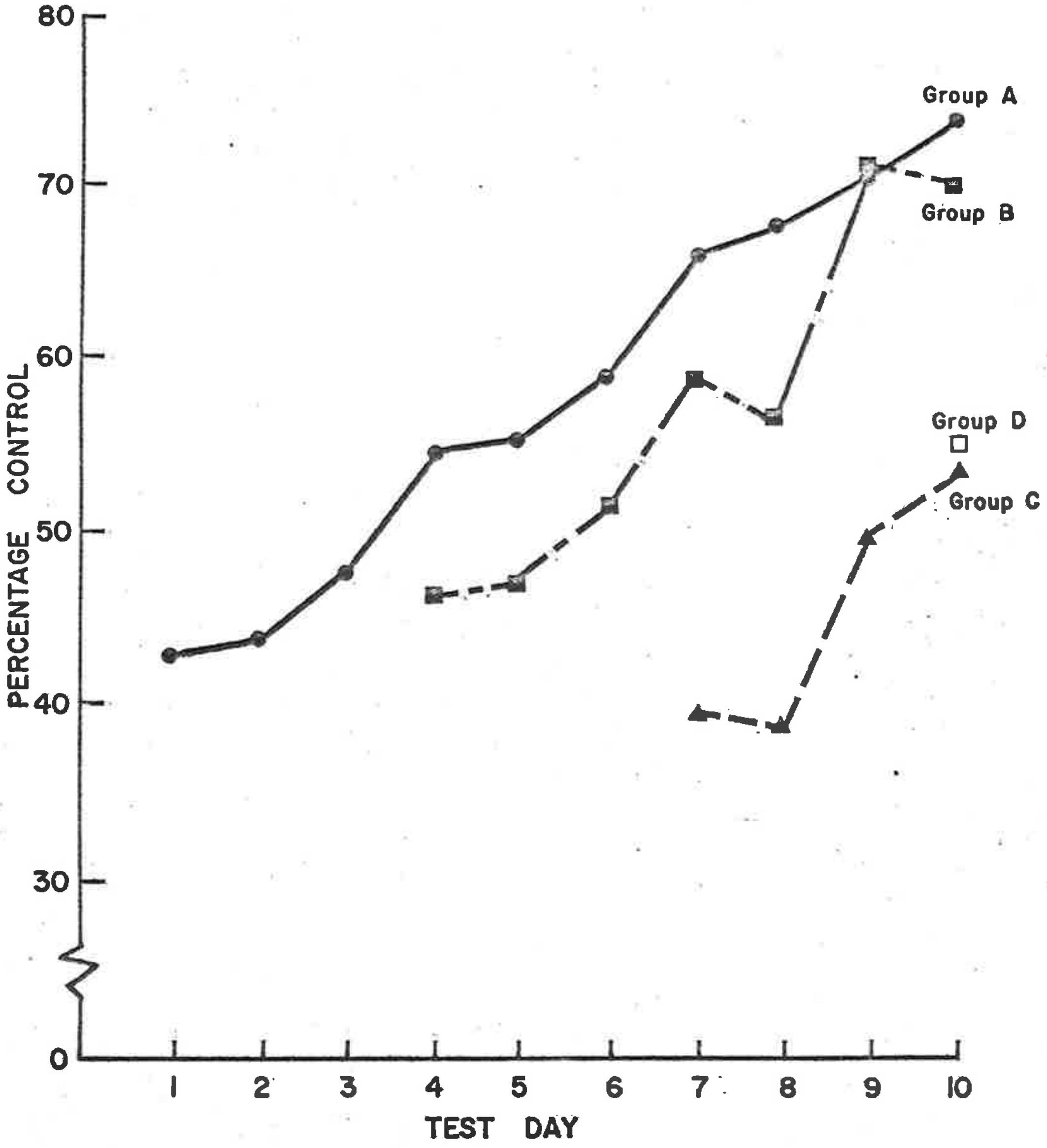


Fig. 2·4. Mean percentage control

passive viewing but does increase over successive days of practice of the "slow rate" and "rapid rate" instructions, it is not surprising to find a significant difference in control between groups on Test Day 10 ($F = 4.61$, $df = 3/31$, $p < .01$).

To get some idea of the extent to which control could be increased with further practice, two volunteers from Group A (R.G. above average in initial control and C.T. below average in initial control) were given "slow rate" and "rapid rate" instructions for another 10 test days. The rivalry rates for both instructions in reversals per minute and control percentages are given in Table 2.2. Both R.G. and C.T. show continued decrease of slow rate and increase of rapid rate over Test Days 10 through 20. As a result, their percentage control measures asymptotically approach 100. By Day 20 both subjects show a remarkable ability to hold one pattern dominant over the other in the slow rate as indicated by a rivalry rate of only one alternation per minute.

In summary, the more passive viewing a subject has before the instructions of "slow rate" and "rapid rate", the greater will be his rivalry rates under either of these control instructions. However, passive viewing does not affect significantly the extent of BR control. Control increases very significantly with spaced practice of both control instructions and approaches asymptotic performance with continued practice.

TABLE 2.2.

Effect of Further Practice of "Slow Rate" and "Rapid Rate" Instruction on the BR Control of Two Subjects from Group A.

Test Day	Subject R.G. "Slow"	Subject R.G. "Rapid"	Subject R.G. Control	Subject C.T. "Slow"	Subject C.T. "Rapid"	Subject C.T. Control
10	7	134	90.1	10	62	72.3
11	8	156	90.3	8	67	78.6
12	8	201	92.3	9	63	75.0
13	4	199	96.1	7	66	80.8
14	4	200	96.1	7	68	81.4
15	3	231	97.5	6	71	84.4
16	5	207	95.3	5	73	87.2
17	4	245	96.8	3	76	92.4
18	2	242	98.4	2	83	95.3
19	2	259	98.5	2	87	95.5
20	1	278	99.3	1	89	97.8

Experiment 3

The previous two experiments have shown that spaced practice of the "slow rate" and "rapid rate" control instructions produces a decrease of slow rate, an increase of rapid rate, and, as a result, an increase of the measure of BR control. Experiment 1 showed no increase in the passive rate when subjects were practicing both the control instructions. Experiment 2 showed that the increase of control occurred only with the practice of the control instructions and not with the practice of passive viewing alone. However, it was found in Experiment 2 that passive rate does increase when only the "passive rate" instructions are given to subjects. For these subjects there is an elevation of both the rapid rate and slow rate but not of BR control on the first day of control practice. Since rapid rate seemed to increase as much from passive viewing as from the practice of the rapid rate, it may be the case that only the practice of the slow rate is crucial to the increase of BR control. This possibility was examined indirectly in the present experiment.

A more important purpose of the present experiment is to analyze in more detail the factors relevant to the increase of BR control with practice. If BR control is a perceptual skill that can be learned, then it should be affected by variables that are usually factors in learning, such as the spacing of practice trials and the knowledge of results (KR). Since these two variables have not yet been investigated, they will be the main concern of the present experiment.

The distribution of practice trials is a variable which has been considered of some importance in learning tasks. It has generally been found that for the same number of practice trials distributed practice produces more rapid learning than massed practice (Tsao, 1948; Hovland, 1951; Woodworth & Schlosberg, 1954). In the previous experiments the eight 30 second practice trials were spaced with 30 second rest periods on any one test day. The 10 test days were spaced one day apart. This arrangement of practice trials would normally be considered to be facilitative for learning (Woodworth & Schlosberg, 1954). However, for some types of learning tasks this degree of spacing may be less beneficial than with practice trials which are massed together. Therefore, in order to understand better the nature of this ability to control BR, it would be instructive to test the effect of massing of practice trials.

The use of knowledge of results (KR) and other social reinforcement was not rigorously specified in the two previous experiments. KR was not given in a systematic way to subjects. In addition, praise was sometimes but not consistently given for improvements in performance. Several reviews of the literature have stressed the importance of KR in learning and performance (Ammons, 1956; Bilodeau & Bilodeau, 1961; Locke, Cartledge & Koeppel, 1968; Annett, 1969). KR facilitates learning both by providing information necessary for correction of inferior performance and by serving as reinforcement of superior performance or improvements of performance. Because of the proximity of the experimenter to the subject in Experiment 1 and the less personal arrangement in Experiment 2, it is not surprising that the increase of BR control in Experiment 1 (37.5%) is somewhat greater than that of Group A in Experiment 2 (30.8%). In any case, it is necessary to investigate more carefully the extent to which the increase of BR control is dependent on explicit KR during practice.

Method

Subjects

Sixty subjects (30 males, 30 females) with normal or corrected to normal vision were obtained from an introductory psychology class. No subject had any prior experience with BR. All subjects were naive to the purposes of the experiment.

Stimuli and Apparatus

The fusion and rivalry stimuli were the same as those used in Experiment 1 and 2. The apparatus was the same as in Experiment 2. The subject received instructions and indicated rivalry dominance changes in the same way as in Experiment 2.

Procedure

The general instructions to subjects and the three rivalry rate instructions were also the same as in the previous experiments. The basic difference of the present experiment is in the experimental design.

The 60 subjects were randomly allocated into 4 practice groups and one passive viewing group as in Table 2.3 with about equal numbers of males and females in each group. The passive group, Group PS-no KR (N = 15), was given the "passive rate" instructions only on a spaced practice schedule. Ten 30 second trials were separated by 30 second rest periods on each of nine test sessions each separated by 24 hours. On Test Session 10 the subjects of Group PS-no KR were also given the BR control instructions of "slow rate" and "rapid rate". They followed the Session 10 trial sequence identical to all the control practice groups of one "passive rate" trial, four "rapid rate" trials, four "slow rate" trials and one final "passive rate" trial. They were naive to the "slow rate" and "rapid rate" instructions until Test Session 10. Group SP-no KR (N = 15) followed the same temporal sequence of spaced trials and sessions as Group PS-no KR but received the "slow rate" and "rapid rate" instructions starting on Test Session 1. As in Experiments 1 and 2 the two control rate instructions alternated in their order of presentation from session to session to avoid a possible development of an order effect in the ability to control BR.

TABLE 2.3.

Experiment 3 Design.

	Active Viewing ("Slow rate" and "Rapid rate")		Passive Viewing (PS)
	Knowledge (KR)	No Knowledge (no KR)	No Knowledge (no KR)
Spaced Practice (SP)	Group SP-KR (N = 15)	Group SP-no KR (N = 15)	Group PS-no KR (N = 15)
Massed Practice (MP)	Group MP-KR (N = 7)	Group MP-no KR (N = 8)	

Group SP-no KR received no KR nor any information before or after practice trials other than the rivalry rate instructions. The experimenter was particularly careful in using a neutral tone in imparting the instructions in order to avoid projecting any expectations of performance or reactions to previous performance. Group SP-KR (N = 15) followed the same testing procedure as Group SP-no KR but in addition received KR after each test trial and session. In addition the subjects in Group SP-KR received secondary reinforcement from the experimenter in the form of mild praise for any improvements in performance compared with the previous session, i.e. decreases in slow rate and increases in rapid rate.

The effect of massing of practice was investigated by the inclusion of two additional, although smaller, active viewing groups. Relative massing was accomplished by collapsing all test trials and sessions into one 60 minute period. Test trials were doubled in length to 60 seconds but reduced in number to half as many trials to retain the same total time of practice. This eliminated half of the intertrial intervals. In addition the remaining intervals were reduced in length to 10 seconds. In this way the massed practice subjects received exactly the same total practice time of each rivalry rate instruction as the spaced practice subjects but with a minimum of intertrial and intersession rest time. Minimum rest periods were required for imparting rivalry rate instructions and KR. Group MP-no KR (N = 8) followed this testing schedule and was given the same treatment of no KR as for Group SP-no KR. Group MP-KR followed the massed schedule but, as with Group SP-KR, was given KR after each trial and mild praise for improved performance.

The treatments for the spaced groups of the present experiment differed from Group A of the previous experiment only in the consistent presence or absence of KR. In addition the massed practice groups differed from Group A in the decreased spacing of practice trials.

Results

Slow rate and rapid rate measures in dominance changes per minute were calculated for each test session. From these the percentage measure of BR control of subjects was calculated for each test session. The slow rates for the four control practice groups on all test sessions and for Group PS-no KR on Test Session 10 are graphically illustrated in Figure 2.5. As in the previous experiments one effect of practicing the rate control instructions is a general decrease of the measured slow rate. The effect of passive viewing, on the other hand, again seems to produce an elevation in the first measured slow rate although the difference between Group PS-no KR on Session 10 and the four practice groups on Test Session 1 is not significant ($t = 1.15$, $df = 58$, $p > .10$).

Because the initial slow rates on Test Session 1 were different, the appropriate tests to compare the relative effects

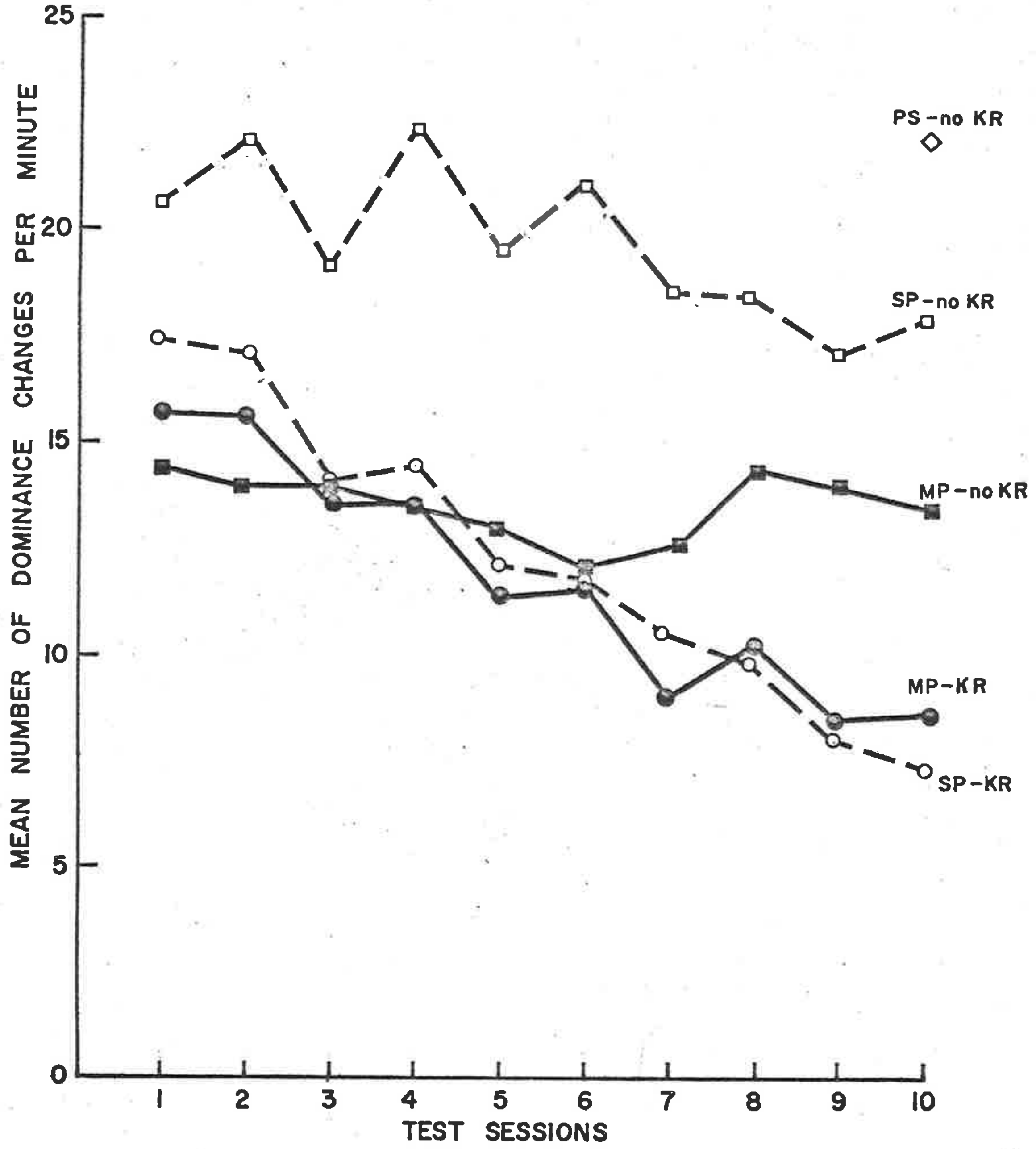


Fig. 2·5. Mean slow rates for the four practice groups and the passive viewing group.

of practice under the four conditions are tests of the differences between Test Session 1 and 10. These differences are shown in Table 2.4.

TABLE 2.4.

Mean Slow rate measures in dominance changes per minute of four practice groups on Test Session 1 and 10, the difference between these sessions and the slow rate of Group PS-no KR on Session 10.

Groups	SP-KR	SP-no KR	MP-KR	MP-no KR	PS-no KR
N	15	15	7	8	15
Test Session 1	17.4	20.6	15.7	14.0	--
Test Session 10	7.5	17.8	8.7	13.4	21.7
Difference	-9.9	-2.8	-7.0	-0.6	--
p (related sample t tests)	< .001	<.05	< .025	n.s.	--

Only the Group MP-no KR decrease fails to reach a significant level. The main effects of spacing of practice trials and knowledge of results on the decreases of slow rate were analyzed in a fixed constants, two-way analysis of variance. Knowledge of results had a very significant effect ($F = 15.2$, $df = 1/41$, $p < .0005$) but spacing did not have a significant effect ($F = 2.08$, $df = 1/41$, $p > .10$) on slow rate decreases.

The effect of practice on increases of rapid rate is

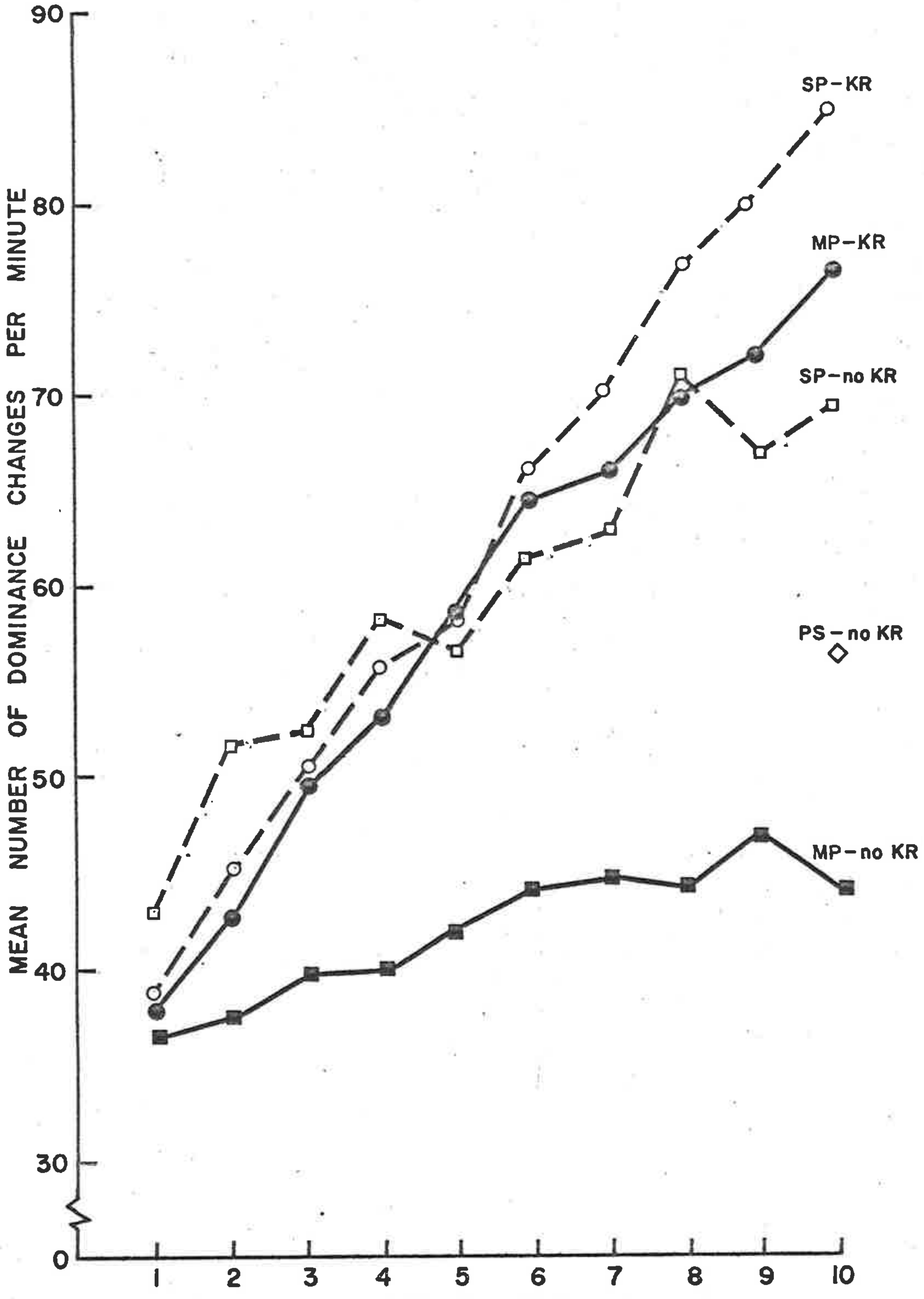


Fig. 2·6. Mean rapid rates for the four practice groups and the passive viewing group.

illustrated in Figure 2.6. The general increases in rapid rate with practice agree with the results of the previous experiments. Passive viewing also has the effect of increasing the first measured rapid rate. But unlike the results of Experiment 2, spaced passive viewing did not increase the first measured rapid rate as much as spaced practice of the control instructions.

The rapid rate increases between Session 1 and 10 are shown in Table 2.5. The Group MP-no KR increase is significant only to a low level. In a two-way analysis of variance of the increase of rapid rate knowledge of results has a significant effect (F = 13.38, df = 1/41, p < .001) and the effect of spacing is significant to a low level (F = 3.28, df = 1/41, p < .10).

TABLE 2.5.

Mean rapid rates in dominance changes per minute of 4 practice groups on Session 1 and 10, the difference between these sessions and of the rapid rate of Group PS-no KR on Session 10.

Groups	SP-KR	SP-no KR	MP-KR	MP-no KR	PS-no KR
N	15	15	7	8	15
Test Session 1	38.9	43.4	37.6	36.8	--
Test Session 10	85.0	69.3	76.4	44.2	56.2
Difference	+46.1	+25.9	+38.8	+7.4	--
p (related sample t tests)	< .0001	<.0005	<.01	< .10	--

It is interesting to note an order effect with some groups similar to that observed in the two previous experiments. On odd numbered test sessions in which slow rate preceded rapid rate Group SP-no KR and to some extent Group SP-KR showed the greatest relative decreases of slow rate. Only Group Sp-no KR shows the order effect of greatest rapid rate increases on even numbered test sessions. If there were any proactive interference effects between sessions, the massed practice groups would be expected to show the greatest order effects. If anything, the spaced practice groups tend to show greater order effects. This would suggest that the order effects arise from proactive interference between the first rivalry rate instruction and second rivalry rate instruction within test sessions.

The mean percentage control values for the 4 practice groups on each test session and for Group PS-no KR on Test Session 10 are shown in Figure 2.7. The groups with knowledge of results and Group SP-no KR show very definite linear increases of BR control with practice. The Group MP-no KR increase is less obvious. The mean increases of BR control between Test Session 1 and 10 are given in Table 2.6. All the group increases of BR control are significant at a high level except Group MP-no KR. The analysis of variance found both the effect of knowledge of results ($F = 29.3$, $df = 1/41$, $p < .0001$) and the effect of spacing ($F = 5.70$, $df = 1/41$, $p < .025$) to be significant.

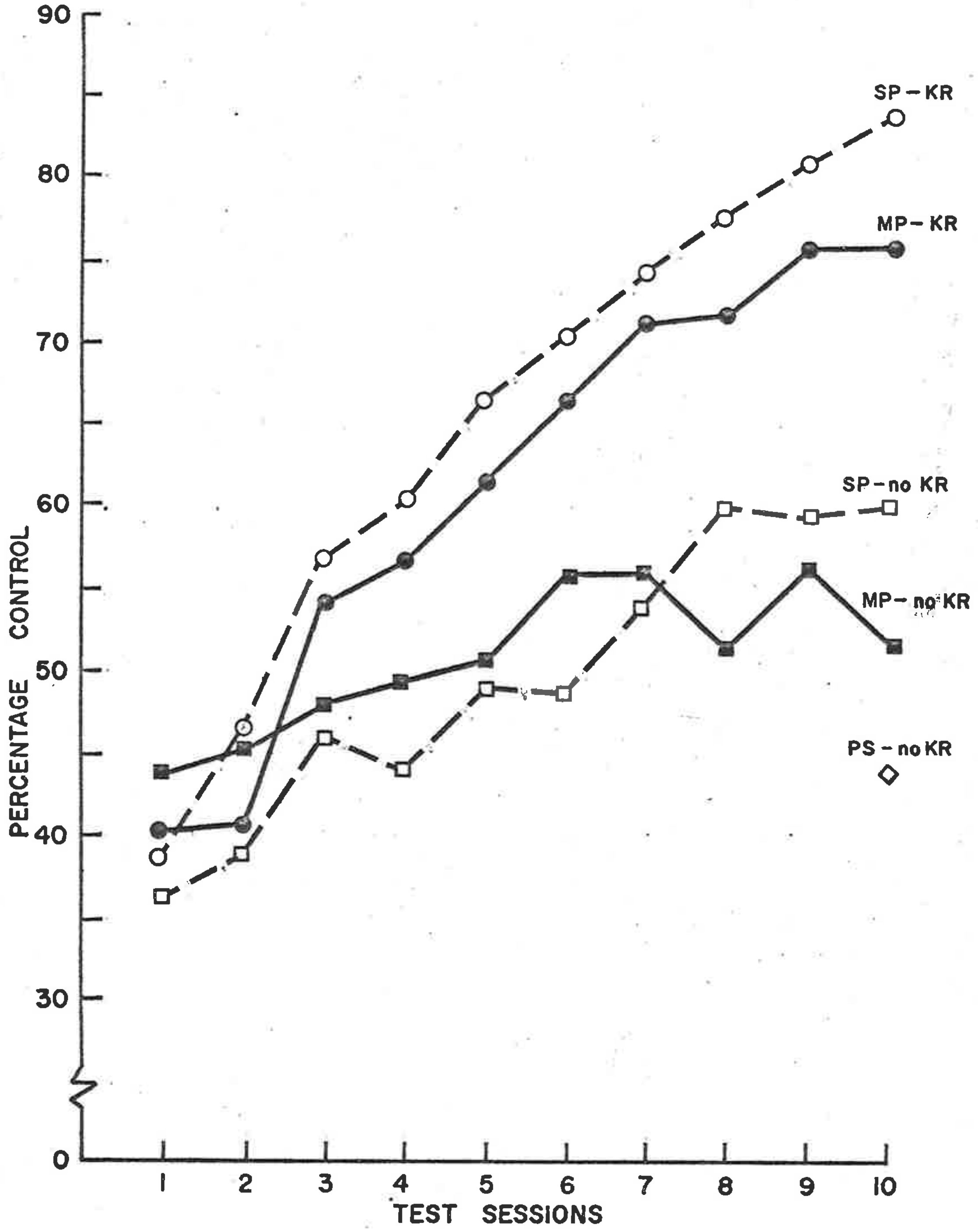


Fig. 2·7. Mean percentage control measures for the four practice groups and passive viewing groups.

TABLE 2.6.

Mean percentage values of BR control of the 4 practice groups on Test Session 1 and 10, the mean difference between these sessions, and control of the passive group on session 10.

Groups	SP-KR	SP-no KR	MP-KR	MP-no KR	PS-no KR
N	15	15	7	8	15
Test session 1	38.9	36.3	39.3	43.6	--
Test session 10	83.3	58.4	75.6	51.3	43.9
Difference	+44.4	+22.1	+36.3	+7.7	--
p (related sample t test)	$< .0001$	$< .0005$	$< .0005$	$< .10$	--

In the analyses of variance for all three measures the KR by spacing interactions were very low and did not approach significance ($F < 1.0$ in all cases). This suggests that the two factors are additive in their effects on the increase of control with practice.

As in Experiment 2, passive viewing increases the first measured slow rate and rapid rate but does not increase the measure of control. The mean control of Group PS-no KR (43.9%) was not significantly greater ($t = 1.01$, $df = 58$, $p > .10$) than the mean test Session 1 control of the four practice groups (38.9%).

Discussion

These results are consistent with those of Experiments 1 and 2 in almost every respect. Under similar experimental conditions Group A of Experiment 2 showed an increase of BR control of 30.7% from 42.4% on Test Day 1 to 73.1% on Test Day 10. Since explicit KR and praise were given only occasionally, Group A could be considered essentially a spaced practice group with some knowledge of results. Thus it is not surprising that Group A showed a performance increase that was intermediate to the performance increases of Group Sp-KR and Group SP-no KR.

It is interesting that Group SP-no KR with no knowledge of results showed a very significant increase in BR control. Of course it is impossible in practice to eliminate all KR from a task (Ammons, 1956). Although unlikely, it was in fact possible for subjects in the no KR groups to have counted the alternations subvocally in order to get exact KR. However, at the conclusion of the experiment no subject admitted actually to have counted alternations. In any case subjects probably could have made relatively accurate estimates of their rivalry rates. On the other hand, the present author would agree with the conclusions of Locke, Cartledge & Koeppel (1968) that the strong facilitative effect of KR depends largely upon the goals set by subjects in response to KR rather than upon the directive aspect of the KR. In Group SP-no KR the significant increase of BR control probably is due to the expectations of improved performance implied by the rivalry rate instructions given on the spaced practice schedule rather than the directive aspect of any implicit KR.

Subjects in Group MP-no KR are much less likely than subjects in Group SP-no KR to have expected increased performance. Indeed, subjects might even expect decreased performance as a result of fatigue during massed practice. Therefore, even with the possibility of implicit KR, Group MP-no KR did not show a significant performance increment. Whereas Group MP-KR with explicit KR, secondary reinforcement and the greater motivation it provides (Annett, 1969), produced a very significant increase of BR control with practice.

Consistent with Experiment 2 the present experiment found that BR control does not increase with passive viewing only. However, the earlier experiment also found as much increase in the rapid rate measure from passive viewing as from practice of the "Rapid rate" instructions. This implied that the increase of BR control was due mainly to the practice of the "Slow rate" instructions. This is consistent with the tendency in the present results for KR to have more effect on slow rate decreases than on rapid rate increases and for spacing to have somewhat more effect on the rapid rate increases than on the slow rate decreases. Since KR is a potent learning variable it would seem that slow rate decreases are due more to learning and rapid rate increases due more to elapsed time. Nevertheless, the fact that KR still had a very significant effect on rapid rate increases suggests that the practice of the "Rapid rate" instructions does play a real part in the learned increase of BR control.

What is clear from these results is that both KR and the distribution of practice are significant independent variables in the increase of BR control. Consistent with the conclusions of Bilodeau & Bilodeau (1961) KR with secondary reinforcement is the more effective variable. These two factors seem to be additive in their effects since there is very little interaction between them. With minimum spacing of practice and with no explicit KR or reinforcement, there is very little increase of BR control. With just the addition of spaced practice Group SP-no KR showed a very significant increase of BR control. This large increase is likely to be partly due to a small but real facilitative effect of distributed practice and partly due to the additional motivation from inferred goals of performance improvements. When motivation is maximized with explicit KR and secondary reinforcement for both KR groups, the increases of BR control with practice are most dramatic.

Discussion and Conclusions

The results of all three experiments support the findings of Meredith & Meredith (1962). The fact that all groups of unpracticed subjects had mean rapid rates in excess of twice their mean slow rates suggests that even naive, unpracticed subjects have on the average a considerable degree of control of rivalry. It is also interesting to note the initial control of subjects in Experiment 1 ranged from 13.2% to 66.0%. This large range of control measures suggests that one possible reason for the past discrepancies between experiments using only one subject is that some subjects possessed a high degree of control while others possessed relatively little control.

All three experiments agree as to the effects of practice of the control instructions on the degree of BR control. It is quite clear that the degree of BR control can be learned. The increase of the measure of control is facilitated with the spacing of practice trials and, especially, with the use of knowledge of results and secondary reinforcement. The massing of practice trials and the elimination of KR reduces the effect of practice to an insignificant level. This corresponds with the experiments of Bruner, Postman & Mosteller (1950) and Pelton & Solley (1968) who found very little change of figure reversal rates over time with either the rapid or slow rate instructions when practice was continuous and no KR was given. Thus the control of the BR rate and the figure reversal rate seem to respond to practice parameters in a similar way.

One may now question whether there is such a large difference in the degree of control between binocular rivalry and the dichotic listening situation. If there is a large difference one may also question the basis of this difference. With the data available it is impossible to compare directly the degree of BR control and selective listening. Results of experiments in which shadowing was used as a device to selectively attend to one ear suggest that shadowing insures a high degree of attention control even with relatively unpracticed subjects. Attention to the shadowed message seems to be continuous without lapses of attention to the rejected message except under special circumstances. However, shadowing may be an exceptional case of selective attention. In any case there is not an equivalent device available in the control of binocular rivalry to allow a more realistic comparison of the two modalities in this respect.

The results of selective listening experiments without shadowing suggest that there is less than complete suppression of the rejected ear message. Moray & O'Brien (1967) presented subjects with 100 pairs of digits per minute dichotically so that the digits of each pair arrived simultaneously at each ear. Occasional letters substituted for digits in these pairs served as target stimuli to which the subjects responded by tapping a telegraph key. Subjects were instructed for two different conditions to attend selectively to one ear throughout a nine minute session or to attend to both ears. Detection performance for the rejected ear was worst (d' = 1.429), performance for the selected ear was best (mean d' = 3.712) and performance on both ears in the shared attention task was intermediate to these values (Left ear d' = 3.001, right ear d' = 2.823). In addition single channel performance of monaural listening with the right ear alone produced performance (d' = 5.021) which was superior to the selected ear condition. Thus, in the selective attention condition the rejected channel intruded to a significant extent and performance on the selected channel was far from that obtained on a true single channel. Even in the dichotic listening task voluntary control appears to be much less than complete.

From Moray & O'Brien's experiment (1967) it is difficult to determine whether attention is fluctuating in an all-or-none way between the ears spending more time on the selected ear or if there is a constant bias to the selected ear. The first case would be more analogous to binocular rivalry. The only data of relevance to this question is the detection performance when two target stimuli arrive simultaneously over the two channels. In these cases the mean probability of detecting one target stimulus is very high (0.812) and the probability of detecting both targets is very low (0.167). This latter probability is lower than the joint probability (0.36) of detecting two targets based on the detection probability

(0.60) from the shared attention task. The simplest explanation for the inability to detect both of the simultaneously presented target stimuli is to assume an all-or-none time sharing mechanism for dichotic listening. However, Moray & O'Brien are reluctant to come to such a conclusion because of the weight of evidence against it from earlier experiments. Although the ability to control selective listening was not measured in the same way as the control of BR, it appears that the difference in the degree of control between the two modalities may not be as great as been previously assumed by Moray (1969) and Treisman (1969).

In addition, if comparable measures of control are applied to both modalities and it is found that unpracticed subjects have less control over BR than in dichotic listening, this would be easily explicable in terms of different amounts of practice. Practice in listening to one ear or to a speaker at one side of the head at the expense of a speaker on the other side is not an uncommon occurrence in every day life; it is effectively the "cocktail party effect" in which most naive subjects must have had some previous experience. If it is the case, as Moray (1969) suggests, that practice in selective listening increases performance, then naive subjects in dichotic listening can be assumed to have increased their control to some extent already from previous practice. On the other hand, apart from an occasional medical or biology student with some practice in selective looking with one eye through a uniocular microscope with both eyes open, most naive subjects in a BR control experiment would be unpracticed. With a sufficient amount of practice it could easily be the case that the control of binocular rivalry approximates the control found in dichotic listening situations.

CHAPTER III

THE DEVELOPMENT OF AN OBJECTIVE MEASURE OF THE CONTROL OF BINOCULAR RIVALRY

Introduction

The experiments of Chapter II established that unpracticed subjects have a considerable degree of control over the alternation rate of binocular rivalry. It was also found that the degree of control can be markedly increased by practicing the control instructions, especially under the conditions in which practice trials are spaced and knowledge of results is given. Thus, a very large degree of BR control is theoretically obtainable. In this sense then, there is no question of the existence of the control of binocular rivalry.

However, the definition of control in terms of the rate measure is perhaps limited in its meaningfulness. Meredith & Meredith (1962) consider the instructional conditions to be the independent variable, thus avoiding the assumption of organismic intervening variables. Instructions are given to subjects to increase or to decrease the rivalry rate. The experimenter then records the number of taps of the indicator key in a specified time period to calculate the rate of rivalry, the dependent variable. This is the typical S-R approach in which the human organism is considered essentially a "black box". Instructions are put in and a rivalry rate comes out. It may be argued from this approach that what has so far been established in Chapter II is that the output from the "black box" conforms to some extent to the input and that it conforms more readily after some practice. If the mechanism and the full effects of BR control are to be understood, then a deeper analysis of binocular rivalry and BR control must be carried out.

There are two questions which must be resolved before such an analysis can proceed: 1. Are the key tapping reports of subjects accurate indications of the phenomenal rivalry? and 2. Is there any objective meaningfulness of BR? Because the answer to the first question is dependent in the end on an objective measure of rivalry which is separate from the subjective reports of subjects, both questions may be resolved together. The problem then is to develop an objective measure which will produce behavioural effects correlated with the subjective reports of rivalry. Thus it may be possible to achieve a better understanding of the behavioural effects of rivalry and at the same time to test the validity of subjects subjective reports.

The general strategy would be to present test signals to an input channel when it was attended and again when it was nonattended. If there was a performance difference in relation to these signals between the attended and nonattended states, this would be an objective, behavioural measure of the attention state. This strategy has been extensively used in studies of selective attention, particularly with dichotic listening experiments. The first application of this strategy to the study of binocular rivalry has occurred only relatively recently (Fox, 1963). In this case test stimuli were presented to an eye either in the rivalry state of nonsuppression (dominance) or the state of suppression. The required responses to these stimuli of reaction responses, detection responses, or recognition responses provided the behavioural performance measure.

In a series of experiments Fox (1963) used moving black-white contours in the left eye to produce periods of rivalry suppression of a fixed stimulus in the right eye. Subjects indicated the suppression and nonsuppression of the right eye stimulus by depressing and releasing an indicator key. Fox found that the reaction time to a target flash superimposed on the right eye stimulus was lengthened when the right eye stimulus was in the suppressed state. The reaction time effect was shown to be a perceptual rather than motor effect since reaction times to acoustic stimuli were unaffected by rivalry suppression and since Fox (1963) also found increases of the detection threshold during rivalry suppression. He found, further, that stimulus offset was much less effective in penetrating rivalry suppression than stimulus onset. In addition the effect of suppression was found to be non-selective in that it was not specific to the right eye stimulus but affected many different test stimuli equally. Fox (1963) concluded that phenomenal rivalry suppression was correlated with an elevation in the energic threshold for test stimuli falling in the area of the right eye suppression stimulus. As a result, he favoured an inhibition model of rivalry suppression.

In further studies Fox replicated and elaborated his earlier findings. Fox & Check (1966) tested forced-choice form recognition for both eyes in both states of rivalry. Rivalry was produced by stimuli similar to the coloured patches with diagonal lines used by Breese (1899). Three letter-form stimuli (A, T, and U) were presented tachistoscopically to either eye in either the suppressed state or nonsuppressed state of rivalry. Subjects indicated states of rivalry by pressing and releasing an indicator key. The luminance of target stimuli was adjusted to give mean recognition performance in the range of 50-70% correct responses or about midway between chance level (33%) and perfect performance (100%). Fox & Check (1966) found that recognition performance was significantly less to target stimuli presented to an eye in the suppressed state as compared to the nonsuppressed state and that nonsuppressed performance did not differ from that of a nonrivalry condition.

Fox & Check (1968) have also found that reaction times to moving stimuli are increased when the movement is initiated in the suppressed phase as compared to movement initiated in the nonsuppressed phase of rivalry. It was found that as test stimulus movement decreased the reaction time difference between suppression and nonsuppression increased. In some cases small velocities of the movement stimulus would not even be detected until the tested eye emerged from suppression in the normal course of alternation. More recently Wales & Fox (1970) have found a larger threshold for increments of light intensity during rivalry suppression than that found in non-suppression and nonrivalry. This threshold elevation was measured to be in the order of .5 log units. They concluded that visual sensitivity during nonsuppression is the same as that during nonrivalry but that rivalry suppression is a non-selective inhibitory state producing a constant .5 log unit increase of threshold.

The conclusion that the inhibitory effect acts non-selectively on all inputs in the immediate area of the suppression target is consistent with the reports of other experimenters. Kaufman (1963) found that the suppression effect from rivalry decreased as a function of the angular distance from the region of the rivalry contours. Hochberg (1964) even found rivalry suppression when contralateral stimuli did not intersect. A contour in one eye apparently "carries with it" a part of the background of the binocular condition. Hochberg (1964, p.157) proposed that "any contour that falls in one eye is surrounded by a zone of some finite size, in the combined field of view, within which all contributions of the other eye are suppressed." Enoksson (1968) also agrees that suppression is not restricted to the specific contours of the pattern in the suppressed field of vision.

Thus, substantial progress has been made in the understanding of the effects of binocular rivalry. Several behavioural indicators have been correlated with the phenomenal states of rivalry. Rivalry is now reasonably well understood as an alternating suppression effect of non-selective reduced visual sensitivity. However the primary concern of this chapter is to develop an objective measure of the control of binocular rivalry. In all the previously cited studies subjects were instructed to observe the rivalry in a passive manner. Thus the effects of BR control on these behavioural indicators remain unknown. Therefore, it would be useful to apply these objective measures to the study of control.

In Chapter II the measure of control was based on the difference in the rate of rivalry alternations produced by the "Rapid rate" and "Slow rate" instructions. Experimenters in the past have also measured the degree of control on the basis of the difference in relative dominance that can be produced for the pattern in one eye (Breese, 1899; McDougall, 1903; and Washburn & Gillette, 1933). Control of dominance and rate of rivalry have been the only ways in which control has been measured. However it would seem possible that there would be other effects of control besides the effect on these two measures.

Some subjects in Experiments 2 and 3 reported that with increasing control of the rivalry rate they seemed to be able to make the rivalry more clearly a unitary, dichotomous fluctuation. Initially most of the rivalry suppression of the unwanted line occurred at the intersection with the attended line. With practice, however, suppression occurred not only at the hypothetical intersection point but extended over the whole of the unwanted line. This suggests that either 1. the subjects were increasing the magnitude of the inhibitory effect of suppression for the whole rivalry pattern, or 2. the subjects were gaining control over a greater extent of the visual field. This second possibility may be considered a result of a greater spread of the previously described suppression effect.

The first possibility of a greater degree of inhibition would be suggested by the work in the auditory modality. Moray & O'Brien (1967) found that selection increased detection performance and rejection decreased it compared with shared attention. Naive subjects were not successful at completely rejecting an unwanted channel nor were they successful at selecting a channel to produce detection performance equal with that in a monaural task. However, Moray (1969) also suggested that, with practice, subjects could improve their ability to select one channel and reject another. Since Moray & O'Brien (1967) concluded that rejection was a result of a constant attentuation, Moray's suggestion (1969) implies that practice would increase the attenuation or decrease the detection performance of the rejected channel and increase the detection performance of the selected channel. If this reasoning were applied to the suppression effect of binocular rivalry, it would suggest that a voluntary effort to make the alternations of rivalry more unitary and dichotomous should result in a greater suppression effect and consequently a greater difference in detection or recognition performance between the selected and suppressed eyes. Then as BR control is increased with practice the difference between the selected and suppressed eye should be increased further.

On the other hand, in a personal communication Fox (1968) expressed doubts that BR control could affect the degree of inhibition in the suppressed state of rivalry. He cited evidence to suggest "that the magnitude of suppression as indexed by the test stimulus method is a relatively constant quantity (Fox, 1968)." He referred to an unpublished dissertation by Check (1969) who found that the inhibitory effects of suppression are uniform throughout a suppression phase. In addition Fox (1968) referred to preliminary studies in which he found that regardless of the energy level of the suppressed target a constant increase of stimulus energy of about .3 log units was required to overcome suppression. However, this evidence is only indirectly suggestive of an unalterable magnitude of the suppression effect. It may still be the case that the voluntary control to accentuate the phases of rivalry could increase the differences between the rivalry phases of tachistoscopic recognition performance. Fox (1968) agrees that "it would be interesting to measure the suppression effect in subjects who have obtained various levels of control over the rivalry process to see if there is a change in the magnitude of the suppression effect."

Thus, the first testable hypothesis would be that the magnitude of the suppression effect can be increased by voluntary control of rivalry in comparison with that found during passive viewing.

Experiment 4

The performance task of forced-choice recognition used by Fox & Check (1966) would provide a useful model to employ in the present series of experiments. In passive rivalry one subject showed a mean difference in percentage correct responses between nonsuppression and suppression states of about 25% while another subject produced a mean difference of about 13% (Fox & Check, 1966). If control can be exerted to enhance the difference between rivalry phases, one would expect the performance differences produced by these two subjects, for example, to be increased. An increase of control as a result of practice should be accompanied by an even greater recognition difference between rivalry phases. Thus the purpose of this experiment is to compare the recognition differences of nonsuppression and suppression phases in passively observed rivalry with that during controlled rivalry.

Method

Subjects

6 males and 6 females from the 15 subjects of Group SP-KR in Experiment 3 volunteered to serve as subjects in this experiment. From Experiment 3 these subjects had a total of 60 minutes of spaced practice of the control instructions "slow rate" and "rapid rate" with knowledge of results. For all subjects Experiment 3 was completed five weeks prior to this experiment. All subjects had uncorrected normal vision and were naive to the purposes of the experiment.

Stimuli

The binocular fusion stimuli consisted of left and right fusion squares surrounded by identical but rather complicated geometrical patterns (see Figure 3.1). The purpose of the fusion patterns was to provide a large number of fusion contours and angles to insure a maximum stability of fusion. When properly mounted in the pre-viewing field of the tachistoscope all black lines of the fusion and rivalry stimuli subtended 10 min of the visual field. The left and right fusion squares subtended 1 degree 20 min, and the geometrical shapes of the fusion patterns subtended a horizontal angle of 4 degrees and a vertical angle of 6 degrees of the visual field.

The rivalry stimuli consisted of diagonal lines filling the fusion squares. The right rivalry stimulus consisted of five parallel lines at 45 degrees from vertical; the left rivalry stimulus was the same but rotated 90 degrees.

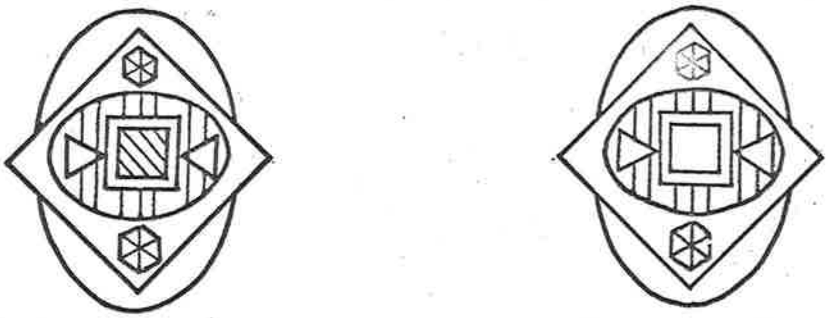
The target stimuli consisted of the letter forms A,S,T, and U, typed in capital letters on white stimulus cards. The cards were inserted into the second field of the tachistoscope so that the letter-forms were visually centred in either the left or right fusion squares and subtended about 25 min of the visual field, about one third the size of the fusion squares.

Apparatus

The basic apparatus consisted of a modified Cambridge two-field tachistoscope combined with a modified Stereoking model HN-44 stereoscope. The stereoscope was mounted to the viewing hole of the tachistoscope and modified to provide

"Suppressed" "Non suppressed"

NON RIVALRY



"Non suppressed" "Suppressed"

NON RIVALRY

Left Eye Right Eye

RIVALRY

Fig. 3·1. Left and right eye fusion patterns and rivalry patterns for Non-rivalry and Rivalry conditions.

clear viewing of the binocular fusion and rivalry stimuli in the tachistoscope at a distance of 35 cm instead of the normal stereoscopic viewing distance of 6 cm from the primary lenses. For this purpose the regular refracting lenses were replaced with +1.25 d lenses and 1.0 d wedge prisms. For all subjects this allowed a very slight degree of convergence with a small degree of accommodation to obtain binocular fusion and focused retinal images. In addition, 2.8 mm artificial pupils were mounted in front of the lenses, adjustable to the interocular distance of any subject. A chin rest was adjusted to provide a fairly stable head position for each subject.

Subjects alternately tapped two telegraph keys to indicate actual rivalry alternations or to simulate hypothetical rivalry alternations. A tap of one key, indicating a shift of dominance, stopped the cumulative timer and accumulated one count on a digital counter. This enabled a measure of rivalry rate and ocular dominance to be taken during a timed period and enabled the experimenter to know which rivalry stimulus was predominant for the subject at any moment. Presentation of the target stimulus during a predetermined dominance phase of rivalry was manually triggered by the experimenter following a warning signal of a .2 second duration 50 Hz buzzer.

The tachistoscope was modified to produce simultaneous rather than successive exposure of the previewing rivalry field and the target stimulus field. This allowed the presence of the fusion and rivalry stimuli to be continuous and the target stimuli to be superimposed on either rivalry stimulus or fusion square for a brief duration. The target stimulus exposure duration was adjustable in steps of 10 msec.

The intensities of both fields were fixed before commencing the experiment so that the fusion and rivalry stimuli were comfortably viewed during the illumination of the first field alone. Then the addition of the illuminated target stimulus field to the first field resulted in clear contrast for the target stimulus and a suitable contrast for the fusion and rivalry stimuli. Before target stimulus exposure the luminance of the black lines of the fusion patterns and rivalry stimuli as measured at the artificial pupils with an S.E.I. spot photometer was 0.016 ft-L. The white background was a uniform 0.4 ft-L. During the additional target stimulus exposure the luminance of the black lines and black target stimuli was 0.1 ft-L and the white background was a uniform 0.5 ft-L.

Procedure

The experiment was divided into four test sessions held on four successive days for all subjects. In the first session all subjects were tested for ocular dominance using the Miles A-B-C test (Miles, 1929) and two binocular rivalry tests. Three trials of the Miles sighting test were given to subjects. For the BR ocular dominance tests subjects observed the rivalry stimuli in the tachistoscope and alternately tapped telegraph keys to indicate alternations of BR. In the first BR ocular dominance test subjects passively viewed the rivalry stimuli for a period of 60 seconds. The total time accumulated out of 60 seconds for the predominance of the left eye stimulus was taken as the measure of ocular dominance. Greater than 30 seconds and less than 30 seconds were classified as left eye and right eye dominant respectively. The second BR ocular dominance test was for active viewing of BR, using the instructional conditions of "slow rate" and "rapid rate". Two "slow rate" periods were followed by four "rapid rate" periods which were followed by another two "slow rate" periods. All periods were 30 seconds in duration and were separated by 30 second rests. The total time accumulated out of 240 seconds for the predominance of the left eye rivalry stimulus was taken as the measure of ocular dominance, with greater than 120 seconds and less than 120 seconds classified as left eye and right eye dominant respectively. From the eight active viewing trials the mean alternation rate under the "slow rate" and "rapid rate" instructions were calculated separately for each subject. From these two rate measures a measure of BR control was calculated for each subject using the formula (100)(Rapid - Slow)/(Rapid + Slow).

In addition, on the first test session a suitable test stimulus exposure duration was established for each subject. For this purpose target stimuli were presented only to the dominant eye in the "nonsuppressed" state of the nonrivalry condition. Letter-forms were randomly presented following the warning buzzer in the normal way. Five trials were presented at each exposure duration starting at 100 msec decreasing in duration by 10 msec steps until the subject was incorrect on two out of five exposures. At this exposure duration an additional fifteen exposures were presented to obtain a performance measure out of twenty trials. If performance was below 40% or above 80% corrective adjustments were made until performance over 20 trials was within these limits. With this procedure exposure durations for the 12 subjects ranged from 30 msec to 80 msec with most of the durations at 40 msec and 50 msec.

After the preliminary test session subjects were tested for letter-form recognition performance on three successive test sessions for three different conditions. The three conditions were those of nonrivalry, passive viewing BR, and active viewing BR. The nonrivalry condition as described earlier used both fusion squares and fusion patterns but eliminated one of the rivalry stimuli. During this condition subjects were instructed to simulate the rivalry conditions by tapping the telegraph keys alternately at about the same rate as their passive viewing condition. The motor action of key tapping may be attention diverting or in some way detrimental to recognition performance. The purpose of rivalry simulation in the nonrivalry condition was to equate between the three conditions the possible detrimental effects of key tapping itself. Since in the nonrivalry condition the one "rivalry" stimulus is usually seen continuously, the state in which the target stimulus is presented to the same eye as the rivalry stimulus was called the "nonsuppressed" state and that in which the target stimulus was presented in the blank fusion square was called the "suppressed" state. During the first half of this condition the rivalry stimulus was on the BR ocular dominant eye and in the second half it was on the non-dominant eye. In each half exposures were divided randomly but equally between "nonsuppressed" and "suppressed" states as indicated by subjects' BR simulated key tapping.

During the passive viewing BR condition subjects viewed the rivalry in a passive state tapping the telegraph keys to indicate BR alternations. Since a key tap indicated the beginning of a nonsuppression phase for a particular eye, it also indicated the beginning of a suppression phase for the opposite eye. An equal number of exposures were presented to each eye an equal number of times in both the suppressed and nonsuppressed states.

The active viewing BR condition was the same as the passive condition in all respects except that subjects were instructed to attend to the dominant pattern and to suppress the nondominant pattern as completely as possible. They were instructed that when it became too difficult to hold the rivalry in this state they were to make the alternation of dominance between rivalry stimuli as dichotomous as possible.

Eighty target stimulus exposures were given for each of the three conditions. Each letter-form target stimulus (A,S,T,U) was presented twenty times on a random schedule and thus had an equal probability of occurrence for any trial. Each letter was presented five times to the left and right eye in both the suppressed and nonsuppressed states. Over the eighty trials the order of eye stimulation and the order of suppression state occurred on a semirandom schedule. The same presentation schedule was used for each of the three conditions. No knowledge of results was given to subjects. The test session order of the three conditions of nonrivalry, passive BR, and active BR was balanced within both the six male subjects and six female subjects.

The eighty trials of each condition were run in four blocks of twenty trials each requiring about six minutes with two minute rests between each block. Following two to five alternations of rivalry or simulated rivalry the experimenter presented the warning buzzer immediately (about .3 seconds) after the first appropriate key-tap as determined by the presentation schedule. The experimenter then triggered the exposure of the target stimulus approximately .5 seconds following the onset of the warning stimulus. The subject was instructed to respond with one of the letter-forms immediately after the target stimulus presentation. At this moment the first priority of the subject was to report the presented letter-form. Following the response subjects were allowed a 5-10 second rest from the key-tapping task as the experimenter removed the stimulus card and inserted the next predetermined card. The subject then resumed the instructional conditions and key-tapping.

Under all three conditions subjects were instructed to fixate the centre of the rivalry stimuli continuously prior to the target stimulus presentation. Subjects were instructed to be as accurate as possible in the key-tapping task, tapping the appropriate key just as the dominance changed from one stimulus to the other. In addition subjects were instructed to inform the experimenter immediately if on any trial the target stimulus had been presented incorrectly, i.e. at a moment when the key-tapping failed to correspond to its appropriate rivalry phase.

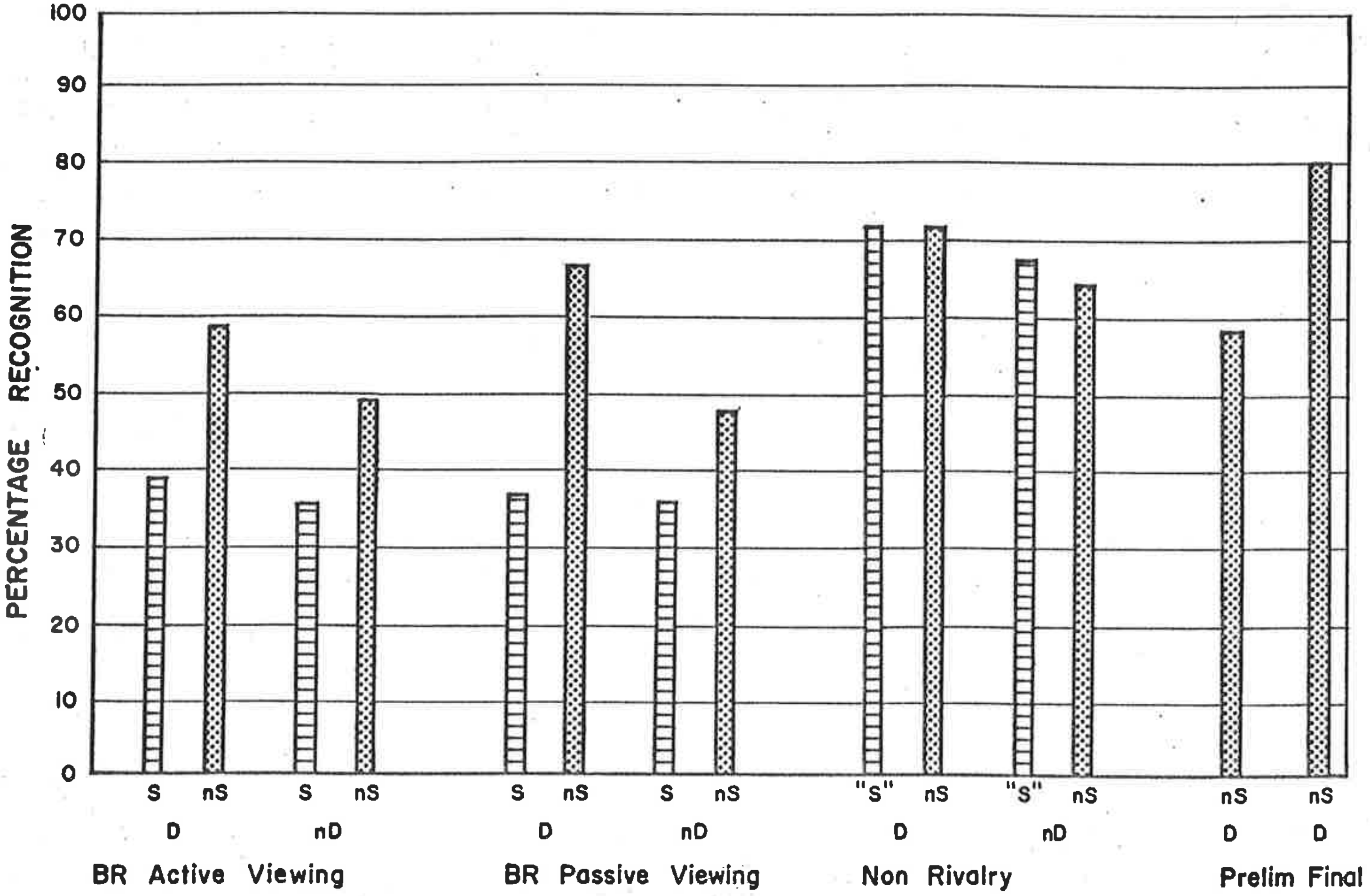
Results

Even though accuracy on the key-tapping task was stressed, a few subjects occasionally reported the incorrect presentations of target stimuli. In these cases subjects merely informed the experimenter of the error without reporting any letter-form. These few trials were usually re-run several trials later in the presentation schedule. Subjects reported that on the whole they were confident of their ability to follow all instructions. Subjects also reported, not surprisingly, that the nonrivalry condition was subjectively easiest, that the passive BR viewing condition was intermediate in difficulty and that the active BR viewing condition was the most difficult.

In a dichotomous classification of ocular dominance into left and right the two BR tests agreed in all 12 subjects. When the more precise ocular dominance information was included, the Pearson correlation between the two BR tests was very high ($r = +.746$, df = 10, $p < .005$). The Miles sighting test and BR tests agreed in ocular dominance for 9 subjects but disagreed for 3 subjects. The overall correspondence was not significant using the chi-square test ($x = 3.09$, df = 1, $p > .05$). Therefore, for most of the following data analysis ocular dominance will be that derived from the BR dominance tests.

In Figure 3.2 are shown the mean percentage recognition scores for the three viewing conditions each separated into dominant and nondominant eye and each eye separated into the suppressed and nonsuppressed states. In addition the mean percentage recognition scores for the preliminary and final tests are shown. Each mean in the bar graph represents scores out of 20 trials from 12 subjects.

Fig.3.2 Mean percentage recognition scores for 12 Ss in the three viewing conditions for both the dominant (D) and non-dominant (nD) eye under both the suppressed (S) and non-suppressed (nS) states and in addition the mean preliminary and final test recognition scores.


PERCENTAGE RECOGNITION
100
90
80
70
60
50
40
30
20
10
0
S
nS
D
S
nS
nD
BR Active Viewing
S
nS
D
S
nS
nD
BR Passive Viewing
"S"
nS
D
"S"
nS
nD
Non Rivalry
nS
D
nS
D
Prelim Final

The main hypothesis of this experiment was that the nonsuppressed-suppressed (NS-S) difference would be greater for the active than the passive condition. Hence, only the active and passive conditions were included in a 4-way analysis of variance of recognition scores which tested the main effects of rivalry phases (nonsuppressed and suppressed), eye dominance (dominant and nondominant) and viewing conditions (passive and active). The results of this analysis are shown in Table 3.1. Since the 12 subjects served under all conditions the appropriate error term to test the main effects is the main effect by subjects interaction. Similarly the interaction with subjects mean squares is the appropriate error term to test the 2-way and 3-way interactions.

It can be seen that the only significant main effect is rivalry phase. Rivalry suppression produces a significant reduction of recognition performance. This seems to be equally true in the active and passive condition since the rivalry phase by condition interaction does not approach significance ($F = 0.78$). Thus, with regards to the main hypothesis there seems to be no difference between the active and passive viewing conditions in the (NS-S) difference.

The difference between nonsuppression and suppression appears in Figure 3.2 to be greater for the dominant than the nondominant eye. In fact, the rivalry phase by eye dominance interaction shows that this difference is significant ($F = 6.55$, $df = 1/11$, $p < .05$). The greater (NS-S) difference for the

TABLE 3.1

EXPERIMENT 4 RESULTS OF A 4-WAY ANALYSIS OF VARIANCE OF RECOGNITION SCORES INCLUDING THE MAIN EFFECTS OF RIVALRY PHASE (P), EYE DOMINANCE (D), VIEWING CONDITION (C), AND SUBJECTS (S).

Source	df	Mean Squares	*F*	*P*
Rivalry phase (P)	1	380.01	19.83	< .005
Eye Dominance (D)	1	55.51	1.31	N.S.
Viewing Condition (C)	1	3.01	0.40	N.S.
Subjects (S)	11	42.58		
P x D	1	29.26	6.55	<.05
P x C	1	6.51	0.78	N.S.
P x S	11	19.17		
D x C	1	1.26	0.49	N.S.
D x S	11	42.35		
C x S	11	7.59		
P x D x C	1	5.51	1.08	N.S.
P x D x S	11	4.47		
P x C x S	11	8.35		
D x C x S	11	2.60		
P x D x C x S	11	5.12		

dominant eye seems to be true for both viewing conditions since that interaction term does not approach significance ($F = 1.08$). On the other hand, if eye dominance is initially designated using the Miles sighting test, there is no difference between the 'dominant' and 'nondominant' eye ($t = 0.57$, $df = 11$, $p > .20$) in the magnitude of the (NS-S) difference. Thus, the dominant eye produces a greater (NS-S) difference than the nondominant eye if dominance is determined by the BR tests but not if it is determined by the Miles sighting test.

The lesser difference between suppressed and nonsuppressed recognition performance for the nondominant eye appears to arise from a reduced recognition performance in the nonsuppressed state rather than from an increased performance in the suppressed state. The four suppressed performance means of the two BR conditions all are at about the same level and all above chance performance.

On the other hand, the four nonsuppressed means of the two BR conditions do appear to vary considerably. The nonsuppressed means for the dominant eye are generally greater than those for the nondominant eye. The passive condition mean for the dominant eye is not significantly less than that of the dominant eye nonrivalry condition ($t = 0.99$, $df = 11$, $p > .20$). On the other hand, the nondominant mean of the passive condition is significantly less than the nonrivalry mean ($t = 3.14$, $df = 11$, $p < .01$). The reduced (NS-S) values for the nondominant eye seem, then, to be due to a reduction of nonsuppressed performance of the nondominant eye rather than any difference in suppressed recognition performance.

There are no differences between any of the four non-rivalry conditions. Even the greatest difference between the "suppressed" dominant eye mean and "nonsuppressed" non-dominant eye mean does not reach a significant level ($t = 1.17$, $df = 11$, $p > .20$). The combined nonrivalry mean of 69.4% is hardly different from the combined preliminary and final test means of 69.8%. Thus there appears to be no suppression effect in the "suppressed" eye of the nonrivalry conditions.

A comparison of preliminary and final tests shows a very significant increase of recognition performance across the conditions of the experiment ($t = 9.9$, $df = 11$, $p < .005$). All subjects showed an increase of performance from preliminary to final test producing a mean increase of 22.1%. However, since the order of the three test conditions was balanced within the 12 subjects, this practice effect should be evenly distributed between the three test conditions.

It was shown that the (NS-S) difference in the active condition was not greater than the difference in the passive condition. This implies that an active voluntary effort to enhance the completeness of the BR alternations has no effect of increasing the (NS-S) value as compared with the difference that occurs with no voluntary assistance in the passive viewing condition. However, the measures of BR control ranged from 33.3% to 71.4% with a mean of 50.4% for the 12 subjects. This was above the mean BR control of unpracticed subjects in Experiment 3. Thus, the lack of difference between the active and passive conditions could not be explained on a general lack of BR control of the present subjects.

Based on the original hypotheses, it would follow that those subjects with the greatest measure of BR control should be able to show the greatest nonsuppressed-suppressed difference. Therefore, one would predict a correlation between this difference in the active condition and the measure of BR control. However, a Spearman rank correlation test applied to the BR control measure and the (NS-S) measure in the active condition (both eyes combined) was not significant ($r = +.279$, $n = 12$, $p > .20$).

A significant correlation which will be of relevance to the discussion of the main hypothesis is that between the conditions combined (NS-S) values of the dominant and non-dominant eyes ($r_s = +.680$, $n = 12$, $p < .025$). This is mainly enhanced by a significant correlation between the difference measures of the dominant and nondominant eyes in the passive condition ($r_s = +.66$, $n = 12$, $p < .025$), and less so by the dominant and nondominant eye correlation in the active condition ($r_s = +.37$, $n = 12$, $p > .05$). This suggests that if a subject shows a large nonsuppressed-suppressed difference in one eye, he tends also to show a large difference in the other eye; and this is especially true in the passive condition.

Discussion

The lack of a significant difference between nonsuppression and nonrivalry in the passive viewing condition is consistent with the results of Fox & Check (1966), at least with respect to the BR dominant eye. On the other hand, in the BR active viewing condition there is perhaps some decrement of performance for the dominant eye in the nonsuppressed state. The mean for this sub-category is 58.8% and is less than the nonrivalry mean of 73% to a low significance level ($t = 2.00$, $df = 11$, $p < .10$). Subjects remarked that the active viewing condition was most difficult. This is not surprising since in addition to maintaining accurate key-tapping and being prepared for the presentation of target stimuli, subjects were instructed to exert an active effort to make the alternations complete. Overall recognition performance may be impaired under these conditions by the considerable demands made upon subjects' attention.

Ocular dominance, for the purposes of this data analysis, was attributed to the eye whose rivalry pattern was seen as predominant in passively and actively viewed rivalry a majority of the time. Since there are an equal number of predominance phases for each eye in the alternating rivalry process, this majority of the total time on the dominant eye must be produced by longer nonsuppression phase durations.

No qualitative differences between the dominant and nondominant eyes for a given rivalry phase has been assumed. It was merely assumed that for the dominant eye the nonsuppressed state would be longer and the suppressed state shorter in duration. However, the nonsuppressed means of the nondominant eye tend to be less than those for the dominant eye ($t = 1.93$, $df = 11$, $p < .10$) and are significantly less than the nondominant eye nonrivalry condition mean ($t = 2.79$, $df = 11$, $p < .02$). This would seem to indicate that, in addition to greater nonsuppression durations, the dominant eye produced better recognition performance than the nondominant eye in the nonsuppression phases. If it is assumed that nonrivalry is free from suppression effects, then the nonsuppressed rivalry state of the dominant eye is also free of rivalry suppression. However, the nonsuppressed state of the nondominant eye does contain some degree of rivalry suppression.

Under the conditions of the present experiment the BR test but not the Miles test of ocular dominance has predictive validity for (NS-S) differences in recognition performance between the dominant and nondominant eyes. This is not surprising considering the close relationship of the recognition task with the BR dominance test. It is interesting to note that Fox & Check (1966) used the Miles test but did not mention any effect of eye dominance on recognition performance. Both subjects in the Fox & Check study (1966) were classed as right eye dominant. An examination of the nonsuppressed-nonrivalry differences for both subjects shows that for subject CM the larger difference appears to be on the left eye. Therefore, one would predict that CM's left eye is nondominant with the Miles test and the BR test. On the other hand, subject DC shows a larger nonsuppressed-nonrivalry difference for the right eye which according to Fox & Check (1966) is significant to a low level ($p < .10$). Therefore, one would predict that although subject DC is right eye dominant by the Miles test, he would be left eye dominant by the BR tests. This would be possible since in the present experiment three out of the twelve subjects lacked correspondence between the Miles and BR dominance tests. Two of the three subjects were Miles right eye dominant but left eye dominant according to the BR tests.

At the end of the results section a significant correlation was found in the nonsuppressed-suppressed differences between the dominant eye and nondominant eye. Subjects with a large difference in one eye also tend to show a large difference in the other eye. Similarly subjects with a small or negligible (NS-S) difference in one eye tend to show little difference in the other eye. This result would be predicted if one assumes that BR is a dichotomous alternation between the eyes. If recognition performance drops markedly in one eye when that eye enters the suppressed state, then simultaneously recognition performance rises markedly in the nonsuppressed state of the other eye.

The main hypothesis in this experiment was that an active voluntary effort of subjects to accentuate the rivalry alternations would enhance the (NS-S) difference in recognition performance as compared to the performance difference during passive viewing of BR. This was based upon the assumption that control could be exerted on the amplitude of the suppression effect. However, if anything, the (NS-S) difference in the active condition tended to be less than that in the passive condition.

Based on the original assumptions it would also have been predicted that subjects with a large degree of BR control would have shown greater (NS-S) differences than would subjects with a small degree of control. Thus, the lack of significant correlation between the BR control measure and the (NS-S) measure in the active condition also fails to support the original hypothesis.

Fox's (1968) suggestion that the depth of suppression is a relative constant now seems to be the most likely explanation of the present results. In well-practiced subjects there is no difference in the depth of suppression between passive viewing BR and an active viewing condition in which subjects attempt to enhance the suppression effect. There is also no significant correlation between the measure of a subject's BR control and the extent of the suppression effect in the active viewing condition. Both of these results are compatible with the results of Fox & Check (1966, 1968) and with the concept of a limited and constant suppression effect in the suppressed state of BR. Presumably when a rivalry stimulus is in the suppressed state, the degree of inhibition is the same regardless of the activity or passivity of viewing or of the extent of a subject's measure of BR control. When a rivalry stimulus is in the nonsuppressed state, except perhaps for the BR nondominant eye, there is no suppression effect and visual sensitivity is the same as that for normal nonrivalry monocular viewing.

It seems clear that BR control as measured on the basis of BR frequencies (slow rate and rapid rate) does not affect the magnitude of the BR suppression effect. It now seems more likely that if BR control has any objective meaningfulness, it is in terms of the BR control measure itself or of the durations of the suppression effect rather than magnitude. In the slow rate subjects are essentially lengthening the durations of the suppressed state in each eye in turn while in the rapid rate subjects are shortening the durations. When subjects increase their measures of BR control they are increasing their ability to shorten and lengthen the durations of suppression on each eye.

This hypothesis of the effect of voluntary control of rivalry would be consistent with the general model of attention proposed by Verhoeff (1935). Considering BR as a paradigm of attention he suggested that attention may be voluntary, involuntary or both. Verhoeff stated that it "may actually be that the action of attention is always involuntary but the place or places in which it acts can be to some extent determined by the will (p.154)." This suggests that the action or effect of attention is a constant involuntary suppression but that this effect can be directed by voluntary control. With respect to binocular rivalry this suggestion would be consistent with the findings of Fox & Check (1968), Check (1969), Wales & Fox (1970) as well as the findings of the present experiment. With respect to BR control Verhoeff (1935) would agree with the previous suggestion that the effect of control is to direct the suppression to either eye or in effect to shorten or lengthen the duration of the suppression phase in either eye.

On the other hand, Moray (1969) in his construction of a terminology for the study of attention, suggested that the direction of the suppression effect in binocular rivalry is not under the control of the observer. He used BR as a case in which "S cannot control which eye he is using to see at any given moment, but where identification of items appearing in the momentarily dominant eye will be better than those in the momentarily nondominant eye (p.26)." He classifies this as an example in which the subject can be "tuned" to a certain signal or channel in which attention is involuntary in contrast to selective attention in which the direction of attention can be voluntarily determined (Moray, 1969).

The results of the experiments of Chapter II showed that the rate or durations of at least the phenomenal effect of binocular rivalry were markedly affected by voluntary control. Since past studies and Experiment 4 have found a correlation of behavioural effects with passively observed phenomenal rivalry, it would seem reasonable to expect to continue to find this correlation, even when the phenomenal aspect of rivalry is being controlled. Thus, the next logical step would be to measure the recognition performance during the suppression and nonsuppression phases of rivalry when these phases are being directed by voluntary control.

Experiments 5 and 6

The purpose of the present experiments is to measure objectively the control of binocular rivalry. If control affects the duration of the suppression or nonsuppression phases, this may be measured directly when subjects are presented with test stimuli for recognition.

Consider the situation of subjects passively viewing rivalry. At some point in time regardless of the phase of rivalry an auditory stimulus is presented by which the subject is instructed to make one of the rivalry patterns dominant.

Shortly after this instruction stimulus a test stimulus is presented to the eye containing the "instructed" (I) pattern or to the eye containing the "noninstructed" (NI) pattern. If subjects have no ability to control the durations of rivalry phases, then rivalry will continue according to some involuntary mechanism and will be in either phase with an equal probability at any time following the instruction stimulus. Therefore, with no control over rivalry phases, recognition performance for test stimuli will be equal for the (I) and (NI) conditions. On the other hand, if after receiving the instruction stimulus, subjects are able to lengthen the nonsuppressed phases and/or to shorten the suppressed phases, then the "instructed" eye will be more likely to be in the nonsuppressed than the suppressed phase of rivalry. As a result, recognition performance for the (I) condition ("instructed" eye trials for both eyes combined) will be greater than that in the (NI) condition.

The difference of (I) and (NI) recognition performance or (I-NI) should be a measure of the extent to which voluntary control can be applied to the phases of rivalry. With no ability to control rivalry the (I-NI) value should be zero. Increasing ability to control rivalry should increase the percentage of total time above 50% that the instructed eye is in the nonsuppressed phase of rivalry. This will produce an increasing positive value for the (I-NI) measure. The maximum degree of rivalry control (100%) would occur when the suppressed phase is shortened to zero and the nonsuppressed phase is extended indefinitely for the instructed eye. Then the (I-NI) measure will reach a maximum value dependent on the difference in recognition performance obtained between the ideal nonsuppressed and suppressed states of rivalry. This would be in the order of the difference obtained in Experiment 4 in the passive viewing condition, assuming subjects were accurately indicating the phases of rivalry. The hypothetical relationship between the degree of BR control and difference in recognition performance between the instructed and noninstructed conditions, or (I-NI) measure, is illustrated in Figure 3.3. No specific recognition performance values are predicted for the (I) and (NI) conditions in this model; it only suggests that the (I-NI) measure is zero in the absence of control and that it approaches the difference between nonsuppressed and suppressed recognition performance for 100% BR control.

Method

Subjects

Eight males and two females volunteered from the staff and postgraduate students of the Psychology Department of Adelaide University to serve as subjects. All had normal or corrected vision. Three (LL, JT, JR) had, as a result of past experiments of practice of BR control, built up higher than average measures of BR control. Three other subjects (IP, AR, CC) had participated in a past experiment in which

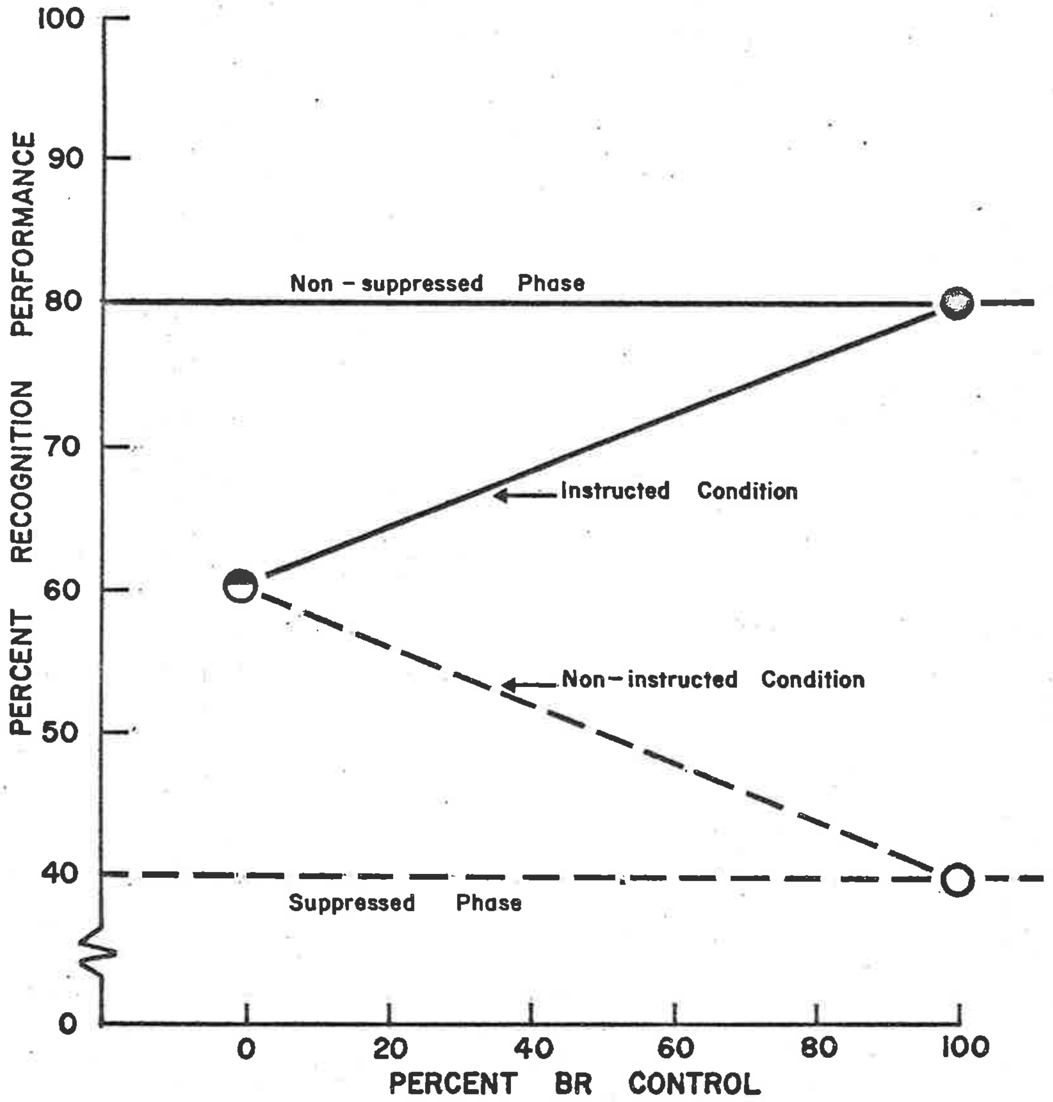


Fig. 3·3. Predicted effect of BR control on recognition performance under the instructed condition (filled circles) and non-instructed condition (open circle)

BR control was required but not practiced with knowledge of results. The other four subjects (NK, BG, EG, PC) had no previous experience of BR.

Stimuli

The fusion contours and BR stimuli in the previewing field of the tachistoscope were the same as those of Experiment 4 (Figure 3.1, bottom pair). The target stimuli were the same as in Experiment 4, consisting of the capital letter-forms A,S,T,U. They could be mounted in the second field of the tachistoscope so that a single letter projected to the same retinal area as the center of the left or right rivalry stimuli.

Apparatus

The basic apparatus was the same as that of Experiment 4 consisting of a modified stereoscope mounted to the viewing port of a modified Cambridge tachistoscope. A chin rest and forehead rest were adjusted to allow a comfortable and fairly stable head position for each subject. Instead of providing simultaneous exposure of the previewing field and test stimuli, the tachistoscope was returned to its normal operation which provided successive exposure of the test stimuli and the previewing field. The luminance of the black lines of fusion and rivalry contours as measured at the lens with an S.E.I. spot photometer was 0.1 ft-L and the luminance of the white background was a uniform 1.0 ft-L.

The overall illumination of the test stimulus field could be adjusted in steps to obtain recognition performance of about 50% with the test stimulus duration between 30 msec and 70 msec. The most frequently used illumination of the test stimulus field provided a luminance of 0.032 ft-L for the black letter-forms and 0.4 ft-L for the white background. The other possible illuminations of the test stimulus field still provided a contrast ratio between white and black of about 12.

Other apparatus similar to that in Experiment 4 included a telegraph key, event counter, and cumulative timer to allow the measurement of BR control and ocular dominance. The continuous depression of the telegraph key by the subject to indicate the presence of the nonsuppression phase of the right eye rivalry stimulus produced one count on the event counter and the continuous activation of the cumulative timer. Thus for a timed period of rivalry the nonsuppression and suppression time of the right eye and left eye stimulus was available in addition to the rate of rivalry alternations.

Additional apparatus included decade timers and two buzzers. This apparatus was assembled so that when the start button on the first decade timer was pressed a 2 second interval elapsed followed by the activation of one of the two buzzers for 0.3 seconds and followed by the activation of a third decade timer to produce a given interval until the triggering of the tachistoscope for the target stimulus. The third timer was adjusted to give one of four possible intervals (1, 3, 5 or 7 seconds) of target stimulus delay. A two position mode switch enabled the experimenter to select the activation of a high intensity 50 Hz buzzer or low intensity 100 Hz buzzer.

Procedure

The general procedure followed on each test trial was as follows. The experimenter inserted a predetermined test stimulus into the test field of the tachistoscope. He then said "ready" to the subject and simultaneously pushed the start button. The subject was instructed to fixate at the centre of the rivalry patterns and to watch the rivalry passively. Two seconds after the "ready" signal one of the buzzers was activated.

The higher pitched 100 Hz buzzer was the instruction stimulus representing the nonsuppression phase of the right eye rivalry pattern while the 50 Hz, stronger intensity buzzer was the stimulus for the nonsuppression phase of the left eye pattern. In other words, if the 100 Hz buzzer sounded, subjects were instructed to bring the right eye pattern into dominance as quickly as possible and to maintain that dominance as long as possible. If it was already dominant then the subject was to maintain the dominance phase as long as possible. If the dominance phase for the instructed rivalry pattern was lost, subjects were instructed to bring it back as quickly as possible. The 50 Hz buzzer was the instruction stimulus for the subject to maximize the duration of the dominance of the left eye rivalry pattern. Subjects were told not to blink or to move their fixation from the centre of the rivalry patterns but to use "attention" or "concentration" only as the means for following the instructions.

The presentation of the target stimulus then followed the initiation of the instruction stimulus by an interval of 1,3,5 or 7 seconds according to a predetermined order. Immediately following the target stimulus presentation the task of the subject was to respond with one of the four letter-form stimuli as quickly as possible. This was followed by an intertrial interval of about 15 seconds in which the experimenter inserted the next target stimulus and set the next instruction stimulus and interval of target stimulus delay.

All 10 subjects were first tested for their degree of BR control and ocular dominance. Subjects were given a series of ten 1 minute timed periods of viewing rivalry in which they depressed a telegraph key to coincide with the presence of the nonsuppression phase of the right eye rivalry pattern. The sequence of instructions for the ten trials is given in Table 3.2. From trials 2-5 were obtained a rivalry dominance control measure, the same as that used by Washburn & Gillette (1933), which was calculated by subtracting the accumulated nonsuppression phase time of the pattern instructed to be nondominant from that instructed to be dominant, multiplying it by 100, and dividing it by the total time. Thus, percentage dominance control = (Dominant time - nondominant time) (100)/Total time. From trials 6-9 could be obtained a rate control measure which was the same as the percentage BR control measure used previously. In addition the degree of ocular dominance was calculated by using the results of all ten trials. It was the percentage of time for which the left eye nonsuppression phase or right eye nonsuppression phase exceeded 50% or 300 seconds of the total time of 600 seconds.

TABLE 3.2.

TRIAL SEQUENCE OF PRE- AND POST-TEST SESSIONS

Trial	Instructions
1	Passive viewing
2	Left eye predominance
3	Right eye predominance
4	Right eye predominance
5	Left eye predominance
6	Slow rate
7	Rapid rate
8	Rapid rate
9	Slow rate
10	Passive viewing

Following the ten trials of the pre-test session subjects were tested to establish tachistoscopic exposure durations for each eye in the monocular, nonrivalry viewing condition that would give approximately 50% correct recognition performance. A descending staircase method was used with knowledge of results after each trial. About 100 trials were normally required to establish the appropriate tachistoscopic duration for both eyes. Following this, subjects were given some conditioning trials with the instruction stimuli. First they were given about 20 presentations of the two instruction stimuli presented in random order, and were required to name each stimulus as quickly as possible by saying "right" or "left". Subjects were then given about 20 trials simulating the experimental conditions in which they had to follow the instruction stimuli by controlling the rivalry in the appropriate way. By the end of these conditioning trials all subjects were quite familiar with the correct relationship between auditory instruction stimuli and the rivalry pattern to be made dominant. They were confident that they knew what was required in following instructions.

The experiment proper was conducted in six sessions of approximately 20 minutes each. For most subjects these sessions were conducted on six consecutive days at about the same time on each day. Each session consisted of 64 trials - the 64 possible permutations of all the conditions of target stimulus presentation. These 64 possibilities are presented in Table 3.3 and result from the multiplication of the 2 instruction stimuli by the 2 eyes to which target stimuli may be presented by 4 possible target stimulus delay intervals by 4 possible letter-form stimuli. Each combination was given a number 1-64 and assigned to an order derived from a random permutations table of blocks of 100 from Moses & Oakford (1963). Each of the six sessions had the 64 possible trials arranged in a different random order derived from different random permutation blocks. This insured that each of four variables was randomized within each session and balanced for any order effects across the six sessions. Subjects were informed at the beginning of the experiment of all the combinations and of the fact that they were equally probable and in random order. Throughout the experiment subjects were given no knowledge of results.

Even though considerable care was taken to establish first a target stimulus intensity and then a tachistoscopic duration which would produce an overall recognition performance of about 50% correct responses, the performance of subjects often varied considerably from this level. Usually performance would improve but in some cases it declined. If recognition performance had approached 25% or 100% the (I-NI) measure may artifactually have been reduced. Therefore criterion limits were established for

Instruction stimulus (EYE)	Target stimulus (EYE)	Target stimulus Delay (Sec)	Target Stimuli (Letter form)	Instruction Condition	Rivalry Phase (Expected)
LEFT	LEFT	1	A,S,T,U	Instructed	(Dominant)
"	"	3	A,S,T,U	"	"
"	"	5	A, S,T,U	"	"
"	"	7	A,S,T,U	"	"
"	RIGHT	1	A,S,T,U	Non-instructed	(Suppressed)
"	"	3	A,S,T,U	"	"
"	"	5	A,S,T,U	"	"
"	"	7	A,S,T,U	"	"
RIGHT	LEFT	1	A,S,T,U	Non-instructed	(Suppressed)
"	"	3	A,S,T,U	"	"
"	"	5	A,S,T,U	"	"
"	"	7	A,S,T,U	"	"
"	RIGHT	1	A,S,T,U	Instructed	(Dominant)
"	"	3	A,S,T,U	"	"
"	"	5	A,S,T,U	"	"
"	"	7	A,S,T,U	"	"

Table 3·3. Experiment 5. All possible permutations of the conditions of target stimulus presentation with the respective instruction condition and expected rivalry phase.

overall recognition performance to keep it from varying too far from the 50% level. If the responses fell below 35% correct for any session of 64 trials then the target stimulus duration was increased by 10 msec for subsequent sessions. On the other hand, if the responses rose above 80% correct for any single session, the duration was decreased by 10 msec. This adjustment of duration was always enough to bring overall recognition performance back into the 35-80% range for correct responses, and usually brought performance into the 50-60% range. Only occasionally was more than one adjustment necessary for any one subject throughout the six sessions.

The variables of major concern were that of instructed eye versus noninstructed eye presentations and target stimulus delay interval. The trials in which the target stimulus was presented to the same eye as the instruction stimulus (see Table 3.3) resulted in instructed eye recognition performance (I). Conversely, recognition performance from target stimuli presented to the non-instructed eye was designated (NI). This (I-NI) value could then be obtained for any session of 64 trials or for each half of the experiment and for each of the target stimulus delays. The significance of these values could be tested for each individual subject using a sign test and for the group as a whole using a correlated means t-test.

Following the six sessions or 384 trials subjects were retested for their measure of dominance control, rate control and ocular dominance under the same conditions as in the pre-test session. Following the experiment, three subjects (NK, BG, EG) were given the additional treatment of a series of twelve rate control practice sessions and a repeat of the experiment. The practice sessions followed the identical procedure of Group SP-KR in Experiment 3.

Following Experiment 5 by approximately four weeks 8 of the 10 subjects were retested in the same type of experiment which will be called Experiment 6. This experiment contained only 96 trials since only one target stimulus delay of 2 seconds was used instead of the previous four. All sixteen conditions were presented in semi-random order in each of six blocks of sixteen trials.

Besides recording the response and marking it correct or incorrect, additional information was obtained from subjects in the second half of Experiment 5 and for the whole of Experiment 6. This information was of the confidence of subjects in their responses. A four point confidence rating scale was used in which "four" represented very high confidence that the response was correct, "three" represented moderate confidence of a correct response, "two" represented low confidence of a correct response or moderate confidence of an incorrect response and "one" represented no confidence that the response was correct or high confidence that the response was incorrect. Experiment 6 and the confidence measures of responses will be discussed in more detail in the appropriate part of the results section.

Results and Discussion

The first question is whether subjects could bring the instructed pattern into dominance and keep it dominant after receiving the instruction stimulus. Table 3.4 shows the percent recognition scores for all ten subjects when target stimuli were presented to the instructed and noninstructed eyes in Experiment 5. Using a Z-score transformation for large samples in the sign test it can be seen that 8 subjects reached the .05 significance level of which 4 subjects reached the .01 significance level for the (I-NI) difference. For the group as a whole the effect of instructions was highly significant ($t = 8.88$, $df = 9$, $p < .0005$). Therefore, it is quite apparent that subjects can make the instructed pattern dominant and noninstructed pattern suppressed to an extent that provides a very significant difference in tachistoscopic recognition performance.

Effect of Target Stimulus Delay

The performance difference between instructed and noninstructed conditions was also analyzed to study the effect of the various delays of target stimulus presentation. First it should be noted that the group of 10 subjects initially had a mean passive rate of 21.6 alternations/minute,

TABLE 3.4.

MEAN PERCENTAGE BR RATE CONTROL AND PERCENTAGE RECOGNITION SCORES FROM BOTH EYES COMBINED UNDER THE INSTRUCTED (I) AND NONINSTRUCTED (NI) CONDITIONS OF EXPERIMENT 5.

Subject	BR Control	(I)	(NI)	(I-NI) Difference	p-level
L.L.	76.1	63.0	45.8	17.2	.013
J.T.	91.4	56.8	31.3	25.5	.0001
N.K.	45.4	54.2	38.5	15.7	.015
B.G.	58.4	72.4	52.6	19.8	.01
E.G.	34.7	51.1	41.7	9.4	.10
J.R.	47.2	64.6	45.8	18.8	.01
I.P.	31.9	57.3	43.2	14.1	.05
A.R.	49.1	61.5	54.2	7.3	.192
C.C.	46.0	54.8	41.7	13.1	.05
P.C.	57.5	53.2	35.9	17.3	.01
Mean	53.8	58.9	43.1	15.8	

a mean slow rate of 11.0 alternations/minute, and a mean rapid rate of 37.5 alternations/minute. This indicates that subjects have a mean phase duration of about 3 seconds under passive viewing; which they can extend to about 5 seconds during slow rate or shorten to about 2 seconds under the rapid rate. Thus, it would seem that subjects in general may be able to make the rivalry phases conform to the instructions best for the 3 second target stimulus delay and least well for the 1 second or 7 second delay.

The mean performance of instructed and noninstructed conditions combined, (I+NI)/2, and the (I-NI) values for each of the target stimulus delays is shown in Table 3.5. Although the mean recognition performance seems to decline linearly with length of stimulus delay, the difference between the 1 second and 7 second delay does not reach a significant level ($t = 1.4$, $df = 9$, $p > .10$). On the other hand, the (I-NI) measures of the 3 second delay and 7 second delay are significantly different ($t = 2.07$, $df = 9$, $p < .05$). All stimulus delays show (I-NI) values which are significant to the $p = 0.01$ level. Thus, it seems that subjects are able to display significant control of rivalry at any of the intervals following the instructions. The fact that this control reaches a maximum at an intermediate delay might suggest that some finite time is required to shift attention in rivalry and that a particular rivalry phase cannot be held indefinitely.

TABLE 3.5

MEAN COMBINED (I+NI)/2 AND MEAN DIFFERENCE (I-NI) PERCENTAGE RECOGNITION SCORES OF INSTRUCTED (I) AND NONINSTRUCTED (NI) CONDITIONS IN EXPERIMENT 5 ANALYZED SEPARATELY FOR TARGET STIMULUS DELAYS

	Stimulus Delay			
	1	3	5	7
(I + NI)/2	53.2	51.8	49.8	49.1
(I-NI)	15.0**	19.0**	17.3**	11.9*

$^{**}p < .005$ $\quad$ $^{*}p < .01$

Relation of (I-NI) measure to BR control

It was predicted that those subjects who had greater measures of BR control would produce, in general, greater (I-NI) values. That prediction will be tested somewhat later. More specific predictions may also be made relating to controlled slow rates, rapid rates and the (I-NI) measures for specific delays of target stimuli. Subjects who have the slowest slow rates should be able to follow the instructions for the longest stimulus delays better than subjects with higher slow rates. Inversely, subjects with fastest rapid rates should show greater (I-NI) values with short stimulus delays than subjects with comparatively slow rapid rates.

The Spearman correlation of rapid rate with the (I-NI) measure for the 1 second stimulus delay approaches significance ($r_s = +.455$, $N = 10$, $p < .10$). The correlation of slow rate with the (I-NI) measure of the 5 second stimulus delay is significant ($r_s = -.623$, $N = 10$, $p < .05$), but the correlation with the 7 second delay is not significant ($r_s = -.260$, $N = 10$, $p > .10$).

Since the mean slow rate produces a mean phase duration of about 5 seconds it may be expected that the 5 second stimulus delay would maximally differentiate between those with lower and higher slow rates. Only 3 subjects had slow rates which gave mean phase durations greater than 7 seconds.

Therefore, the significant correlation of slow rates with the (I-NI) measure from the 5 second delay but the lack of significance for the 7 second delay is understandable. Generally then, the specific predictions relating slow and rapid rates to different stimulus delays have been confirmed. Those subjects who have greater rapid rates are better able to conform to the rivalry control instructions within 1 second. In addition, those subjects with slower slow rates are better able to conform to rivalry control instructions as long as 5 seconds after the instruction stimuli but not necessarily as long as 7 seconds.

The degree of BR control is a fairly consistent ability of subjects. The pre-test, post-test correlation of rate control was significant at a high level ($r = +.931$, $df = 8$, $p < .005$). The dominance measure of BR control has usually been highly correlated with the rate control and this is also the case in Experiment 5. The correlation of mean rate control with mean dominance control was highly significant ($r = +.932$, $df = 8$, $p < .005$).

The ability to produce a large difference in recognition performance between instructed and noninstructed conditions is also consistent. The Pearson correlation between the (I-NI) measure of the first and second halves of Experiment 5 was significant ($r = +.790$, $df = 8$, $p < .005$). This consistent ability to make the state of rivalry conform to instructions even extends between Experiments 5 and 6. The correlation of overall difference measures (I-NI) of Experiment 5 with the equivalent for those subjects ($N = 8$) who repeated Experiment 6 was highly significant ($r = +.856$, $df = 6$, $p < .005$). In other words, both the ability to control binocular rivalry and the ability to produce greater recognition performance in the instructed condition than in the noninstructed condition seem to be fairly consistent abilities within subjects as evidenced by their high reliability. The next logical step would be to examine the relationship between those two abilities.

Combining the pre- and post-test measures, the mean BR control of slow and rapid rate for Experiment 5 is shown in Table 3.4. The Pearson correlation between BR control and the (I-NI) measure was significant ($r = +.742$, $df = 8$, $p < .01$). As one would expect, the dominance control also correlated significantly with the magnitude of the (I-NI) measure ($r = +.632$, $df = 8$, $p < .025$). Figure 3.4 is the scatter diagram placing the 10 subjects with respect to percentage BR rate control and percentage difference between instructed and noninstructed conditions. The best fit regression line for predicting (I-NI) differences from rate control gives a slope, $b = +.224$, and is indicated by the solid line passing through the point of the joint means. It can be seen that the line intersects the 100% point of BR control at a (I-NI) value of about 26% and intersects the 0% control point at a value of

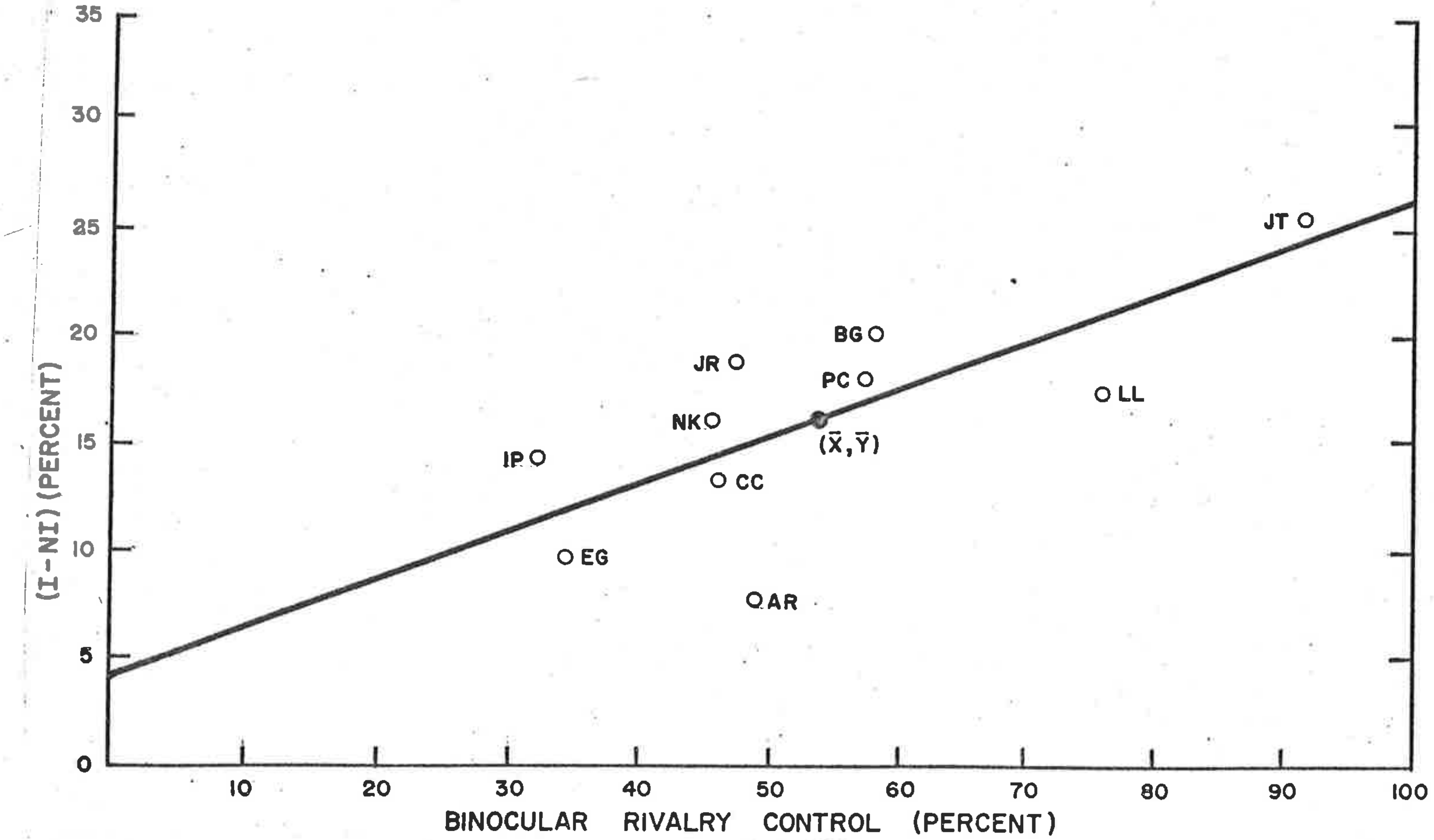


Fig. 3·4. Scatter diagram showing the BR rate control measure and (I-NI) measure of 10 subjects of Experiment 5 including the calculated regression line passing through the point of joint means $(\bar{X},\bar{Y})$.

about 4%. This is not far off from the predictions of the model, which would suggest a 0% (I-NI) value with 0% BR control.

If the relationship between percentage BR control and the (I-NI) percentage difference is a linear one, then the maximum (I-NI) measure estimated from the regression line would be about 26%. This suggests that there is a limit on the magnitude of the (I-NI) measure. The theoretical maximum (I-NI) value would be 75% when instructed performance is 100% and noninstructed performance is at chance level (25%). However, Fox & Check (1966) did not find the dominant-suppressed difference to approach the maximum possible difference even under conditions in which subjects indicated dominance and suppression only when it was complete and unambiguous. Where the maximum possible difference was 67% their subjects showed differences of 13% and 25.5% (Fox & Check, 1966).

Since the completion of the present series of three experiments, a very relevant article has appeared by Collyer & Bevan (1970). Using a method similar to that of Fox & Check (1966) they found a mean difference between dominant and suppressed conditions of 15.5%. In a condition similar to the present experiment, in which their subjects had to shift attention to an instructed pattern within a constant 3 second delay after the instruction stimulus, the dominant-suppressed difference dropped to about 11%. This indicates that under conditions in which subjects had to control rivalry before target stimulus presentation, some subjects at least controlled the rivalry less than perfectly. These studies seem to confirm the model relating the (I-NI) measure to BR control which was proposed in the introduction to this experiment. That is, with greater degrees of BR control the (I-NI) measure approaches the nonsuppression-suppression difference.

The effect of practice on the (I-NI) measure

It has already been shown that the mean rate control is highly correlated with the (I-NI) measure and that both measures are very reliable within subjects. In other words, the experimental design is successful in providing an objective, behavioural measure of the degree of BR control. What still needs to be determined is the extent to which practice of BR control may affect the (I-NI) measure. In the present experiment there are a number of ways in which the data can be analyzed to examine the effect of practice.

It may be recalled that some of the subjects were well-practiced in BR control. JT and LL had participated in a series of experiments involving BR control and had practiced control with knowledge of results always given. Both subjects initially had about average BR control but by the time of this experiment had attained initial rate controls of 90.3% and 74.7% respectively. On the other hand Subject JR had only 10 practice days in Experiment 1. The initial rate control of JR in the present experiment was 46.7%, only somewhat greater than the initial mean rate control of the seven unpracticed subjects (38.7%). Nevertheless, if the group of 10 subjects were to be divided into groups with and without prior practice of BR control, JR must be allotted to the former. The effect of practice on the BR control measure has been found previously to be an increase of the control measure. In this case the initial mean control of 71.5% for the three practiced subjects is significantly greater ($t = 3.37$, $df = 8$, $p < .005$) than that of the unpracticed subjects.

The mean (I-NI) measure for the seven unpracticed subjects is 13.6%. It is interesting that the same measure applied to the results of Collyer & Bevan (1970) is about 11%. Since Collyer & Bevan used three target stimuli instead of four as in the present experiment, their maximum range of recognition performance was 67% rather than 75%. A comparable measure of performance can be derived for each of these percentage correct measures by converting into signal strength (d') values using Table II in the Appendices of Swets (1964). In that case the d' difference from the (I-NI) measure is 0.42 for the seven unpracticed subjects in the present experiment and is very similar to the d' value of 0.39 for the unpracticed subjects of Collyer & Bevan (1970). The seven are thus fairly representative of unpracticed subjects in general.

The group of three well-practiced subjects, on the other hand, had a mean (I-NI) measure of 20.5% ($d' = 0.63$) which is significantly different from the unpracticed group ($t = 2.06$, $df = 8$, $p < .05$). This finding is consistent with the correlation described earlier between BR control and the (I-NI) measure. Thus, the subjects who had previous practice of BR control showed a greater mean value of BR control and greater (I-NI) measure.

There was also a wide range of initial BR control measures in the group of unpracticed subjects from 26.0% to 53.5%. If the original correlation between BR control and (I-NI) derived mainly from the inclusion of the well-practiced subjects, this correlation for the seven unpracticed subjects would not be significant, and the (I-NI) measure would be considered only a reflection of BR control practice and not a general concomitant of the degree of BR control. However, the correlation between the BR control measure and (I-NI) measure for the seven subjects was also significant ($r = +0.682$, $df = 5$, $p < .05$). In summary, the (I-NI) measure is a reliable, objective indicator of the degree of BR control and is increased for subjects who have increased their BR control as a result of practice.

The second source of information regarding the effects of practice on BR control and the (I-NI) measure may come from the practice of the main task of Experiment 5. It will be recalled that this task consisted of 384 trials on each of which subjects received an instruction stimulus to make dominant one of the two rivalry patterns until the target stimulus had been presented, sometimes as soon as 1 second following the instruction stimulus, and sometimes as long as 7 seconds following the instruction stimulus. In other words each trial required an effort of rivalry control either to maintain a dominant pattern or to shift dominance to the instructed pattern. If it is assumed that this would require an average of 3 seconds of control for each of 384 trials, then subjects may be considered to have obtained a total of 20 minutes of BR control practice throughout the experiment. This would be spaced practice but would be without any external feedback. Nevertheless, according to the results of Experiment 3, this should produce an increase of BR control. Just previously it was shown that those subjects who had prior practice of BR control instructions of slow and rapid rate had greater (I-NI) measures. The question here is whether the practice of BR control required in the main task of the experiment (an ability which should be directly related to the (I-NI) measure) has any effect on the (I-NI) measure and on the subsequent measure of BR rate control. To study this question (I-NI) measures for the first half (192 trials) were compared with the second half, and increases of this measure were compared with increases between the initial and final BR rate control measures.

First, either because of adjustments of target stimulus duration during the experiment or because practice beyond a certain point may not have been effective, overall recognition performance (I + NI)/2, did not improve over the duration of the experiment. On the other hand, the difference between instructed eye recognition performance and noninstructed performance showed a mean increase of 5.3% from the first to the second half of Experiment 5 which was highly significant ($t = 4.4$, $df = 9$, $p < .005$). The measure of BR rate control increased by a mean of 10.4% from the initial test to final test ($t = 2.53$, $df = 9$, $p < .025$). This circumstantially relates the increased (I-NI) measure to the increased rate control measure. The more direct test, comparing the increases of rate control measure with the (I-NI) increases, produced a significant correlation ($r = +0.647$, $df = 8$, $p < .025$). Thus, there is a general increase in BR control measure and (I-NI) magnitude across Experiment 5 which derives its main contribution from subjects who show an increase in both control and (I-NI) magnitude. Some subjects seem to benefit from the practice of rivalry control required in the experiment. Furthermore, these increases seem to be exclusively related to each other and are not correlated with overall mean recognition performance, with the overall (I-NI) difference measure, or with the mean BR control measure.

A third way of examining the effect of practice of BR control on the (I-NI) measure would be to give subjects a series of BR control practice sessions interposed between a pre- and post-test session of the recognition task. Because of the lack of time and subject availability, only three of the seven unpracticed subjects undertook this procedure. Table 3.6 shows the results for these 3 subjects in the order of their initial BR rate control (RC_i), the (I-NI) measures of the first and second halves and the total 384 trials, the rate control measure for the first of the practice sessions (RC_1), the control measure in the last of twelve practice sessions (RC_{12}), the (I-NI) measures in the repeated experiment, and the final rate control measure (RC_f).

The main test would be to compare the (I-NI) measure after practice of control with the measure before practice. For the three subjects combined this test is not very successful. Subject NK showed an increase in the (I-NI) measure of 8.4% from 15.6% to 24.0%. Subject BG showed only a 0.5% increase from 19.8% to 20.3%. Subject EG showed, in fact, a decrease of 7.3% from 9.4% to 2.1%. The effect of the practice treatment seems to be mixed, with only one subject showing a fair increase, a second showing a slight increase, and a third showing a decrease.

Some reasons for these apparently inconsistent results may be deduced from a more detailed analysis. First, subject NK showed results which fit with earlier findings and confirm the hypothesis with regards to the effects of practice. He showed an increase of (I-NI) from the first to second half of the pre-test session of 6.3%, indicating that he had

TABLE 3.6.

EFFECT OF RATE CONTROL PRACTICE ON THE (I-NI) MEASURES OF 3 SUBJECTS. RIVALRY RATE CONTROL MEASURES ARE SHOWN FOR THE INITIAL TEST SESSION (RC_i), THE FIRST PRACTICE SESSION (RC_1), THE LAST PRACTICE SESSION (RC_{12}), AND FINAL TEST SESSION (RC_f). THE (I-NI) PERCENTAGES ARE SHOWN FOR THE FIRST AND SECOND HALF AND MEAN OF BOTH THE PRE- AND POST-TEST EXPERIMENT.

	Pre-Test				Control Practice		Post-Test			
Subject	RC_i	(I-NI)			RC_1	RC_{12}	(I-NI)			RC_f
		1st half	2nd half	Mean			1st half	2nd half	Mean	
NK	37.5	12.5	18.8	15.6	53.2	80.2	25.0	22.9	24.0	76.2
BG	41.2	16.7	22.9	19.8	75.5	85.4	19.8	20.9	20.3	87.7
EG	30.0	7.3	11.5	9.4	39.4	84.1	-1.0	5.2	2.1	51.3

benefited considerably from the practice of the experiment itself. This coincided with an increase in control of 17.7% from 37.5% to 53.2%. NK continued to increase his control during the practice sessions by 27% to a value of 80.2%. This is also reflected in an increase of the (I-NI) measure of 8.4%. When comparing the six subsections of the pre-test with those of the post-test, this increase is significant to a low level ($t = 1.63$, $df = 10$, $p < .10$). The final (RC_f) for NK is maintained at 76.2%.

Subject BG also showed a considerable increase in the first 384 trials of 6.2% from 16.7% to 22.9%. This seems to have had a great effect in bringing BG's rate control to 75.5% in RC_1, an increase of 34.3% from his initial control. The next twelve practice sessions only produced a further increase of 9.9% to a value of 85.4%. The retest session produced an (I-NI) measure of 20.3%, only slightly more than the pre-test measure. BG maintained his increased control at 87.7%. What seems to be the case for BG is that the effect of practice of control was obtained entirely within the first experimental session of 384 trials. BG already had a high (I-NI) measure of 16.7% in the first half and increased it to 22.9% which is close to the (I-NI) measure of 25.5% of subject JT, who possessed the greatest rate control for the group (91.4%). The idea that subject BG benefited maximally from the first 384 trials is supported by the fact that his rate control increased 34.3% over this session, but only increased a further 9.9% over the next eleven practice sessions. With this in mind one would not have expected BG to show much further increase in the re-test (I-NI) measure.

Subject EG seems to be the anomolous case. EG started with an unimpressive rate control of 30.0% and a rather low (I-NI) measure of 7.3%. He increased his (I-NI) measure 4.2% to 11.5%. which seems to be reflected in the moderate increase of his control to 39.4%. Then EG made rather an impressive gain of control of 44.7% in the practice sessions to the value of 84.1%. However, his detailed results show that the entire increase occurred over the first four practice sessions as his control went from 39.4% to 71.8% to 77.5% to 86.5% by the fourth test session to remain fairly constant thereafter. On the other hand, the increase of control for NK, as with all other subjects in earlier experiments, was a gradual process. His largest increase was 14.0% between sessions 2 and 3. This makes EG's remarkable increase in control from session 1 to 2 somewhat suspicious.

It was only after the first practice session that these three subjects were given knowledge of results and told that the purpose of the practice sessions was to increase their measure of BR control. It may have been that subject EG became less reliable in his reporting of BR alternations in order to conform readily to expectations. Toward the end of the practice session EG volunteered that he occasionally noted a loss of fusion of the fusion stimuli, particularly when exercising the slow rate instructions. If the loss of fusion occurred frequently, then EG may have been practicing convergence movements rather than control of BR. It is perhaps also relevant that EG showed a substantial decrease in the final control measure to 51.3%. It seems possible, therefore, that either through unreliable reporting of rivalry alternations or a frequent loss of fusion, subject EG benefited little from the practice sessions. If this is the case, then it seems likely that EG has a minimal level of control in the experiment, perhaps enough to produce a measure of about 5% in the long run, and that the 9.4% and 2.1% values are merely chance variations from this value.[1]

Despite the negative results of subject EG in the retest measure in this particular section of the experiment, the overall results generally support the notion that the practice of BR control has the effect of increasing the difference between instructed and noninstructed eye recognition performance. When a well practiced group of subjects is compared with an unpracticed group, not only does the practiced group

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[1] An interesting sidelight to this discussion is that not long after participating in Experiment 5 subject EG was dismissed from his position as technical assistant in the Psychology Department. The dismissal was allegedly the result of a lack of conscientiousness and reliability in his job.

possess a greater measure of BR control, but they also produce a greater (I-NI) measure. In addition, the practice of rivalry control required in the experiment itself has the effect of increasing both the (I-NI) and the rate control measures. Therefore, despite the inconsistent results in the last experimental design, it can be concluded that the practice of the control of binocular rivalry does have the effect of increasing the objective measure (I-NI) of BR control.

Analysis of the results of Experiment 6

Subjects BG and PC were unobtainable for Experiment 6, so comparisons between Experiments 5 and 6 were with 8 subjects. Since there was a significant increase of performance for all subjects from the first to the second half of Experiment 5, only the second half performance was used to compare with Experiment 6. For subjects NK and EG the second half of the retest session was used.

The (I-NI) measures in the second half of Experiment 5 were analyzed by stimulus delays. It was earlier found that the measure in Experiment 5 was greatest for the 3 second target stimulus delay. This was also the case for the 8 subjects in the second half of Experiment 5. The (I-NI) means for the eight subjects are presented in Figure 3.5. The mean (I-NI) value in Experiment 6 was 20.6% and is represented by the filled circle in the figure. This value is approximately equal to the value for the 3 second delay.

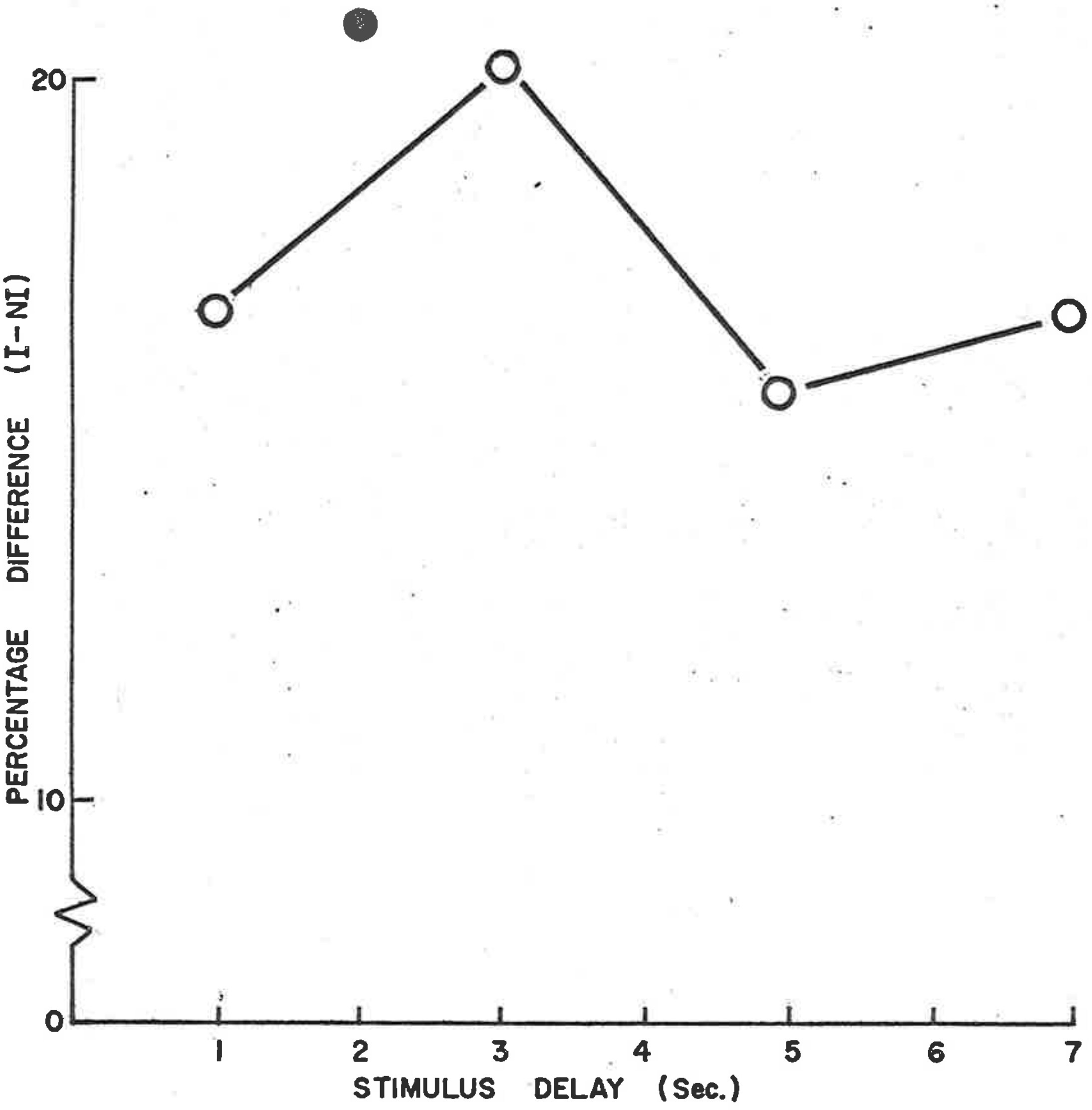


Fig. 3·5. Mean (I-NI) values for eight subjects for each test stimulus delay from the last 192 trials of Experiment 5 (open circles) and mean (I-NI) value in Experiment 6 (filled circle)

The rather high (I-NI) value in Experiment 6 may be attributed to the similarity of the 2 second delay to the 3 second delay, but it may also be attributed to the fact that only the 2 second stimulus delay was used in Experiment 6. This meant that subjects had only to insure that they were following rivalry instructions over a very restricted time interval. In Experiment 5 subjects often had to follow the instructions over a comparatively long time interval since there was an equal probability of four different stimulus delays on every trial. Thus the uncertainty of stimulus delay in Experiment 5 might have tended to reduce the (I-NI) values in comparison with those in Experiment 6.

On the other hand, it seems unlikely that the theoretical uncertainty of stimulus delay would have had much practical effect on the strategies of subjects for the 1 and 3 second delay. Many subjects volunteered statements about their strategies to this effect. Subjects attempted to shift dominance to the instructed pattern as quickly as possible in order to have it dominant by the 1 second delay. No subject reported difficulty in maintaining the instructed pattern in dominance for the 3 second delay, though many lost the instructed dominance by 5 seconds and most had lost it by 7 seconds. Once the instructed pattern had been lost it was a matter of re-establishing it to dominance as quickly as possible. Therefore, because of probable strategies in following instructions, the variable of stimulus delay uncertainty was probably not operative on the (I-NI) measure for the 1 and 3 second delays.

The only other variable that may enhance the (I-NI) measure in Experiment 6 would be that of practice. However, this effect has been minimized by comparing only the last 192 trials in Experiment 5 with the 96 trials of Experiment 6. Therefore, the (I-NI) value of 20.6% for Experiment 6 is probably a reliable indicator of what it would have been for the 2 second stimulus delay had that condition been included in Experiment 5. Thus, it seems reasonable to suggest that the magnitude of the (I-NI) measure may be a quadratic function of target stimulus delay with the maximum (I-NI) value obtained at a delay of about 2-3 seconds.

Analysis of the use of confidence ratings

It will be recalled that in the second half of Experiment 5 (192 trials) and for the whole of Experiment 6 (96 trials) subjects gave confidence ratings following their responses in the forced-choice recognition task. Because subjects PC and NK completed Experiment 5 before the use of confidence ratings was adopted, the analysis included 8 subjects in each experiment seven of which participated in both experiments.

The use of the confidence rating scale in forced-choice recognition tasks is an uncommon but potentially useful extension of techniques developed from signal detection theory.

Multiple category rating scales have been used to good effect in simple signal detection tasks (Swets, 1964). The replacement of dichotomous Yes-No responses by multiple category rating scales has resulted in an increase of information transmitted for each response of the subject (Swets, 1964). The use of the multiple criteria rating scale allows the simultaneous analysis of signal strength (d') and the confidence levels of multiple criteria (beta values).

Forced-choice recognition tasks, on the other hand, have rarely used confidence rating scales since they are discrimination rather than simple detection tasks and are usually less affected by different confidence criteria. However, information about the confidence of forced-choice judgements in a multiple choice task is most definitely available (Egan & Clarke, 1966, p.243). Pollack & Decker (1958) have shown how this information can be measured using a confidence rating scale. Obtaining the judgements of confidence in subjects' responses apparently does not interfere with recognition performance and it provides useful information about the receiver's operating characteristics (Pollack & Decker, 1958).

For the purposes of the present experiment the use of the confidence rating scale may provide two additional bases of comparing performance in the instructed and noninstructed conditions besides that of the percentage correct measure. First, it is necessary to determine if the confidence ratings were used equally under the two conditions. One way in which this can be determined is to compare the difference in mean confidence ratings of the two conditions with the difference in recognition performance. In other words, are the differences in mean confidence ratings more or less sensitive to the effect of rivalry phases than are the percentage correct measures?

Another, more direct, way of comparing the use of confidence ratings is to calculate the probabilities of correct responses for each condition separately within each confidence rating category. A similar use of confidence ratings in both conditions will be reflected in equal probabilities of correct responses for the same confidence ratings. In psychological terms, for a given recognition performance a decrease in mean confidence rating, the result of an increase in the probability of a correct response for separate confidence ratings, reflects a decrease in confidence of judgements. This is the case in which each of the categories is used as a more conservative criterion.

In addition to the analysis of the criterion values under both conditions the use of the category rating scale provides a method for determining and illustrating signal detectability for the two conditions. Receiver operating characteristic (ROC) curves can be derived for each of the instructed and noninstructed conditions in order to compare visually the effect of attention or instructional conditions on the detectability of target stimuli.

The first task is to analyze the use of the confidence ratings. Figure 3.6 shows the distribution of all responses across the four rating categories in Experiments 5 and 6 for both the instructed and noninstructed conditions. There is a fairly equal use of the four categories for the instructed condition, but for the noninstructed condition there was a linearly decreasing probability with higher confidence ratings. Table 3.7 shows a greater mean confidence rating for the instructed condition than for the noninstructed condition in each experiment. If the difference between the conditions in mean ratings is converted to a percentage difference by dividing by the theoretical range of four, the resulting values are 13.5% and 20.4%. Interestingly, this compares closely with the mean (I-NI) values of the two experiments.

TABLE 3.7

	Percentage Correct Response			Mean Confidence Rating		
	I	NI	Difference	I	NI	Difference
Experiment 5	65.2	48.5	16.7	2.44	1.90	0.54 (13.5%)
Experiment 6	71.6	51.1	20.5	2.57	1.75	0.82 (20.4%)

This similarity in percentage differences may suggest that the effect of the instructional conditions is essentially the same for recognition scores and confidence ratings. The increased (I-NI) value for Experiment 6 is reflected in an increased

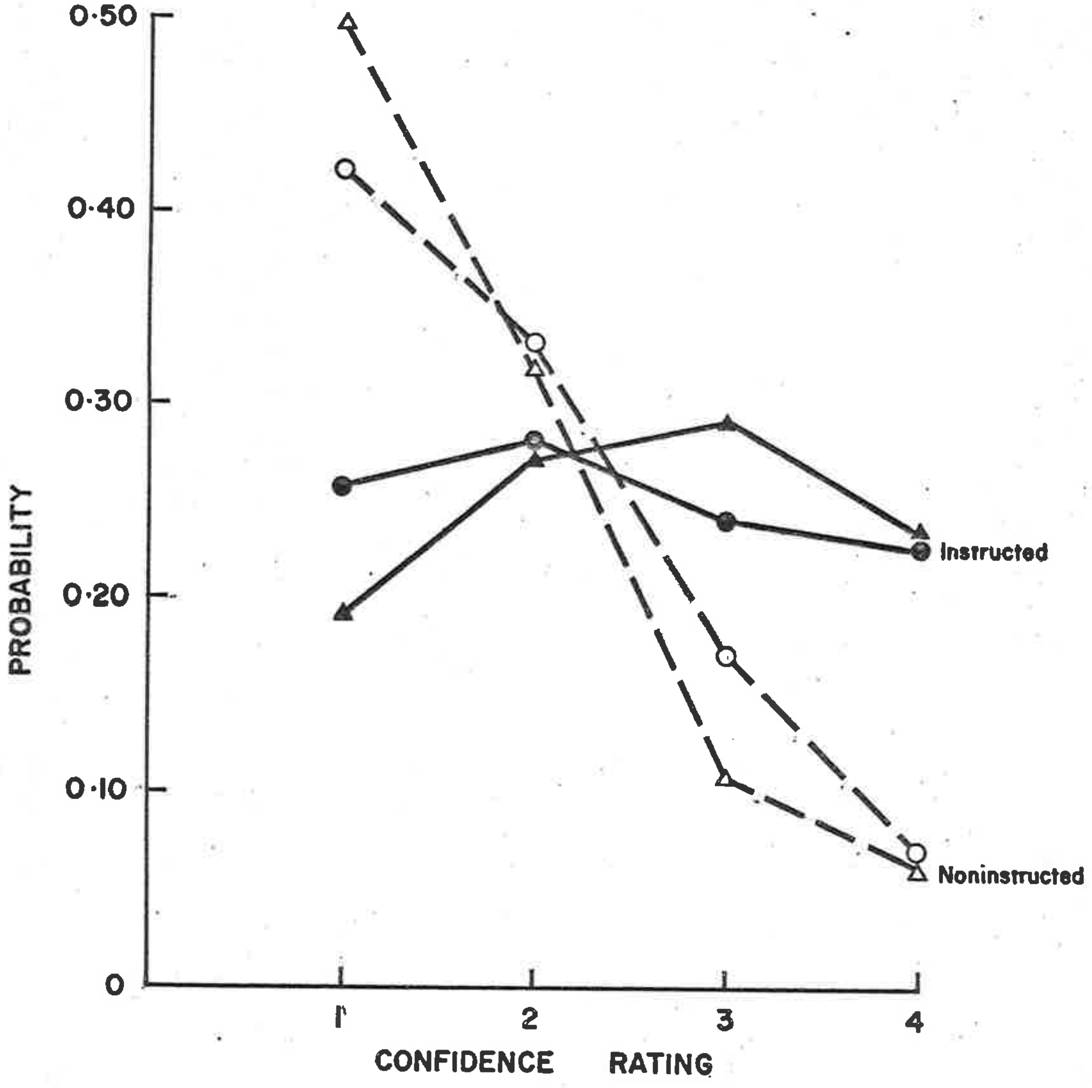


Fig. 3·6. Probability of each of the four confidence ratings in Experiment 5 (circles) and Experiment 6 (triangles).

difference of mean confidence ratings and is illustrated in Figure 3.6 by a greater difference between the slopes of the response distributions for Experiment 6.

As was stated earlier the use of confidence ratings in the two conditions may be directly analyzed by comparing the probabilities of correct responses separately for each confidence rating. The correct response probabilities for each condition in both experiments are illustrated in Figure 3.7. As expected, the correct response probabilities increase monotonically from confidence rating "one" to rating "four" in both conditions of each experiment. It seems clear then, that subjects were correctly following instructions in the assignment of confidence ratings.

The crucial comparison of the two conditions within each experiment shows very little difference in the probabilities of correct responses. The largest difference for both experiments is with confidence rating "three" but neither of these differences approach significance. Therefore, it seems that subjects use the confidence ratings as instructed, and use them in the same way for both instructed and non-instructed conditions. This means that subjects are essentially using the same psychological criterion for the same confidence rating under both conditions. This suggests that in terms of signal detection theory, the decreased signal detectability (d') in the noninstructed condition is not accompanied by a change of criterion (beta).

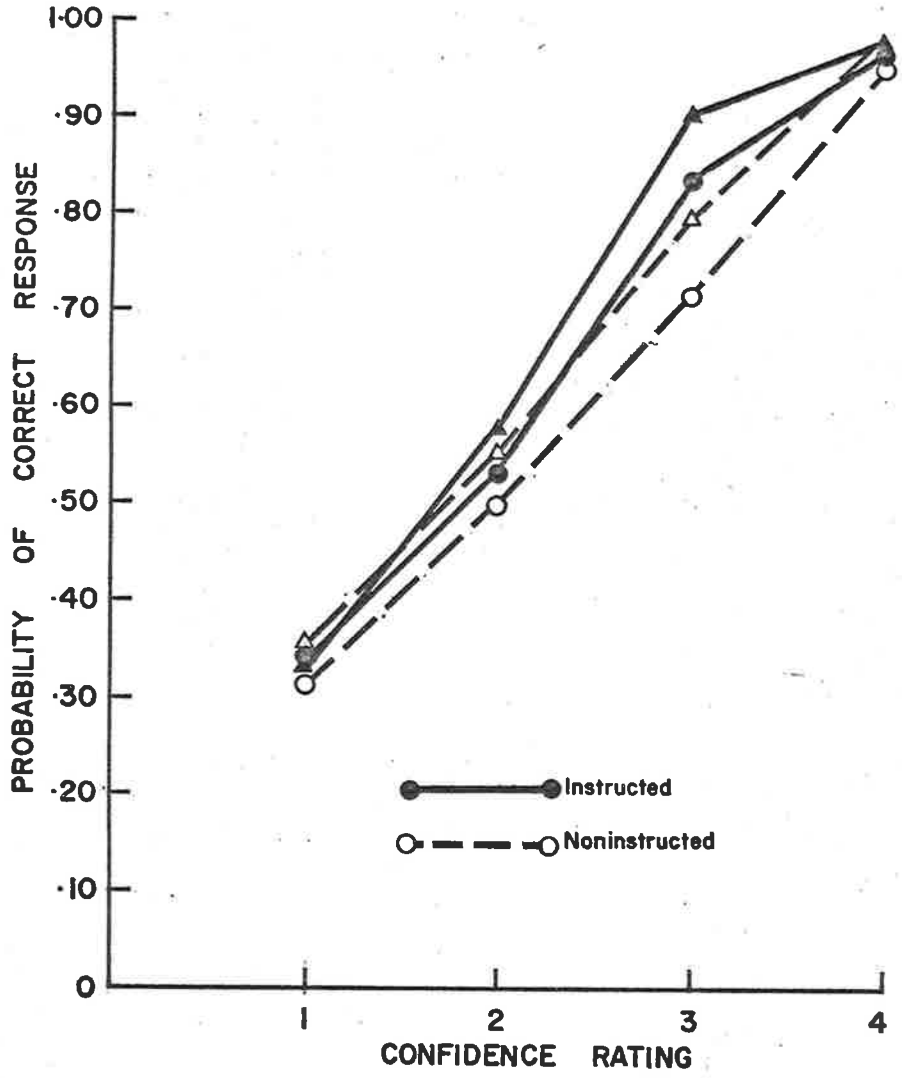


Fig. 3·7. Probability of a correct response with each of the four confidence ratings in Experiment 5 (circles) and Experiment 6 (triangles).

ROC curves for 8 subjects in each condition of Experiment 5 and 6 are illustrated in Figure 3.8. The ordinate is the linear cumulative probability of a correct acceptance or "hit". It represents the subjects' judged probability of a correct response, when in fact their responses were correct. The abscissa is the linear cumulative probability of a "false alarm" or subjects' judged probability of a correct response when in fact the response was incorrect. The 45 degree diagonal from probability (0,0) to probability (1,1) represents chance level performance (d' = 0), when it is impossible for a subject to discriminate between signal and noise.

Figure 3.8 shows greater deviations from the diagonal for the (I) condition than for the (NI) condition for both Experiments 5 and 6. The ROC curves for the (NI) conditions of the two experiments happen to be very similar as a result of similar recognition performance or d' values. Table 3.8 shows the similarity of mean percentage correct values for the (NI) conditions of both experiments. As was mentioned earlier the mean (I-NI) values for Experiments 5 and 6 were 16.7% and 20.5% respectively, producing d' differences between the (I) and (NI) conditions of 0.53 and 0.67.

In summary, Experiments 5 and 6 have shown that rivalry control has the effect of shortening or extending the phases of rivalry in order to produce a difference between the

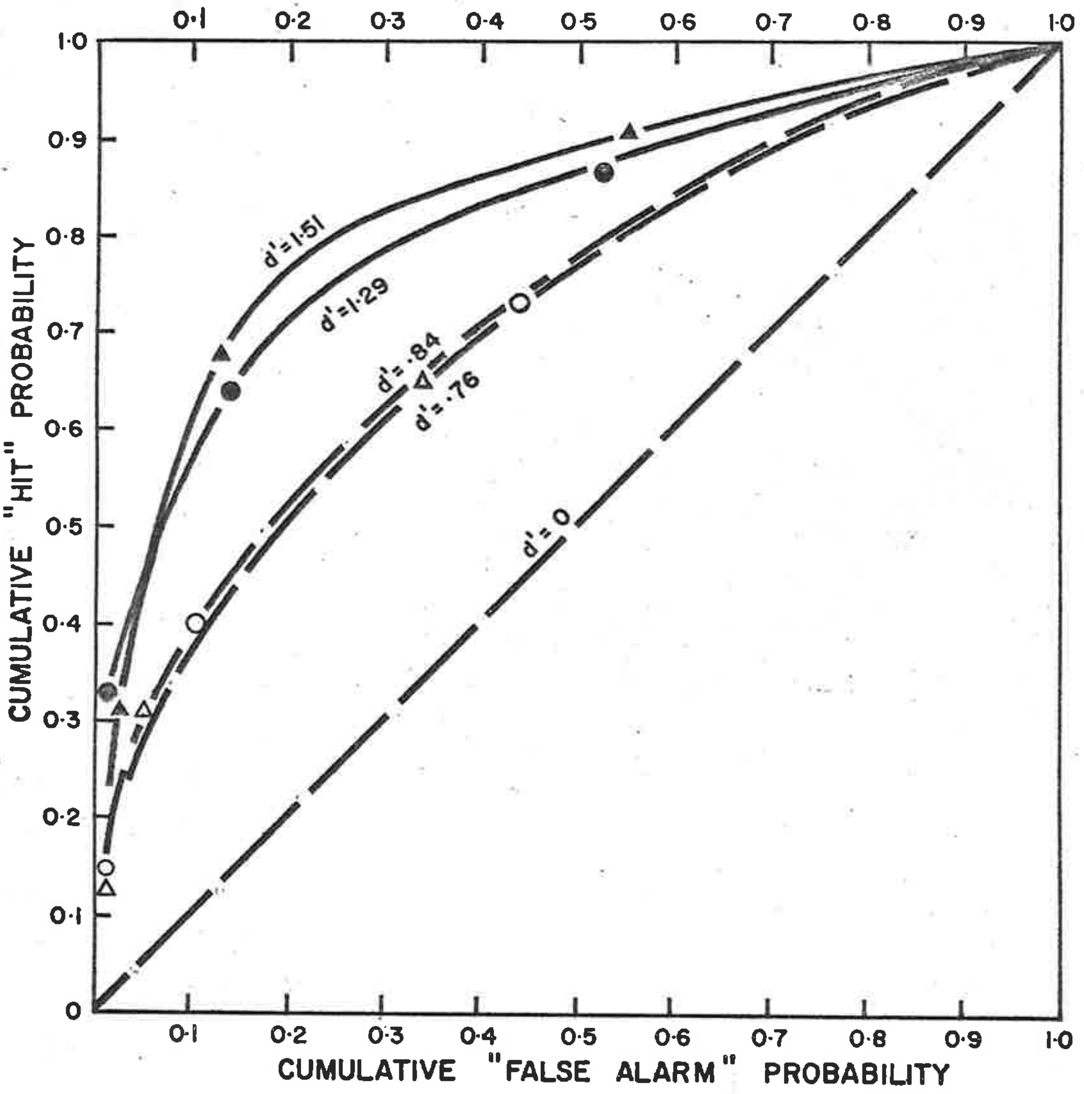


Fig. 3·8. ROC curves from Experiment 5 (circles) and Experiment 6 (triangles) of the instructed (solid lines) and non-instructed (broken lines) conditions separately.

TABLE 3.8.

MEAN PERCENTAGE CORRECT RESPONSES (P) AND EQUIVALENT SIGNAL DETECTABILITY VALUES (d') FOR BOTH THE INSTRUCTED (I) AND NONINSTRUCTED (NI) CONDITIONS AND DIFFERENCE FOR EXPERIMENTS 5 AND 6.

	(I)		(NI)		Difference	
	P	d'	P	d'	P	d'
Experiment 5	65.2	1.29	48.5	0.76	16.7	0.53
Experiment 6	71.6	1.51	51.1	0.84	20.5	0.67

instructed and noninstructed conditions. As control increases with practice the (I-NI) value increases and approaches its maximum value: the difference between the nonsuppression and suppression phases of rivalry. BR control affects signal detectability but not confidence criteria of responses since the use of confidence ratings is invariant between conditions.

Conclusion

The results of Experiments 5 and 6 in terms of the analysis according to signal detection theory are similar to those of earlier investigations of selective attention in hearing. Broadbent & Gregory (1963) had subjects use a five point confidence rating scale in a simple detection task of a tone burst embedded in noise. The signal was presented to one ear during the presentation of digits to the other. Under the divided attention condition subjects had to recall the digits before giving a detection judgement. Under the selection condition subjects could ignore the digits. The conditions markedly affected the signal detectability (d') but did not affect the confidence criteria (beta). Under the divided attention condition d' was 2.90 and under the selection condition it was 5.05, resulting in a d' difference of 2.15.

Treisman & Geffen (1967) had subjects "shadow" the speech message in one ear and tap with a ruler to indicate target words in both ears in a dichotic listening situation. They also found no change in beta but a significant difference in d' between target words to the shadowed and nonattended ears. The shadowed ear d' was 4.2 and the nonattended ear d' was 1.8 resulting in a d' difference of 2.4. Moray & O'Brien's (1967) experiment, which was discussed earlier, also resulted in a large d' difference of 2.28 but no significant difference of beta between the selected and rejected ears.

Although selective attention in binocular rivalry seems to produce basically the same effects as selective attention in dichotic listening, there appears to be a difference between the degree of attenuation in selective listening and the degree of suppression in BR. In all three selective listening experiments the d' differences were greater than 2.15. The mean d' difference between instructed and noninstructed conditions in Experiment 5, however, was only 0.49. Even when considering the more favourable target stimulus delay of 2 seconds in Experiment 6, the mean d' difference was still only 0.63. Subject JT with the greatest BR control and (I-NI) measure produced a d' difference of 0.80. In addition the projected (I-NI) measure of 26% for a hypothetical subject with 100% control would produce a d' difference of about 0.80.

However, this apparent limitation of the magnitude of the d' difference for the (I-NI) measure is a limitation of the magnitude of rivalry suppression and not a limitation of the degree of control. The subject producing the greatest nonsuppressed-suppressed difference in the experiment of Fox & Check (1966) produced a d' difference of about 0.90. Because Fox & Check (1966) took great care to insure complete suppression and nonsuppression phases for target stimulus presentations, this difference would seem to be a maximum effect of rivalry suppression. Experiment 4 found a d' difference between nonsuppressed and suppressed phases in passive viewing of 0.66 and in active viewing of 0.54. Thus, it seems that there is a limitation on the magnitude of the suppression effect that is correlated with the phenomenal states of rivalry. However, the direction or location of these phases of rivalry can be controlled to a very large extent.

CHAPTER IV.

THE ROLE OF PERIPHERAL MECHANISMS IN THE CONTROL OF BINOCULAR RIVALRY

Introduction

One of the main obstacles to the recognition of the relevance of BR to the study of a selective attention has been the long held assumption of the necessary role of peripheral mechanisms in the control of BR. Chapter I reviewed the evidence regarding the effects of eye movements, accommodation and blinking on the control of rivalry. A striking feature of this review was the paucity of experimental evidence and the disagreement between experiments as to the importance of these mechanisms. In brief, Helmholtz (1925) felt that eye movements were facilitative but not necessary, whereas Breese (1899) felt that eye fixations were necessary for the control of rivalry. Washburn & Gillette (1933) felt that eye movements or "ideas" were not involved in BR control. Their findings that control, although reduced, still existed with afterimages would suggest a facilitative but not necessary role of eye movements.

Fry (1936) found that BR control was abolished with the use of small artificial pupils or the paralysis of the intrinsic eye muscles. He concluded that accommodation was the basis of BR control and operated through retinal image blurring or intraocular pressure changes. However, neither McDougall (1903) nor George (1936) found BR control to be abolished by the paralysis of the intrinsic eye muscles. Indeed, McDougall found little effect and warned against the overemphasis of peripheral motor systems in the control of attention (McDougall, 1906).

The role of blinking, in fact, has not been directly investigated in past studies. Washburn & Gillette (1933) suggested that subjects may have used blinking as a method of control. Bárány & Halldén (1947) argued that blinking would not affect the rivalry rate in the long run. Meredith & Meredith (1962) warned subjects against blinking but did not measure blink rate. On the other hand, blink rates were measured in Experiment 2 and were found not to vary between conditions or over time. In fact, most subjects did not produce noticeable blinks at all during the 30 second trials. Because the mean measure of BR control and the increase of control with practice in Experiment 2 was comparable with that in Experiments 1 and 3, it would suggest that blinking plays no role in BR control. However, it may still be the case that small unnoticeable blinks occurred in Experiment 2. In any case, the investigation of the BR control of after-images may provide a test of the effects of blinking.

Not only the disagreement between experimenters but the tenuous reliability of their experiments are sources of disquiet with past findings. Helmholtz (1925), Breese (1899), McDougall (1903), and Fry (1936) all based their conclusions on the data from only one subject--presumably themselves in each case. In studying factors affecting voluntary control of attention, it is obviously desirable to minimize subjects' expectations and to take care to control motivation or instructional conditions. A necessary prerequisite would be to use a sufficient number of subjects naive to the purposes of the experiment. The purpose of the following experiments was to overcome past experimental deficiencies in clarifying the role of the peripheral mechanisms of accommodation, pupillary activity, eye movements, and blinking in the control of binocular rivalry.

Experiment 7

The first experiment was to test the effect of artificial pupils on BR control. Fry (1936) found that the reduction of artificial pupil size from 3.94 to 2.06 mm pupils was sufficient to abolish control in his subject. In any case, with artificial pupils smaller than 0.5 mm in diameter, BR control would necessarily be abolished, since accommodation changes would become completely ineffective in blurring the retinal images. In the present experiment, subjects were tested for their degree of control of BR under the conditions of no artificial pupils, and with 2.8 mm artificial pupils, 1.7, 1.0, and 0.5 mm pupils.

Method

Subjects

Nine volunteer subjects (5 males and 4 females) were obtained from the nonacademic staff of the Psychology Department. All subjects had normal vision without the use of corrective lenses. The natural pupil diameters of all subjects were measured to the nearest 0.5 mm in the viewing condition of no artificial pupils. The mean natural pupil size was 5.7 mm, with no subject having natural pupils less than 4.5 mm in diameter. Thus, it seems reasonable to assume that all the artificial pupil conditions produced reductions of effective pupil size in all subjects. No subjects had ever practiced BR control, and only three had any previous experience of BR. All subjects were naive to the purpose of the experiment.

Stimuli

The fusion stimuli consisted of left and right black rings, 58 mm apart, with inner diameters of 8.5 degrees and outer diameters of 10.5 degrees. Each ring was centred on a 28 degree square white field. The white fields were on black surrounds of a stereocard which provided a second fusion contour for the two fields. The rivalry contours were a black vertical diameter, 1 degree in width, in the right fusion ring and a black horizontal diameter, 1 degree in width, in the left fusion ring. The fusion rings and rivalry lines were inked on thin white paper and mounted in the black stereocard.

Apparatus and procedure

The apparatus consisted mainly of a Stereoking Model HN-44 stereoscope, in which could be fixed a 4 x 10 cm stereocard, 5.5 cm from refracting lenses, providing fixation at infinity. Immediately in front of the refracting lenses, artificial pupils could be mounted and adjusted to the interocular distance of any subject. The stimuli were transilluminated by a 500-W incandescent bulb placed behind the stereocard. To keep retinal illumination constant for all pupil conditions, adjustments were made in the distance of the incandescent bulb from the stereocard and the input voltage to the bulb by the use of a Variac transformer. The effective luminance was measured at the lens for the no-pupil condition or behind the artificial pupil with an S.E.I. spot photometer. In all conditions, the luminance of the black fusion rings, vertical and horizontal diameters was 0.31 ft-L. The white background luminance was a uniform 4.0 ft-L. A chinrest and nose slot were adjusted for the subject in order to provide a comfortable and fairly stable head position. During a test trial, the subject pressed a small event counter in his preferred hand to indicate each alternation in BR. Rate of alternation was measured for 30 second timed trials which were separated by 30 second rest periods.

All subjects were given the general instructions: (1) "at the (ready) signal look into the steroscope and fixate at the apparent intersection point of the vertical and horizontal lines", (2) "after the (start) signal press the counter once for each alternation in rivalry", and (3) "at the (stop) signal stop pressing and look away." Subjects were instructed to keep their heads stationary and not to blink excessively during test trials. In addition, subjects received one of three different instructions for any one test trial. The instructions were identical to those detailed in Experiment 1 of "passive rate", "slow rate", and "rapid rate". The "slow rate" and "rapid rate" instructions were essentially the same as Fry's (1936) "attempted retardation" and "attempted acceleration" conditions. They were then given 2 minutes viewing in the no-pupil condition to familiarize them with counting alternations during BR and to allow the BR rate to stabilize after what Cogan & Goldstein (1967) found to be an initial increase of BR rate commonly observed in naive subjects. In each viewing condition, all subjects followed the same sequence of instructions over nine test trials: the "passive rate" for the first 30 second test trial, the "slow rate" for the next four trials, and the "rapid rate" for the last four trials. Initially, all nine subjects were tested under the three viewing conditions of no artificial pupils, 2.8 mm pupils, and 1.7 mm pupils in balanced order so that each condition appeared three times in each position of order.

Approximately 2 months later, all nine subjects were tested in the viewing conditions of no artificial pupils, 1.0 mm pupils, and 0.5 mm pupils in a similar balanced order. A complete testing session was about 45 minutes in duration. Subjects were given no knowledge of results throughout the experiment.

Results and Discussion

After the initial 2 minute familiarization period, all subjects reported no difficulty in indicating rivalry alternations of the vertical and horizontal lines. The experimenter observed no head movements of subjects during all the test trials. Subjects also followed the instructions not to blink excessively. Most subjects, in fact, did not blink at all during any 30 second test trial. Subjects who did blink occasionally during test trials did so at about the same low frequency regardless of the viewing condition or instructions.

The measure of rivalry rate under the "slow rate" and "rapid rate" instructions in alternations per minute and the percentage BR control measure, (100)(rapid - slow)/(rapid + slow), were the same as described in previous experiments.

Table 4.1 gives the mean slow rates, rapid rates, and percentage control measures for both test sessions. Since there was no practice effect between the two test sessions,

TABLE 4.1

MEAN SLOW RATES AND RAPID RATES IN ALTERNATIONS PER MINUTE AND MEAN BR CONTROL PERCENTAGES FOR THE SIX CONDITIONS OF BOTH TEST SESSIONS.

	Natural Pupils I	2.8 mm	1.7 mm	Natural Pupils II	1.0 mm	0.5 mm
Slow Rate	14.6	13.4	12.8	14.0	12.3	13.0
Rapid Rate	33.9	32.9	32.9	32.4	31.1	31.1
Percentage Control	38.3	39.6	40.1	41.2	42.7	40.5

presentation order was not included in the subsequent data analysis. An analysis of variance applied to the slow rate and rapid rate measures showed a significant difference ($F = 27.9$, $df = 1/8$, $p < .001$) between the rivalry rates but no significant effect ($F = 0.98$, $df = 5/40$, $p > .50$) of pupillary conditions on the rivalry rate measures. A Subject by Condition analysis of variance applied separately to the BR control measures found no significant effect ($F = 0.11$, $df = 5/40$, $p > .50$) due to pupillary conditions. In summary, the instructions of "slow rate" and "rapid rate" consistently produced a very significant difference of rivalry rates in all pupillary conditions. In this experiment, the reduction of artificial pupil size had no effect on BR control.

The discrepancy of the present results with Fry's (1936) findings are unlikely to be due to differences in stimulus conditions. The retinal area subtended and the black-white contrasts were about the same in both cases. The main difference in stimulus conditions was that Fry (1936) had three bars in each rivalry stimulus compared to one bar in the present experiment. In any case, according to the retinal blurring hypothesis, the BR control of any illuminated stimuli should be lost with the use of the very small artificial pupils.

A second source of discrepancy may be due to differences in the experimental subjects. As far as possible, the subjects in the present experiment were kept naive and free from expectations about their ability to control the rivalry in any of the pupillary conditions. The fact that the overall mean slow rate, rapid rate, and percentage control is nearly identical to these respective measures in naive unpracticed groups of subjects in the similar conditions of Experiments 1, 2, and 3 suggests that the subjects in the present experiment were a representative naive sample. On the other hand, any prior expectations on the part of Fry's (1936) subject may have made it difficult for him to exert equal amounts of effort under the two pupillary conditions. Whatever the case, the reliability of Fry's (1936) results with respect to the effect of small artificial pupils on BR control would seem to be in question.

The lack of any difference due to artificial pupils does not exclude the possibility that accommodation changes do provide the basis of BR control. It only suggests that if there are acommodation changes concomitant with BR control, the resulting image blurring in the natural pupil or large pupil condition has no effect on BR control as compared to the small artificial pupil condition in which retinal image blurring is eliminated. One is left with the necessity of developing alternative explanations if accommodation is still held as the basis of BR control. In any case, BR control should be abolished when the accommodation function is eliminated due to paralysis of the intrinsic eye muscles. The next experiment, therefore, examines the effect of intrinsic eye muscle paralysis on BR control.

Experiment 8

A mydriatic and cycloplegic named Mydrilate was used. One drop in each eye was sufficient to produce complete ciliary muscle paralysis and pupillary dilation commencing approximately 15 minutes after administration and lasting approximately 6 hours. Its effects could be more rapidly reversed after a testing session with the administration of one drop in each eye of 0.5% solution physostigmine. The present author initially tested the effect of Mydrilate on himself and observed that the inability to focus was subjectively disturbing and seemed to produce increased caution. These introspections suggest that intrinsic eye muscle paralysis may produce a generalized motivational decrement in subjects. To test for this possibility a visual task (simple reaction time, RT) and a nonvisual task (hand squeeze strength) were included in addition to the test of BR control. If BR control was abolished but the RT task and squeeze strength task were unchanged with Mydrilate, it would be clear confirmation of accommodation as the basis of BR control.

Method

Subjects

Twenty subjects (10 males and 10 females) with uncorrected normal vision and under 30 years of age were obtained from an introductory psychology class. No subject had any prior experience with BR. All were naive to the purpose of the experiment.

Apparatus and Procedure

The apparatus, illumination, and testing procedure for BR control were the same as that in Experiment 7, except that only the 0.5 mm artificial pupils were used. In addition, subjects were instructed to maintain for all three instructional conditions the same criterion of what they considered to be a BR alternation. This instruction was to test the extent to which subjects in Experiment 7 may have enhanced their BR control measures by distorting their criterion under the "slow rate" and "rapid rate" instructions.

The apparatus for the visual RT task consisted of telegraph key, reaction stimulus, reaction timer, and electrical circuitry, in addition to the chinrest and stereoscope used in the BR task. Subjects viewed the stimulus through the stereoscope with the stereocard and artificial pupils removed. The stimulus (a 24-V, 3-W red light bulb placed 60 cm behind the stereoscope) provided a binocularly viewed red disk of 25 ft-L uniform illumination. Subjects were positioned at the stereoscope in a lightproof and sound-deadened room. The subject was instructed to hold the fingers of his preferred hand immediately above the telegraph key and to respond as quickly as possible at the onset of the reaction stimulus by tapping the telegraph key. Thirty-five reaction trials were presented in serial order with no warning signals. The onset of reaction stimuli followed previous trials by varying intervals of time on a semi-random schedule. The intertrial intervals of 3, 4, 5, 6, and 7 seconds occurred an equal number of times in the total of 35 trials. Subjects were warned to wait for the onset of the reaction stimulus to avoid anticipatory tapping.

The apparatus for the squeeze task consisted simply of a hand dynamometer hydraulically connected to a pressure gauge. Subjects were instructed to squeeze the dynamometer bulb as strenuously as possible on each of three trials, separated by 30 second rest intervals.

All subjects performed the three tasks in the same order (BR control, RT task, and squeeze strength task) on each of two separate test sessions held 1 week apart at the same time of day. For both sessions, the instructions and procedures were exactly the same except that in one session subjects had Mydrilate administered 20 minutes prior to testing.

The 20 subjects were divided randomly into two groups so that both Group A and Group B contained five males and five females. Group A first had the normal test session followed by the treatment test session; Group B had the reverse order of conditions. At no time were any subjects given any knowledge of results.

Results and Discussion

In the BR task the same measures as used in Experiment 7 were taken of passive rate, slow rate, and rapid rate in alternations per minute, and the percentage BR control. In the RT task, the first 10 trials from each subject in each test session were considered as warm-up trials and were excluded from the results. The median RT from the remaining 25 trials was used as the subject's RT in each test session. In the squeeze strength task, the mean of the three trials in $\mathrm{lbs/in.}^2$ was used as the subject's squeeze strength for each test session.

The mean values of each of these measures for the 20 subjects under each treatment condition are shown in Table 4.2.

The effect of intrinsic eye muscle paralysis tends to be the same as that found by Fry (1936)--a reduction of rapid

TABLE 4.2.

MEANS FOR BOTH GROUPS COMBINED OF RIVALRY RATES, PERCENTAGE BR CONTROL, REACTION TIME, AND SQUEEZE STRENGTH UNDER NORMAL CONDITIONS AND WITH THE INTRINSIC EYE MUSCLES PARALYZED.

	Slow (Alternations/Min)	Rapid (Alternations/Min)	BR Control (Percent)	RT (Msec)	Squeeze Strength (lbs/in.^{2})
Normal	12.6	32.8	42.8	260	18.4
Paralyzed	13.8	30.5	37.9	269	17.8
Difference	n.s.	$< .10$	$< .10$	$< .05$	$< .10$

rate and an increase of slow rate. However, the changes are so slight that neither reaches the .05 level of significance with a one-tailed test. The mean reduction of the BR control measure approached significance ($t = 1.62$, $df = 19$, $.10 > p > .05$), but the mean increase of reaction time is significant ($t = 1.87$, $df = 19$, $p < .05$), and the mean decrease of squeeze strength also approached significance ($t = 1.64$, $df = 19$, $.10 > p > .05$). Therefore, the effect of eye paralysis produces a slight decrement in performance, which reaches about the same level of significance for all three tasks. The differences between the mean slow rate and mean rapid rate is still very significant ($t = 6.5$, $df = 19$, $p < .0001$) in the eyes-paralyzed condition.

The only difference in procedure between the otherwise identical testing conditions of the Experiment 7 0.5 mm pupil condition and Group A in the normal condition of the present experiment was the additional instruction given to Group A to use the same criterion for alternations under both rivalry rate instructions. The two groups have almost identical mean values of slow rate, rapid rate, and BR control. Therefore, it seems reasonable to conclude that subjects do not distort their criterion to obtain fewer alternations in the slow rate and more alternations in the rapid rate.

In conclusion, intrinsic eye muscle paralysis does not produce a specific loss of BR control. On the contrary, very significant BR control is present with the complete abolition of accommodation activity. If the nonsignificant tendency of decreased BR control with eye paralysis is real, it is probably due to some central factor that produced performance decrements in all three tasks.

Experiment 9

Fry (1936) found that BR control of afterimage stimuli was practically abolished with the use of homatropine. He reasoned that BR control of afterimages was mediated through the intraocular pressure changes resulting from accommodation. Although research investigating the effects of accommodation on intraocular pressure (Armaly & Rubin, 1961) did not find the sort of pressure-changing mechanism envisaged by Fry, it is still possible that intrinsic eye muscle paralysis does abolish control of afterimage rivalry. Therefore, this possibility needed to be investigated. It was also decided to include a test of the comparative controllability of single line and triple line rivalry stimuli during eye paralysis to determine if the discrepancy of the findings of the present experiments with Fry's (1936) was due to the difference in rivalry stimuli.

Experiments 1, 2, and 3 found that spaced practice of the "slow rate" and "rapid rate" instructions produced a decrease in the measured slow rate, and increase in the measured rapid rate, and hence an increase in the measure of BR control. Because this result was obtained with eyes normal and without the use of small artificial pupils, it is possible that an accommodation mechanism provided the basis for the increased control of well-practiced subjects. This possibility was also tested in the present experiment.

Method

Subjects

Twenty-eight subjects (14 males and 14 females) with uncorrected normal vision and under 30 years of age were obtained from an introductory psychology class. All subjects were naive with respect to BR and the purposes of the experiment.

Stimuli

One pair of rivalry stimuli (single vertical and horizontal diameters of fusion rings, H-V), was the same as that of Experiments 7 and 8. A second pair of rivalry stimuli (3H-3V) was produced by adding two equally spaced lines parallel to each of the rivalry diameters of the first pair. The additional rivalry lines were 7 degrees in length and 1 degree in width and had the same illumination as the other black fusion and rivalry lines. Instead of producing one intersection point of rivalry as the first rivalry pair, this pair produced the intersection of three vertical and three horizontal lines, or nine rivalry intersections. The afterimage rivalry stimuli consisted of a single vertical bar on the right eye and a single horizontal bar on the left eye, which bisected each other in the binocular condition. Both bars were 4 degrees in width and 28 degrees in length. They were produced by a photoflash behind the stereoscope projected through cut-out slots of a black stereocard.

Apparatus and procedure

The apparatus, instructions, and stimulus illumination for the two pairs of illuminated rivalry stimuli were the same as in Experiment 8. The apparatus for the test of afterimage rivalry control was the same as that of Experiments 7 and 8, except that the artificial pupils were removed and the black stereocard with the vertical and horizontal bar slots was inserted in the stereoscope. A Blaupunkt manually triggered photoflash was mounted 20 cm behind the stereoscope equidistant from the two eyepieces. It produced a flash with a constant output of 150 J for a duration of approximately

1 msec. The subjects were instructed to close their eyes immediately after the flash and to view the afterimages. The "start" signal for the beginning of rivalry alternation counting was given always 5 seconds after the flash.

The 28 subjects were allotted randomly to two groups so that a well-practiced Group P and an unpracticed Group U each contained seven males and seven females. Group P was initially tested with Mydrilate, using only the single vertical and horizontal rivalry stimuli, and without knowledge of results. Group P was then given 12 consecutive practice days with eyes normal. Prior to each practice day after Practice Day 1, each subject was given knowledge of his previous day's performance in terms of mean slow rate, mean rapid rate, and percentage BR control. The subject was then given knowledge of results after each trial and was reinforced with mild praise for any improved performance at the end of the practice day. According to the findings of Experiment 3, this procedure gives the maximum increase of BR control. Following the 12th practice day, Group P was given a final test day with Mydrilate and without knowledge of results. Subjects were tested with the single line rivalry stimuli, then triple line rivalry stimuli, and finally with the afterimage rivalry stimuli, following the normal test trial sequence in each case. For the afterimage stimuli, the 30 second rest periods were extended to 100 seconds. Group U was tested under the same conditions and procedure as the final test day of Group P.

Results and Discussion

The subjects found no difficulty in indicating BR alternations of the afterimage stimuli on the final test day. The alternations were reported as being unambiguous, with a complete disappearance of one afterimage bar usually occurring with the appearance of the other. This virtually eliminated the possibility of criterion problems for subjects.

The main results of this experiment are illustrated in Figure 4.1. Group P's practice of the "slow rate" and "rapid rate" instructions showed very significant effects between Practice Day 1 and Practice Day 12. The mean slow rate showed a highly significant decrease ($t = 9.73$, $df = 13$, $p < .0001$); the mean rapid rate showed a highly significant increase ($t = 11.2$, $df = 13$, $p < .0001$); and the percentage control measure showed a highly significant increase ($t = 21.0$, $df = 13$, $p < .0001$). The effects due to practice are very similar to the results of Experiments 1, 2, and 3. The fact that this increase of BR control, using the 0.5 mm pupils, is at least as great as that without artificial pupils is further confirmation of the conclusions of Experiment 7.

Comparisons between the Initial Test Day and Practice Day 1 found no significant differences of slow rate, rapid rate, and BR control. This confirms the results of Experiment 8, that eye muscle paralysis has no effect on

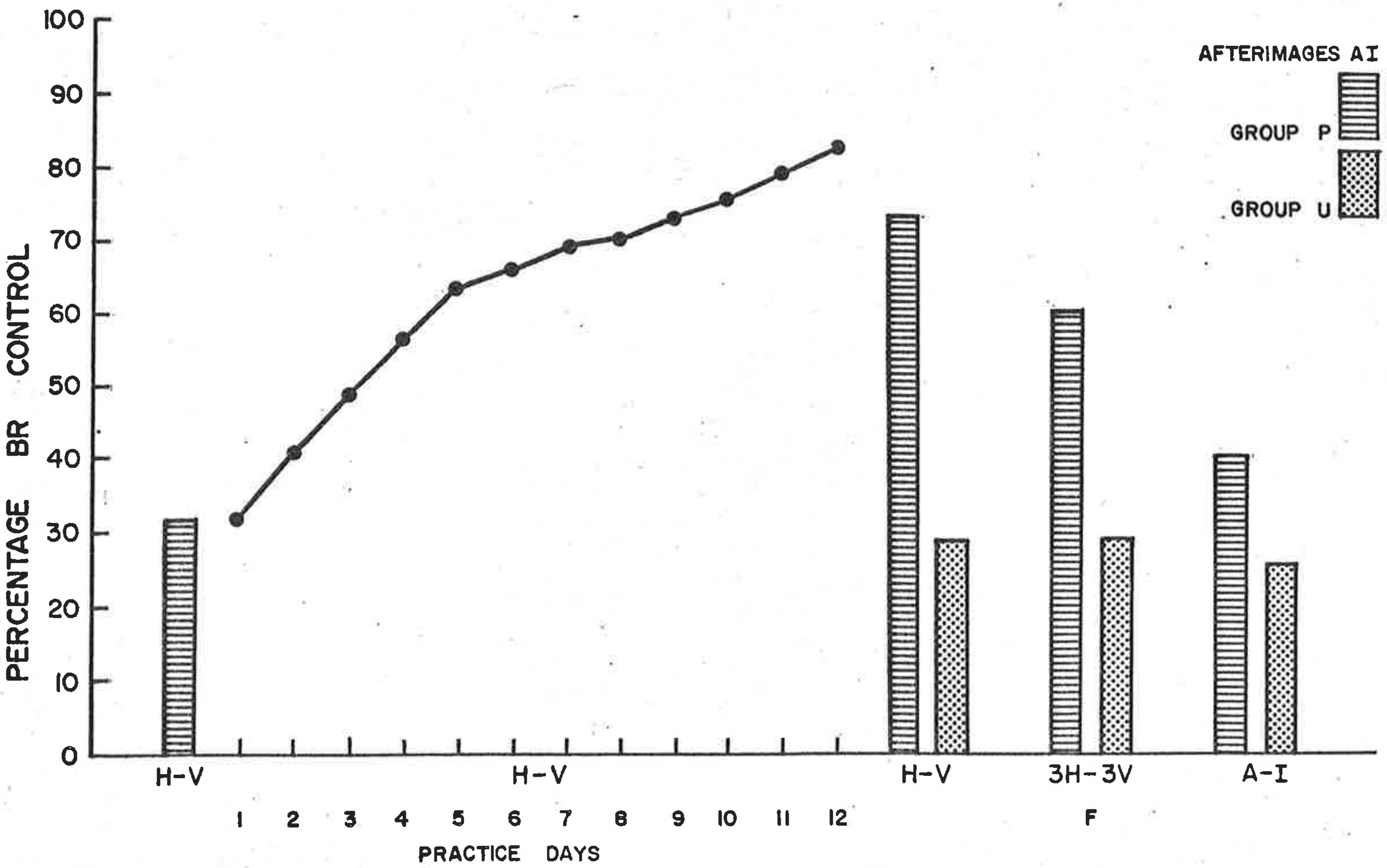


Fig. 4·I. Mean BR control percentages with eyes paralyzed for Group P on the initial test day (I) and for Group P and Group U on the final test day (F) and means for Group P with eyes normal pn the twelve practice days.

unpracticed control. On the other hand, the differences between Practice Day 12 and the Final Test Day did reach significance ($p < .01$). It is doubtful if these differences can be attributed to a specific loss of an accommodation factor in well practiced control because there are other factors which would tend to decrease the performance of Group P on the final test day. A general performance decrement with Mydrilate would be expected to produce the same proportional decrement as with unpracticed control, but this would produce a greater absolute reduction of well-practiced control. According to the generalization of Ammons (1956) the absence of knowledge of results and reinforcement on the final test day must also tend to decrease Group P's performance in comparison with Practice Day 12.

This drop of performance on the Final Test Day is also consistent with the results of Smode (1958). He gave subjects 11 spaced practice trials on a tracking task under high or low information feedback. Following these trials subjects were given a further 3 trials with the same or a different level of feedback. Smode's Group 3 (1958) had similar treatment to Group P of the present experiment--high information feedback during training followed by a low information feedback condition. Interestingly, the learning curve for this group over 11 practice trials was very similar to that of Group P. Then Smode's Group 3 showed a drop of performance from the last high feedback trial to the first low feedback trial which was about 29% of the increase of performance obtained from practice. The drop of performance of Group P from Day 12 to the Final Test Day was about 20% of the increase obtained from practice. If Smode's results (1958) can be used as a standard with which to compare the present results, it would seem that the lack of knowledge of results in the Final Test Day would be a sufficient cause by itself for the reduction of BR control. Thus, the significant reduction of BR control on the Final Test Day cannot be attributed specifically to the effects of the paralysis of intrinsic eye muscles.

Although the effect of eye paralysis is a significant decrease of BR control from a mean of 84.0% on Day 12 to a mean of 74.3% on the final test day, a comparison with the initial test day mean of 32.0% shows that what control was developed through practice has been mostly (80%) retained. The comparison between the Initial Test Day and Final Test Day for Group P showed highly significant ($p < .0005$) differences of slow rate, rapid rate, and BR control, as did the comparison between the unpracticed Group U and the Group P Final Test Day. In summary, the practice of "Slow rate" and "Rapid rate" instructions with eyes normal produces a marked increase of control between the initial and final eyes-paralyzed conditions. In addition, it seems unlikely that this increased control is dependent on accommodation.

The effect of practice with the H-V stimuli clearly transferred to the control of the 3H-3V stimuli and afterimage stimuli since the BR control measures were significantly elevated ($p < .001$) above these respective values for Group U.

What is most important with respect to the original purpose of the experiment is that the naive unpracticed Group U with Mydrilate and using very small artificial pupils had very significant control with all BR stimuli. The rapid rate/slow rate difference with the H-V stimuli is highly significant ($t = 5.73$, $df = 13$, $p < .0005$), as is the difference with the 3H-3V stimuli ($t = 7.75$, $df = 13$, $p < .0005$), and also with the afterimage stimuli ($t = 5.84$, $df = 13$, $p < .0005$). With the afterimage stimuli, the peripheral factors of accommodation, pupillary activity, retinal image movements, and blinking are eliminated, as is the possibility of criterion distortions. Even in this condition there is significant BR control by naive unpracticed subjects and highly significant control ($t = 10.6$, $df = 13$, $p < .0001$) by well practiced subjects. This argues strongly for the existence of some component of control that is exerted on a higher, nonperipheral level.

George (1936) concluded that BR represents a "lower level function" than reversible perspective, and as a result, BR is under less voluntary control than is reversible perspective. In any case, he is implying that the main source of control still accessible to BR is a component that can be affected on a higher level. This corresponds with McDougall's (1906) conclusions that despite the slight effect of atropine in reducing voluntary attention in BR, the role of motor adjustment of sense organs is one that is only secondary to what he calles "cerebro-ideational activity." The results of the present experiments also suggest that the peripheral mechanisms of accommodation, pupillary activity, blinking, and retinal image movement, if they have a real effect at all, play only a minor role in the control of binocular rivalry.

CHAPTER V

THE STRENGTH OF AFTERIMAGES AND MOVEMENT AFTEREFFECTS FOLLOWING INDUCTION PERIODS WITH BINOCULAR RIVALRY.

The purpose of the following series of experiments is to gain some information regarding the nature of binocular rivalry suppression and rivalry control in relation to its effect on afterimages (AI) and the movement aftereffect (MAE). A negative AI can be clearly seen on a homogeneous background after prolonged stable fixation of a visual pattern with at least a moderate intensity of illumination. It has been hypothesized that the AI is due to some kind of neural "fatigue" of cells specific to the configuration of the fixated retinal image. The discussion of the origins of AIs will be included in the general discussion at the end of the chapter.

A general strategy to investigate the neural effects of binocular rivalry would be to compare the strengths of AIs following two different stimulation periods. 1. an induction period in which the fixated pattern is viewed with only the right eye, and 2. an induction period in which the fixated pattern is viewed with the right eye and a rivalry stimulus pattern is viewed with the left eye. All the right eye stimulus variables during induction and AI measurement would be identical in the two conditions. The only difference between conditions is the addition of rivalry stimulation during the induction period of Condition 2. Rivalry stimuli may be used which do not produce interfering AIs during the post-induction period. Then a reduction in strength of the right eye AI following Condition 2 may be attributed to interference effects of rivalry stimulation during only the induction period. If this is the case, it may be inferred that rivalry stimulation had a neural effect on those levels which give rise to the AI. Thus, to the extent that the neural substrates of AIs are understood, neural effects of BR and BR control may be investigated.

If a subject maintains a constant fixation point so that a moving pattern continues to stimulate the retina in the same way, a movement aftereffect (MAE) is observed as an opposite movement immediately after the moving pattern is stopped. In a similar fashion to the examination of the effect of rivalry on the AI, one may investigate the question of the extent to which rivalry stimulation during the induction period of a moving pattern affects the strength of the subsequent aftereffect.

There is some controversy as to the level at which the MAE originates. In a personal communication, Pickersgill (1970) maintains that a retinal element has not been disproved.

However, she admits that what she calls a "retinal" element may not be in the retina, but might be ocular dominant cortical cells similar to those found in the monkey by Hubel & Wiesel (1968). Many experimenters would concede at least the existence of a central component in the origin of the MAE. In any case it seems most likely from the existing evidence that the MAE originates from higher, more central levels than does the AI. The existing evidence for the origin of the MAE will be discussed in more detail at the end of the chapter.

The difference in the levels of origin of the AI and MAE, at least to the extent to which they have been verified physiologically, may provide a technique for investigating the level of action of binocular rivalry suppression and the control of rivalry. It will be assumed that the presence of rivalry stimulation during the induction periods for the AI or MAE can only have a detrimental effect on the subsequent AI or MAE as compared with those resulting from monocular induction periods. With these assumptions of the effect being detrimental, and with the origin of the MAE being more central than the AI, three basic results seem possible depending on the level of rivalry suppression. 1. If neither the AI nor the MAE are decreased after a period of rivalry stimulation, it may be inferred that the effect of rivalry suppression is more central than the origins of both the AI and MAE. 2. If the MAE but not the AI is decreased, then rivalry suppression is acting on the same level as the MAE but on a more central level than the AI. 3. If, however, both the AI and the MAE are decreased, it may be inferred that rivalry suppression occurs on the same level as the AI or on a level peripheral to both the AI and the MAE.

Experiment 10

The purpose of this experiment was to establish whether or not BR would decrease the strength of a subsequent MAE as compared to that following a monocular, nonrivalry induction period. The basic procedure was to measure the strength of the aftereffect in terms of its duration and the magnitude estimate of the initially observed velocity. The strength of the monocular MAE was measured following two types of stimulation conditions. 1. monocular rotational stimulation for 60 seconds with no rivalry stimulation, and 2. monocular rotational stimulation with binocular rivalry of a nonmoving stimulus pattern. If the MAE is less following the BR period than the monocular period, the difference may be attributed to the addition of BR stimulation during the induction period.

Method

Subjects

Twelve subjects (7 females, 5 males) were obtained from an introductory psychology course. All had normal vision without corrective lenses. None had any previous laboratory experience of binocular rivalry or movement aftereffects. All subjects were naive to the purpose of the experiment.

Apparatus and Stimuli

The basic apparatus consisted of a modified Brewster/ Holmes type stereoscope, mounted in a rigid frame with a chin rest. The combined wedge prism and refracting lenses in the two viewing windows provided focusing at infinity for binocular stimuli at a distance of 20 cm for subjects with normal vision. 2.5 mm artificial pupils were mounted to the viewing windows and could be adjusted to the interocular distance of any subject. The separation between the binocular stimuli could be adjusted to provide a comfortable degree of convergence under conditions of binocular fusion. This distance separation was typically about 9 cm. A light proof partition was added between the two viewing areas to allow independent illumination of the two stimuli. A small slide projector was mounted adjacent to each viewing area to provide illumination, which was varied by the addition or subtraction of neutral density filters to the slides of the projectors. The use of 6 v, 12 watt cold lamp projection bulbs avoided the noise usually associated with fan-blown, air-cooled slide projectors. The projectors illuminated circular areas subtending 15 degrees of visual angle in both the left and right ocular fields. These disks of light with black surrounds provided a fusion contour for the two eyes in the binocular condition.

Left and right eye fields contained identical fusion stimuli centred in the illuminated disks. The fusion stimuli consisted of various lines and geometric shapes enclosed by a diamond shaped perimeter 10 degrees across opposite points of the diamond (see Figure 5.1). The black fusion lines subtended 10 min of visual angle on white backgrounds and provided a larger number of contours to facilitate fusion. A circular area 4 degrees in diameter was removed from the centre of each fusion pattern. Vertical and horizontal white cotton threads, 2 min thick, were mounted to bisect each fusion stimulus. They intersected in the centre of each fusion stimulus and served as fixation points during the experiment. Behind the intersection midlines in the cut-out circular area visual patterns could be mounted to serve as rivalry stimuli.

The left eye rivalry stimulus was composed of 8 white threads horizontally and evenly spaced across the central circular area, 4 above and 4 below the horizontal midline. This provided high contrast contours for the left eye rivalry stimulus since a black background resulted from the negligible intensity of ambient illumination behind the apparatus. The right eye induction stimulus was a pattern of randomly placed black dots each subtending 10 min of visual angle on a white background. The dots accounted for approximately 33% of the total area of the pattern.

A neutral density filter was mounted on the back of the right fusion stimulus to cover the cut-out circular area behind

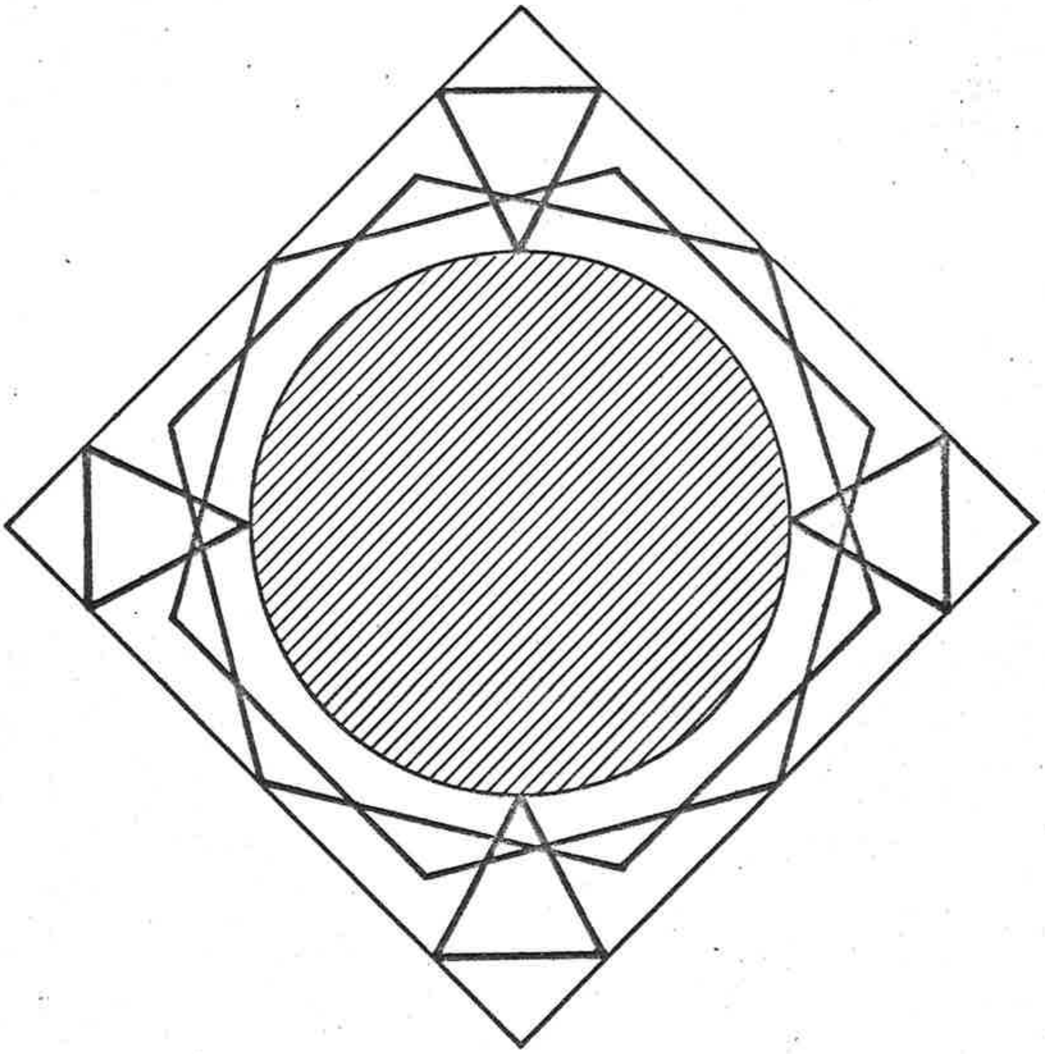


Fig. 5·1. Fusion stimulus for left and right eyes in Experiments 10, 11, and 12. The MAE or AI induction stimuli were mounted in the shaded area of the right eye and the rivalry stimuli were mounted in the left eye shaded area.

the intersecting horizontal and vertical midlines. The random dot pattern was mounted on a disk attached to a gear box powered by a synchronous motor. This apparatus produced a rotation of the random dot pattern at a constant angular velocity of 36 degrees/second. The rotational apparatus was placed so that the dot pattern filled the cut-out circular area and rotated about the central fixation point. The purpose of the neutral density filter in front of the rotating dot pattern was to reduce the contrast of the pattern, thereby reducing its predominance in rivalry to a suitable level without reducing the illumination of the right eye fusion stimulus.

Other apparatus included an incandescent light for additional illumination of the random dot pattern at the cessation of rotation, a stop watch for timing the induction period and the duration of the MAE, and switches to control the rotation and illumination of the stimuli.

The luminances of the right eye fusion and rivalry stimuli during the induction and test periods as measured at the artificial pupils with an S.E.I. spot photometer are given in Table 5.1.

To terminate the 60 second induction period the rotation was stopped and simultaneously the right eye visual field was given additional illumination from an incandescent lamp. This increased the illumination by a factor of three,

TABLE 5.1

LUMINANCES IN FT-L OF THE RIGHT EYE FUSION AND RIVALRY STIMULI DURING THE INDUCTION PERIOD AND TEST PERIOD AND LUMINANCES OF THE LEFT EYE FUSION AND RIVALRY STIMULI DURING THE INDUCTION PERIOD OF THE WEAK AND STRONG RIVALRY CONDITIONS.

Right Eye	Period	
	Induction	Test
White fusion background	3.0	9.0
White horizontal and vertical fusion lines	3.0	9.0
Black fusion lines	0.3	0.9
White rivalry background	0.5	1.5
Black rivalry dots	.05	0.15

Left Eye	Weak rivalry	Strong rivalry
White fusion background	5.0	20.0
White horizontal and vertical fusion lines	5.0	20.0
Black fusion lines	0.5	2.0
White horizontal rivalry lines	5.0	20.0
Black rivalry background	0.01	0.01

producing the luminances as shown in Table 5.1. The purpose of increasing the illumination of the right eye field during the test period was to facilitate the observation of the MAE and to suppress more reliably any possible transferred after-image from the left eye. These conditions of rotation and illumination of the right eye field were constant throughout the experiment regardless of conditions of stimulation of the left eye. The purpose of the 2.5 mm artificial pupils was to maintain a constant right eye retinal illumination between the different experimental conditions.

There were two basic experimental conditions, binocular rivalry and monocular nonrivalry. For the monocular condition the view through the left eye was occluded with a black opaque disk mounted in the viewing window of the stereoscope. This resulted in homogeneous darkness of about 0.01 ft-L illumination. There were two binocular rivalry conditions differing only in the illumination of the left eye patterns. A "weak" rivalry condition was produced by a moderate level of left field illumination, and a "strong" rivalry condition was produced by the removal of some neutral density filters in the slide projector resulting in a four-fold increase of left eye illumination (see Table 5.1). Since the left eye rivalry stimulus of the present experiment had a black background of a fixed low level illumination, changes in the front illumination of the left eye pattern resulted in changes of contrast in the rivalry stimulus. According to Levelt (1968) this increased contrast should result in a greater proportion of suppression time of the rotating random dot pattern during the induction period.

Procedure

Subjects were comfortably seated at the stereoscope in a very dimly lighted room. Since subjects had no previous experience of the MAE, they were first given one trial in the monocular condition as practice. In this trial no suggestion was given to subjects as to the nature or strength of the effect. Subjects were then instructed to fixate at the intersection point of the white horizontal and vertical lines. Subjects were told that the random dot pattern would be rotated clockwise for a period of 60 seconds, that at the end of the period the rotation of the pattern would be stopped, but that they should continue fixation as before and observe what happens to the random dot pattern. All subjects reported seeing the apparent rotation of the random dot pattern in the anticlockwise direction. They also reported that it seemed to decay in strength over time until it stopped entirely. Subjects were instructed that on a typical trial they were to observe the MAE in the same way and to say "stop" when the apparent anticlockwise rotation of the random dot pattern entirely stopped.

Subjects were also instructed to observe the initial strength of the aftereffect in terms of its apparent angular velocity and to make a magnitude estimate of its strength relative to the initial strength of the MAE from a standard trial. They were to report this magnitude estimate after they said "stop" so as not to disturb the ongoing MAE. Subjects were instructed to assign a value of 10 to the initial strength (apparent angular velocity) of the MAE in the standard trial. If the initial strength in a subsequent trial was greater, subjects should give a magnitude estimate value greater than 10. Conversely, if the initial strength in a subsequent trial was less, subjects should give a magnitude estimate less than 10. The magnitude estimates should also reflect the proportional strength of subsequent MAEs, e.g. an MAE half as strong as the standard should be given a value of 5 or one twice as strong initially given a value of 20. Subjects were instructed that in making a magnitude estimate they should use only the initial strength of the MAE and not be influenced by its duration. They were instructed always to use the standard trial as a reference rather than other test trials. The purpose of using both a duration measure and a magnitude estimate of the initial strength of the MAE arose from the hypothetical possibility of there being two components to the MAE. These two components (initial strength or "amplitude" and duration) may be independent to some extent or may be related in a nonlinear way. If that is the case, then one may be affected but not the other by rivalry suppression, or they may both be affected to different extents. To allow for this possibility both measures were used.

Subjects were also given practice fixating during binocular rivalry with the rotating random dot pattern and the stationary left eye pattern under the high illumination condition. Any adjustments of distance separation between the two patterns or in the lens-stimulus distance were made to provide comfortable fusion and clearly focused patterns. All subjects reported vigorous rivalry between the patterns with no loss of fusion. After a rest period of about five minutes subjects were presented with a trial under the monocular condition which served as the standard trial. Subjects said "stop" at the cessation of the MAE in this trial for practice but the recorded duration was not included in the subsequent data analysis. Subjects were then given a series of six trials with 60 second induction periods in which the subsequent duration of the MAE and the magnitude estimate of the initial strength of the effect were recorded. Intertrial rest periods were three minutes in length. Before each trial subjects checked to see if there was any apparent movement of the random dot pattern; if there was any residual or regenerated apparent movement, this previewing act always had the effect of eliminating it.

The six trials consisted of three conditions presented in a specified order with that order repeated once. The presentation order of the three conditions was balanced across subjects with 2 subjects following each of the six possible presentation orders. The three conditions consisted of the monocular and two binocular conditions. They differed only in the condition of binocular stimulation during induction periods. The monocular condition had no stimulation on the left eye and was free of rivalry. The "weak" rivalry condition had moderate illumination of the left eye pattern during the 60 second induction period resulting in a relatively small amount of rivalry suppression of the rotating dot pattern. The "strong" rivalry condition had high illumination of the left eye pattern resulting in a greater amount of rivalry suppression of the rotating dot pattern during the induction period. Following the induction period the illumination was increased for the right eye pattern and in the rivalry conditions the left eye illumination was terminated. Because the stimulus condition for viewing the MAE was identical for all three conditions, any differences in the strength of the MAE between conditions must be attributed to differences in left eye stimulation during the induction period.

Results and Discussion

All subjects reported that the rotating dot pattern was less dominant or more suppressed in the induction period of the "strong" rivalry condition than in the "weak" rivalry period. Apparently, then, the increased illumination of the left eye rivalry pattern produced the expected increase in rivalry suppression of the rotating dot pattern. No subject reported the appearance of a negative afterimage during the observation of the MAE in the test period even after the "strong" rivalry condition. Apparently the illumination of the dot pattern in the test period was sufficient to suppress any afterimage which may have transferred to the right eye.

The mean durations and magnitude estimates of the MAE in the 3 conditions are shown in Table 5.2. Because there was quite a wide range of MAE durations (3 seconds to 34 seconds) across subjects for the monocular condition, it seemed reasonable to standardize durations for each subject in terms of the percentage of his monocular condition duration. The mean percentage values for duration and magnitude estimates are illustrated in Figure 5.2. These percentage values were then used in individual comparisons. The difference in duration percentages between the monocular and "weak" rivalry condition was significant using a correlated means t-test ($t = 2.69$, $df = 11$, $p < .025$), and the difference between the "weak" and "strong" conditions in duration percentages was

TABLE 5.2

MEAN DURATION AND MAGNITUDE ESTIMATES OF THE MAE FOLLOWING THE THREE INDUCTION PERIOD CONDITIONS OF MONOCULAR NONRIVALRY, "WEAK" BINOCULAR RIVALRY AND "STRONG" BINOCULAR RIVALRY.

	Induced Period Condition		
	Nonrivalry	"weak" rivalry	"strong" rivalr
Duration (sec)	11.5	9.8	7.3
Magnitude Estimate (initial strength)	10.1	7.5	5.5

also significant ($t = 3.32$, $df = 11$, $p < .01$). Similarly the magnitude estimates were standardized in terms of percentage of the monocular condition for each subject. Here also the monocular -"weak" rivalry difference was significant ($t = 3.08$, $df = 11$, $p < .01$) as was the "weak"-"strong" difference ($t = 5.22$, $df = 11$, $p < .01$). Thus, the introduction of a weak binocular rivalry stimulus during the induction period produced a significant reduction of MAE strength. In addition, the increase of the rivalry stimulus strength produced a further decrease of MAE strength.

It may be premature at this point to conclude that the phenomenal visual suppression of BR is, itself, the cause of the reduced MAE. It may be the case that the contralateral effects of rivalry stimulation which reduce the MAE are operating at a level prior to that at which the phenomenal BR alternations arise. The induction stimulus may be inhibited

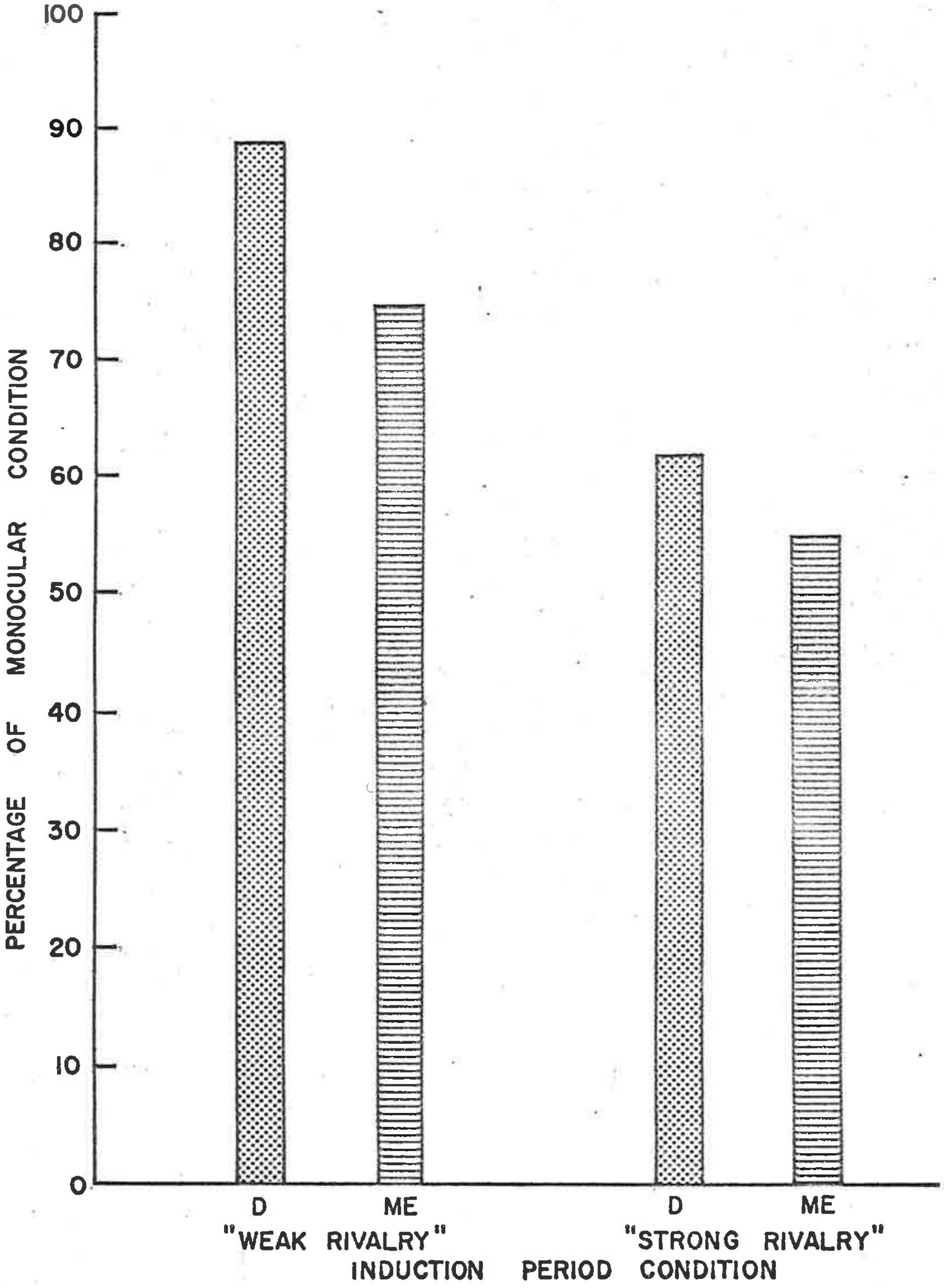


Fig. 5·2. Mean percentage values in terms of the monocular condition of durations (D) and magnitude estimates (ME) in Expt. 10.

or suppressed by rivalry stimuli on the first central level at which contralateral effects occur. This interference may be continuous and proportional in strength to the strength of the rivalry stimulus. According to this hypothesis, the phenomenal alternations of BR then operate at a subsequent or higher level where the percentage of time for which the induction stimulus is in phenomenal suppression is also a function of the strength of the rivalry stimulus. This hypothesis would generate a number of specific predictions, some of which will be tested in Experiments 11 and 12.

Experiment 11

The main purpose of this experiment is to examine the effect of BR stimulation on the subsequent strength of a negative afterimage (AI). If rivalry stimulation affects the MAE but does not affect the AI under similar conditions it may be inferred that the rivalry stimulation produces contralateral effects at a level below that of the MAE but above that of the AI.

In addition to this purpose, there are a number of other noteworthy alterations from the previous experiment in the present experiment. It may be recalled that the mean duration of the MAE in Experiment 10 was 11.5 seconds in the monocular condition. This is not a particularly vigorous MAE considering that the induction period was 60 seconds.

Presumably the low luminance of the rotating dot pattern limited the strength of the aftereffect. It is well known that a moving stimulus pattern dominates strongly in rivalry with a nonmoving pattern. In attempting to create a rivalry condition in which the rotating pattern would be suppressed a significant amount of the time the intensities and contrasts of the two rivalry stimuli were weighted strongly in favour of the left eye rivalry stimulus. This had the desired effect of producing a significant degree of suppression despite the movement attribute of the rotating pattern. However, even with the greater contrasts of the left eye rivalry pattern in the "strong" rivalry condition, the rotating pattern was in suppression a minority of the 60 second induction period.

For the purpose of providing a stronger MAE in the monocular condition and perhaps allowing a greater susceptibility of the MAE duration to the effects of rivalry, the dot pattern received a greater illumination for the present experiment. This would, however, make it virtually impossible to provide the left eye rivalry stimulus with sufficient intensity to produce significant BR suppression of the rotating induction stimulus. The only way to provide an equally strong left eye rivalry stimulus would be to use a moving stimulus there also. The drawbacks to this suggestion are obvious. A rivalry stimulus moving linearly in any direction or rotating about the fixation point will produce its own movement aftereffect which may transfer to the right eye during the test period following induction. This transferred effect may contribute to or subtract from the MAE being measured thereby being confounded with the possible effect of rivalry suppression during the induction period.

A possible way to overcome this drawback but still use a moving rivalry stimulus in the left eye is to use movement that is perpendicular to the rotating pattern at all points on the induction stimulus. This requires that the visual contours diverge symmetrically from or converge symmetrically towards the central fixation point. This requirement can be satisfied by using a spiral pattern which is rotated about the fixation point. Rotation of the spiral results visually in radial rather than rotational contour movement. Any movement aftereffect which is transferred from the left eye to the right eye during the test period would only produce an apparent radial movement aftereffect which should not be confused with the anticlockwise rotation of the MAE. Thus the use of a rotating spiral for the left eye rivalry stimulus should provide strong suppression of the rotating dot pattern without producing interfering transferred movement aftereffects during the test periods.

One additional reason for using a moving rivalry stimulus is that it can also be used as the rivalry stimulus for the induction period of the negative afterimage condition. The use of a stable pattern would produce its own AI which would then rival and suppress the measured AI during the test period. The suppression effect acting in the test period would confound the suppression effect acting in the induction period. Therefore it is necessary to use a moving rivalry stimulus in the AI condition.

A potentially useful source of information which was not utilized in Experiment 10 was the degree of rivalry suppression actually produced during the induction period by the left eye rivalry stimulus. The rather crude subjective estimates by subjects indicated that the induction stimulus was suppressed less than half of the time during "strong" rivalry and that the "weak" rivalry stimulus suppressed the induction stimulus even less of the time. It would be informative and rather easy to obtain more exact information regarding suppression time of the induction stimulus. Subjects could tap telegraph keys alternately to indicate shifting of dominance from one rivalry stimulus to the other. In this way the effect of various intensities of rivalry stimuli could be measured in terms of rivalry suppression which in turn could be related to the effect on the MAE.

Method

Subjects

Twelve subjects (6 males, 6 females) were obtained from an introductory psychology course. All subjects had normal vision without corrective lenses. None had any previous experience of BR or the MAE. All subjects were naive to the purpose of the experiment.

Apparatus and Stimuli

The apparatus was the same as that of Experiment 10 with the addition of two telegraph keys, a cumulative timer, and a second synchronous motor. The fusion stimuli were the same as those used in Experiment 10. The random dot pattern for induction of the MAE was the same as used previously, except that a neutral density filter was removed to increase the intensity of the dot pattern. For the induction of the negative afterimage, the left eye rivalry pattern from Experiment 10 of the eight thin white horizontal lines on a black nonreflecting background replaced the random dot pattern and neutral density filter on the right eye. The induction period rivalry stimulus on the left eye for both the MAE condition and AI condition was a one-throw black spiral on a white background. It replaced the horizontal line pattern from Experiment 10 and was centred on the intersection of the white horizontal and vertical fusion lines. The spiral pattern filled the 4 degree diameter circular rivalry area of the left eye. It was mounted on a disk which could be rotated clockwise by a synchronous motor at a constant 40 rev/min. This produced what appeared to be nearly concentric circular contours expanding radially at a constant rate from the centre fixation point to the periphery of the rivalry area.

It took approximately 3 seconds for a contour to move along any radius from centre to periphery.

Although variation of overall illumination has less effect than variation of contour contrasts in affecting rivalry dominance, three different intensities of illumination for the left eye rivalry stimulus were used in the MAE condition. The resultant amount of suppression was measured to see exactly what effect variation of intensities did have. Intensity condition 1 was provided by a low overall illumination of the left eye field with a neutral density filter placed over the spiral pattern. Intensity condition 2 was produced by an increase of illumination of the spiral only by removing the neutral density filter. Intensity condition 3 was produced by an increased overall illumination and without the filter covering the spiral pattern. Luminances of the left eye stimulus for these three intensities and luminances of the right eye induction stimuli for the MAE and AI conditions are presented in Table 5.3. For the test of the MAE the right eye induction stimulus of rotating random dot pattern was paired with the left eye rivalry stimulus under one of the three possible intensity conditions. If variation of intensity alone does affect the strength of a stimulus in rivalry this should be reflected in changes of measured suppression time and changes in MAE strength. The MAE was measured following the induction period under the same

TABLE 5.3.

LUMINANCES IN FT-L OF THE RIGHT EYE FUSION AND INDUCTION STIMULI FOR THE MAE AND AI CONDITIONS AND OF THE LEFT EYE FUSION AND RIVALRY STIMULI FOR THE THREE INTENSITY CONDITIONS OF EXPERIMENT 11.

	Condition		
Right Eye	MAE Induction	MAE Test	AI Induction
White fusion background and vertical and horizontal lines	3.0	9.0	20.0
Black fusion lines	0.3	0.9	2.0
White rivalry background	1.50	4.5	--
Black rivalry dots	0.15	0.45	--
White horizontal rivalry lines	--	--	20.0
Black rivalry background	--	--	0.01

Left Eye	Intensity Condition		
	1	2	3
White fusion background and vertical and horizontal lines	5.0	5.0	20.0
Black fusion lines	0.5	0.5	2.0
White spiral arm	1.0	5.0	20.0
Black spiral arm	0.1	0.5	2.0

conditions as it was in Experiment 10. The rotation of the dot pattern was stopped and illumination was increased by a factor of three at the same time as the left eye spiral rotation was stopped and its illumination terminated.

For the test of AI strength the right eye induction stimulus of horizontal white lines was paired with the left eye spiral stimulus at intensity condition 1. This intensity was sufficient to produce quite marked rivalry suppression of the induction stimulus. Following the induction period subjects were instructed to close their eyes to view the afterimage and at the same time the illumination of the left eye field was terminated. This provided a low level illumination for the right eye of long wavelengths resulting from the white light passing through the right eyelid.

Procedure

The general procedure and instructions given to subjects in the measure of the MAE strength were similar to those for Experiment 10 except for three changes. One change was that subjects were instructed to give a value of 100 to the initially observed angular velocity of the MAE in the standard trial instead of the value of 10 used in Experiment 10. Similarly subjects were instructed to give a value of 200 to MAE's twice as strong and 50 to MAE's half as strong in their initial component as that of the standard trial. The second change was that subjects were instructed to tap the right hand telegraph key to denote the termination of the MAE instead of saying "stop" as in Experiment 10. This change was introduced to eliminate the possibility of head movements arising from the act of vocalising "stop" which may affect the duration measure of the MAE. The third addition was that for the induction periods subjects were instructed to tap the right telegraph key with their right index finger when the rotating dot pattern became dominant in rivalry. When the dot pattern entered suppression and the spiral pattern became dominant subjects were to tap the left hand telegraph key. A tap of the right telegraph key activated a cumulative timer, a tap of the left key stopped the timer and produced one count on an event recorder. This provided a measure for the amount of time the induction stimulus was in rivalry suppression. Subjects were given one practice trial observing the MAE and were given practice in tapping the appropriate telegraph keys to denote alternations during rivalry.

Within the MAE condition a trial was added to check for the presence of any transferred MAE from the left eye spiral pattern to the right eye. Although contour movements in the rotating spiral pattern should only have been radial, some texture elements of the material on which the spiral had been drawn may have been perceived in rotation and consequently have produced some rotational aftereffect. If a MAE is produced by the spiral it may conceivably transfer to the right eye during the test period and confound the results of the right eye MAE.

However, a few subjects were tested prior to the beginning of test trials to check for any rotational movement in the spiral aftereffect. They observed the rotating spiral with their left eyes for a 60 second induction period under the high intensity condition. The spiral was then stopped and aftereffect observed. Subjects reported only the diverging radial movements or collapsing of the spiral during the aftereffect. Nevertheless, all subjects were given one trial in the experiment following the Intensity 3 rivalry condition for the MAE. In this trial subjects viewed the spiral pattern with the left eye for 60 seconds followed by viewing of the stopped dot pattern with the right eye. Subjects were instructed to report the nature of any movement of the random dot patterns.

Although it seems unlikely, it may still be the case that the spiral pattern transfers some effect to the strength of the dot pattern MAE. However, because the spiral pattern is rotated clockwise in the induction period any transferred MAE will tend to enhance the dot pattern MAE following the rivalry induction period. If a decrease of MAE following rivalry is expected, then any transferred MAE from the spiral pattern will only tend to reduce this difference. Therefore, significant differences between the monocular and binocular conditions may be taken as significant of a real effect of suppression from the binocular rivalry stimulus.

The general procedure for measuring the strength of the negative AI was similar to that for the MAE. During the 60 second induction period in the rivalry condition, subjects fixated continuously at the vertical and horizontal line intersection point and tapped telegraph keys to indicate rivalry alternations. Immediately following completion of the induction period the subject closed his eyes to observe the AI. Because the maximum intensity of the AI was often not seen immediately for two or three seconds following eye closure, subjects were instructed to make a magnitude estimate of the maximum intensity of the AI. AIs also differed from MAEs in that they usually disappeared and reappeared several times before disappearing finally. This fact made it impossible for subjects to signal the last disappearance. Instead, the duration measure was obtained by instructing subjects to tap the right telegraph key when the AI appeared and to tap the left key every time the AI disappeared. The duration measure was then taken as the accumulated time of the AI presence.

The order of the MAE and AI conditions was balanced within the 12 subjects. The MAE condition consisted of six trials. The first and sixth trials were the monocular condition, of which the first was the standard trial whose magnitude was given a value of 100. Between Trial 1 and 6 subjects were given one trial for each of the three intensity values for the rivalry conditions. In addition, following the rivalry condition with Intensity 3, subjects were given one trial to test for any rotational movement in the dot pattern transferred from the spiral pattern. The order of the three rivalry intensity conditions was balanced across the 12 subjects with 2 subjects each taking one of the six possible presentation orders. Subjects had rest periods between trials of 3 minutes.

In the AI condition four trials (two in the monocular and two in the binocular condition) were presented in the ABBA order design. With 6 subjects the monocular condition was first and with the other 6 subjects the binocular rivalry condition was first. Whichever trial was first served as the standard trial for magnitude estimates by giving a value of 100 to the maximum intensity of the AI. Subjects had intertrial rest periods of 3 minutes.

Results and Discussion

No subjects reported any transferred MAE following monocular stimulation of the spiral pattern. Not even converging radial movements were transferred to the right eye. This suggests that the use of the rotating spiral pattern was successful in providing a rivalry stimulus that would not produce an interfering aftereffect of its own during the test period. Nevertheless, the spiral produced strong rivalry suppression during induction periods of the MAE and AI condition. The mean rivalry suppression times out of a possible 60 seconds for the three intensity conditions of the MAE condition and for the AI condition are shown in Table 5.4.

TABLE 5.4.

MEAN RIVALRY SUPPRESSION TIME IN SECONDS FOR THE THREE INTENSITY CONDITIONS OF THE MAE CONDITION AND FOR INTENSITY CONDITION 1 OF THE AI CONDITION IN EXPERIMENT 11.

Condition	MAE			AI
Intensity	1	2	3	1
Time (sec)	28.5	36.3	39.9	36.5

A 2-way analysis of variance applied to the suppression times in the MAE condition showed a highly significant effect of intensity on suppression time ($F = 22.9$, $df = 2/11$, $p < .0005$). Increases of intensity of the left eye rivalry stimulus produced increases of rivalry suppression time of the right eye induction stimulus. It may also be noted that the Intensity Condition 1 in the AI condition produced a mean rivalry suppression time about the same as Intensity 2 in the MAE condition. This indicates that the stable horizontal pattern was suppressed more than the rotating dot pattern with the same intensity rivalry stimulus. In fact the mean suppression time of the AI condition was significantly greater ($t = 2.58$, $df = 11$, $p < .05$) than that of the rotating dot pattern in rivalry with Intensity 1.

There was no order effect comparing trial 1 with trial 6 of the MAE condition. The durations and magnitudes following monocular viewing showed no change between the first and last trials. However, this was not a reflection of a large unreliability of the MAE measures. For instance, the correlation of the first and second monocular condition duration measures was highly significant ($r = +.783$, $df = 10$, $p < .005$). Hence, for the purposes of data analysis the average of the two monocular trials was used. For the same reasons the two trials of each condition were combined for each subject in the data analysis of AI strength.

The mean durations and magnitudes for the four MAE conditions and for the two AI conditions are shown in Table 5.5. From the mean data it can be seen that the durations of the MAE in the monocular condition of this experiment are considerably greater than the monocular mean of 11.5 seconds in Experiment 10. This increase obviously reflects the greater illumination of the rotating dot pattern in this experiment.

Similar to the results of Experiment 10 the rivalry conditions, particularly with stronger illumination of the rivalry stimuli, produce marked decreases of the MAE in both duration and magnitude estimates. The effect of rivalry stimulus intensity between the three rivalry conditions was tested using a 2-way analysis of variance. Intensity had a

TABLE 5.5.

MEAN DURATIONS AND MEAN MAGNITUDE ESTIMATES FOR THE MONOCULAR (M) AND THREE RIVALRY INTENSITY TRIALS OF THE MAE CONDITION AND THE MONOCULAR AND RIVALRY TRIALS OF THE AI CONDITION IN EXPERIMENT 11.

	MAE				AI	
Rivalry stimulus Intensity	M	1	2	3	M	1
Duration (sec)	20.6	11.9	9.8	6.2	14.0	10.7
Magnitude Estimate (standard trial = 100)	100	73.8	45.9	48.8	112	93

significant effect on durations (F = 5.03, df = 2.11, $p < .05$) and also a significant effect on magnitude estimates (F = 7.32, df = 2/11, $p < .01$).

As was found in Experiment 10 there was also a wide range of MAE durations in this experiment. There was also a wide range of AI durations (6.3 seconds to 29.3 seconds). In order to compare rivalry conditions with respective monocular conditions and to compare relative effects of rivalry suppression of the MAE condition and AI condition it was necessary to standardize the new raw scores. For this purpose durations and magnitudes in the rivalry conditions were converted to percentages of their respective monocular condition for each subject.

To illustrate the effects of the rivalry stimuli on the nonsuppression time of the induction stimulus along with the mean duration and magnitude percentages of the MAE and AI these measures are shown in Figure 5.3. It is clear that increases of rivalry stimulus intensity produces decreases of the non-suppression time of the induction stimulus, decreases of MAE duration, and decreases of magnitude estimates. It also seems to be the case that strong rivalry suppression of the induction stimulus does not markedly reduce the AI duration and magnitude estimates from the monocular condition.

Since the working hypothesis was that rivalry stimulation would reduce the MAE but not the AI compared with their monocular conditions the following post hoc comparisons were made. Both the MAE measures and AI measures for rivalry stimulus Intensity 1 were compared with their respective monocular conditions. The Intensity 1, AI percentages were compared with the Intensity 1 and Intensity 2, MAE percentages. The results of correlated means t-tests and associated probability levels for these comparisons are shown in Table 5.6. This shows that both the duration and magnitude estimates of the MAE are markedly reduced from their monocular condition when the induction stimulus is in rivalry with the least intense rivalry stimulus. On the other hand, it cannot be confidently concluded that rivalry stimulation during the induction period reduces the strength of the AI. Only the

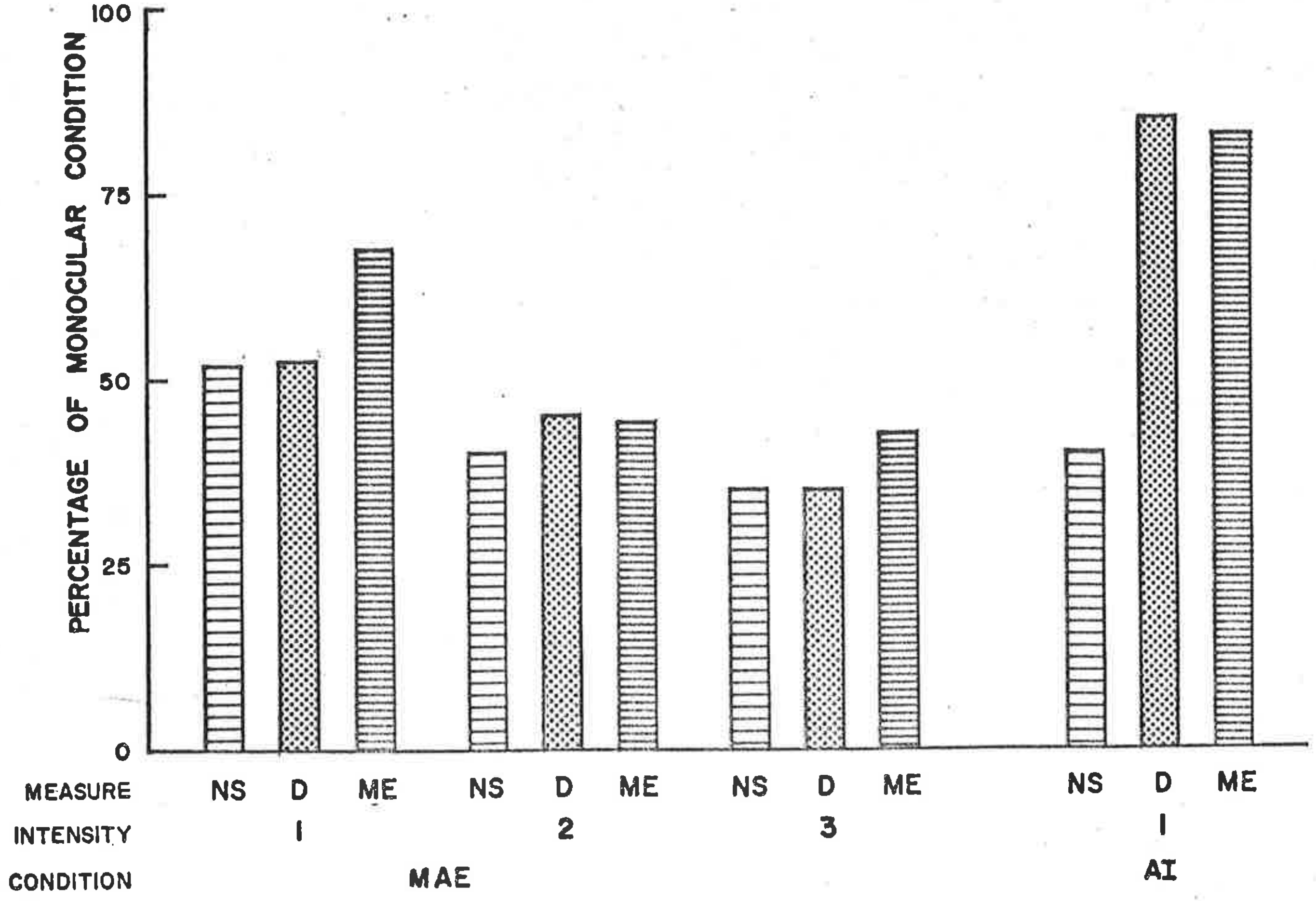


Fig. 5·3. Experiment II. Mean percentages of respective monocular conditions of MAE non suppression (NS) times, durations (D), under the three rivalry stimulus intensities and for the AI condition under intensity 1.

TABLE 5.6.

POST HOC COMPARISONS OF STANDARDISED PERCENTAGE DURATION AND MAGNITUDE MEASURES SHOWING CORRELATED MEANS t VALUES AND ASSOCIATED ONE-TAILED PROBABILITIES IN EXPERIMENT 11.

Comparison	Duration Difference		Magnitude Difference	
	t	p	t	p
MAE, Monocular vs Binocular 1	6.68	.001	2.73	.01
AI, Monocular vs Binocular 1	0.50	n.s.	1.85	.05
AI, Binocular 1 vs MAE, Binocular 1	2.00	.05	1.37	.10
AI, Binocular 1 vs MAE, Binocular 2	3.32	.01	4.48	.001

reduction of magnitude estimates for the AI following the binocular condition reaches a significant ($p = .05$) level.

Table 5.6 shows the results of the direct test between the AI and MAE percentage values. When the same Intensity 1 rivalry stimulus was used it produced a somewhat greater reduction of MAE than of AI. The duration measures are significantly different ($p < .05$) and the magnitude measure is different to a low confidence level ($p < .10$). It could be argued that the more appropriate comparison of the AI Intensity 1 condition is with the MAE Intensity 2 condition instead of MAE Intensity 1. The Intensity 2 condition provides the same amount of rivalry suppression of the rotating dot pattern as the Intensity 1 condition does of the AI induction stimulus. That comparison shows the mean MAE percentages to be less than the AI percentages at high confidence levels. If it is also assumed that any slight eye movements during the induction periods will probably be more detrimental and consequently reduce the strength of the AI to a greater proportional extent than the MAE, then the difference in the MAE and AI conditions should be accepted as real.

It was suggested in Experiment 10 that the reduction of the MAE may not be caused directly by the phenomenal rivalry suppression of the induction stimulus. The detrimental effects to the MAE may be occurring on a lower level during the induction period than the level which is the basis of phenomenal rivalry. It is clear from the results that both the percentage of suppression time of the induction stimulus and the percentage MAE strength are a function of the rivalry stimulus strength. It also seems to be the case that in the rivalry conditions the percentage MAE strength seems to approximate the percentage nonsuppression time of the induction stimulus. This circumstantially would suggest that the strength of the MAE results directly from the amount of phenomenal nonsuppression time of the induction stimulus. A more direct test of this hypothesis will be undertaken in the next experiment by varying the amount of suppression through voluntary control without varying the rivalry stimulus intensity. Using the data of the present experiment it may also be possible to examine the relationship between BR suppression and the MAE reduction.

First, it may be noted that quite a wide range of BR nonsuppression times exist within the group of 12 subjects. For instance with rivalry stimulus Intensity 1 the percentage of the time the induction stimulus is in nonsuppression ranges from 30.3% to 81.1%, with Intensity 2 the range is from 23% to 59.8% and with Intensity 3 the range is from 2% to 56%. For whatever reasons, be it ocular dominance or BR pattern preferences, different subjects show quite large differences of percentage suppression time with the same intensity rivalry stimulus. It is also the case that large differences exist within one intensity condition of MAE duration percentages and magnitude percentages. The range of MAE duration percentages for the three intensity conditions are respectively 25% to 99%, 0% to 113% and 0% to 87%. The ranges of magnitude percentages were comparable to these.

Now if the percentage MAE is a direct result of the percentage nonsuppression time in the induction period, then within a given intensity condition one would predict a positive correlation between percentage nonsuppression time and percentage MAE duration or magnitude. In other words, the less the induction stimulus is suppressed by a particular rivalry stimulus intensity, the less the MAE strength should be reduced. This would also provide a convenient explanation to account for the large amount of variance of the MAE measures within an intensity condition. On the other hand, if the MAE results from the operation of a different mechanism on a different level from that of the phenomenal rivalry suppression, then a correlation may not be found. The Pearson correlations between nonsuppression time and MAE duration, nonsuppression time and MAE magnitude, and MAE durations and magnitudes for each of the intensity conditions are shown in Table 5.7.

TABLE 5.7.

PEARSON CORRELATION COEFFICIENTS BETWEEN NONSUPPRESSION (NS) TIME PERCENTAGES AND MAE DURATION (D) PERCENTAGES AND MAGNITUDE (M) PERCENTAGES ARE SHOWN FOR EACH OF THE THREE RIVALRY STIMULUS INTENSITY CONDITIONS.
(* = significant at p = .05)

Intensity	NS x D	NS x M	D x M
1	-.126	+.04	+.30
2	+.130	-.32	+.44
3	-.362	-.32	+.55*

It is clear from Table 5.7 that nonsuppression time is not correlated with either of the MAE strength measures. The duration and magnitude percentages do seem to be correlated at least for Intensity 3 condition.

Another possible way to test the relation between nonsuppression time and MAE strength is to correlate the reduction of nonsuppression time from Intensity 1 to Intensity 3 with the reduction of MAE strength between these two conditions. Based on the previous hypothesis individuals who show a large decrease of nonsuppression time from Intensity 1 to 3 should also show a large decrease of both MAE duration and magnitude. However, the correlation between the nonsuppression time reductions and MAE duration reductions was negative (r = -.60) as was the correlation with the MAE magnitude reductions (r = -.18).

Another approach may be to vary rivalry stimulus intensity but to keep BR suppression time constant. This cannot be done experimentally, but it may be possible to accomplish essentially the same thing by matching subjects between Intensity condition 1 and 3 with approximately the same BR nonsuppression times. This could be done by comparing the seven subjects with the lowest nonsuppression times in Intensity Condition 1 with the seven subjects with the greatest nonsuppression times in Intensity Condition 3. This gave the group of 7 subjects in the Intensity 1 condition a mean nonsuppression percentage of 44.7% and the group of 7 subjects in Intensity 3 condition a mean of 44.9%. Now if MAE strength is a function of BR nonsuppression time there should be no difference between the groups. However, if MAE strength is a function of rivalry stimulus intensity, there should be a difference. Independent samples t tests were applied to the difference in MAE duration and MAE magnitudes between Intensity Condition 1 and 3. The mean values for each condition and the resultant t values are presented in Table 5.8. Although the differences between Intensity Condition 1 and 3 reach only low significance levels, the percentage differences (23.9% and 24.2%) were somewhat larger than the percentage differences of the whole group (19.3% and 24.0% respectively) which were significant to at least the same levels ($p < .10$ and $p < .0001$ respectively). Therefore, it seems reasonable to conclude that variation of rivalry stimulus intensity while keeping nonsuppression time constant results in a change in MAE strength.

TABLE 5.8.

THE MAE DURATION AND MAGNITUDE PERCENTAGES OF THEIR RESPECTIVE MONOCULAR CONDITION ARE SHOWN FOR THE SELECTED GROUPS OF N=7 IN EACH OF INTENSITY CONDITION 1 AND 3 WITH THE RESULTANT DIFFERENCE (D).

	Intensity Condition		Difference			
	1(N=7)	3(N=7)	D	t	df	p(1-tailed)
MAE Duration (%)	51.4	27.5	23.9	1.68	12	< .10
MAE Magnitude (%)	69.6	45.4	24.2	1.37	12	< .10

In summary, the presence of rivalry stimulation sufficient to produce marked phenomenal rivalry suppression of the induction stimulus does not affect the subsequent strength of the AI. On the other hand, rivalry stimulation sufficient to produce rivalry suppression of a rotating induction stimulus does produce a marked decrease of MAE strength. Two alternative explanations of the basis of the MAE reduction were examined. Although variation of rivalry stimulus intensity produced variation of rivalry nonsuppression time and concomitant variation of MAE strength, it was found that these two variables within one intensity condition or changes across intensity conditions were not positively correlated. It was also found that without changes of phenomenal rivalry suppression, changes of rivalry stimulus intensity were sufficient to produce changes of MAE strength. Therefore, the weight of evidence from the present experiment would seem to favour the hypothesis that MAE strength is dependent on the strength of rivalry stimulation during induction but it is not dependent on the amount of phenomenal rivalry suppression time during induction.

Experiment 12

The purpose of the present experiment was to clarify two conclusions of the previous experiment and to obtain more detailed information about the effect of rivalry stimulation on the MAE. Experiment 11 showed that rivalry stimulation during an induction period produced a small reduction of AI strength as compared with the monocular induction period.

However, the reduction of AI duration was not significant and the reduction of AI magnitude estimates reached only a low confidence level ($p < .10$). In addition, it was suggested that slight fixation losses may tend to occur more frequently during binocular rivalry and thus contribute to a reduction of AI strength. Although it appeared unlikely that rivalry stimulation had a real effect on AI strength, it would be desirable to gain further evidence regarding this question.

Three changes were incorporated into the present experiment to reduce the possibility of fixation losses and their effects on the induction of the AI. Since it is likely that fixation losses would tend to occur toward the end of the 60 second induction period, the length of the induction period was reduced to 45 seconds. Second, the subjects of the previous experiment had only brief practice of tapping telegraph keys to indicate rivalry alternations while at the same time attempting to maintain correct fixation. Unpracticed subjects may find a strong tendency to shift fixation from the centre of the pattern in order to make decisions about the alternations of rivalry. Therefore subjects who had extensive past experience in maintaining correct fixation while indicating rivalry alternations were used in the present experiment. Third, the induction pattern for the AI was changed to a pattern of horizontal white bars on a black background in place of the pattern of thin white horizontal lines.

Slight eye movements, if they do occur, are likely to have a less detrimental effect on the AI induction of a broad striped pattern than on a thin striped pattern since slight eye movements may reverse the contour for the latter but not the former. If the small reduction of AI strength following a rivalry induction period was artifactual and not really a result of rivalry stimulation per se, then one would predict even less AI reduction under the conditions of the present experiment.

The second question was whether the reduction of MAE was a function of the presence of rivalry stimulation rather than a function of the amount of phenomenal nonsuppression time. It was suggested that rivalry nonsuppression time was a function of rivalry stimulus intensity but it was not by itself the cause of the MAE reduction. This conclusion was reached following two types of examination of the data. In one, the effect on MAE strength was tested when rivalry stimulus intensity was varied and BR suppression time was essentially held constant. This *post hoc* manipulation showed changes in MAE strength. The second examination was to consider the various nonsuppression times of subjects for a constant rivalry stimulus intensity. The lack of positive correlation showed that MAE strength did not vary with nonsuppression time within a constant stimulus intensity. In the present experiment well-practiced subjects used voluntary control to alter the BR suppression time in a given intensity condition.

If subjects reduced the nonsuppression time of the induction stimulus for one trial and increased it for another trial under the same intensity conditions, would there be a difference produced in MAE strength?

Method

Subjects

Three volunteer subjects (LL, JT, CC) including the author were used in the present experiment. JT and CC had normal vision without corrective lenses; LL had normal vision with corrective corneal lenses. All 3 subjects had participated in other experiments which required voluntary control of BR and key tapping to indicate BR alternations. All subjects, especially JT and LL, had extensive previous practice of BR control with knowledge of results using various kinds of rivalry stimuli. However, both JT and CC were naive as to the purpose of the present experiment.

Apparatus and Stimuli

The apparatus was the same as that used in Experiment 11 with the addition of decade timers and electromechanical relays. This additional equipment was used to turn on and off an incandescent lamp for short intervals of time in order to produce a low frequency stroboscope effect during the observation of the AI. The incandescent lamp was directed at a low diagonal ceiling 0.6 meters distant from the subjects' eyes and produced a disk of light subtending 20 degrees of the visual field. Activation of the stroboscope mechanism produced 40 ft-L luminance for 100 msec alternating in time with a homogeneous dark field of 0.01 ft-L luminance for 100 msec. This resulted in five flashes/second of intense luminance.

One minor alteration was made of the placement of the telegraph keys. Instead of being placed separately the two keys were placed adjacent to each other in the right hand position. This enabled subjects to operate both keys with the right hand. Subjects used the right index finger to tap the right key indicating a shift of dominance to the right eye pattern, and used the right thumb to tap the left key indicating a shift of dominance to the left eye pattern. Although the procedure sounds complicated, it proved to be a simple and convenient method for subjects to indicate BR alternations.

The main purpose of this change was to free the left hand so that it could be used to cover the left eye during the observation of the AI in the presence of the flashing light. If there were any movement aftereffects from the rotating spiral pattern which may have interfered with the AI they would be minimised by eliminating the light stimulation of the left eye during the AI test period. In any case, in order to compare percentage MAE reductions with percentage AI reduction it was necessary to provide the same stimulation conditions of the left eye for both the induction periods and test periods of the two conditions. Since illumination for the left eye was terminated in the MAE test period it would also have to be terminated for the AI condition test period.

The left and right eye stimuli for the MAE and AI conditions were the same as used in Experiment 11 with the exception of the AI induction stimulus. The eight thin (2 min of visual angle) white horizontal lines were replaced by four thicker (24 min of visual angle) white horizontal bars, two evenly placed above the horizontal midline and two below. The white bars were spaced alternately with black bars of the same width. The white bars were illuminated by the right hand slide projector and had the same luminance of 20 ft-L as the white fusion background in Experiment 11. The black bars had the same background as used earlier with the low luminance of 0.01 ft-L. The luminances for the right eye stimuli in the induction and test periods of the MAE condition were the same as those of the previous experiment. The luminances for the left eye stimuli for both the MAE and AI conditions were the same as those in Intensity Condition 3 of Experiment 11. Thus, instead of the lowest rivalry intensity condition, the greatest intensity of rivalry stimulus was used in the induction period of the AI condition.

Procedure

The experimental procedure and the method of obtaining measures of the duration and magnitude estimates for both the

MAE and AI conditions were the same as those used in Experiment 11 with the minor exceptions already mentioned of the use of 45 seconds induction periods, key tapping with the right hand only, and the placement of the left hand over the left eye during the test period for the AI. With regards to the latter change it was found that the left palm could be comfortably placed over the left eye in a way that practically occluded all light stimulation without putting any pressure on the eyeball itself.

The main purpose of the experiment was to test the effect of voluntarily altering the amount of BR suppression time on the resultant MAE. Subjects were instructed on some trials to use voluntary effort to increase or to decrease the non-suppression time of the induction stimulus during an induction period. There were three types of BR induction periods all using the same rivalry stimulus intensity of Condition 3, Experiment 11:

1. Subjects were instructed to view the rivalry in a passive manner and not to attempt to control the BR in any way;
2. Subjects were instructed to maximize the dominance of the right eye induction stimulus in the 45 second induction period;
3. Subjects were instructed to maximize the dominance of the left eye spiral rivalry stimulus or, in other words, to maximize the amount of suppression time of the right eye

induction stimulus in the induction period.
During each of the BR induction periods the subjects tapped the telegraph keys in the appropriate way to indicate alternations of rivalry. In this way the amount of BR nonsuppression time of the induction stimulus could be measured and the percentage BR control of the subjects could be calculated by taking the difference of right eye nonsuppression time between Instruction 2 and Instruction 3 and multiplying that difference by 100/45. For example, a subject who could produce no difference of right eye suppression time for the two control instructions would register zero percentage control. A subject who could maintain the dominance of the right eye stimulus for the full 45 seconds under Instruction 2 but reduce the dominance time of the right eye to zero under Instruction 3 would have (45-0)(100/45) = 100% control.

At the beginning of the experiment it was observed that JT failed to observe any AI either following BR induction periods or following monocular nonrivalry induction periods. An AI could not be elicited in JT following low or high intensity stimulation of the induction stimulus, after short or long duration induction periods, or while observing with eyes closed in darkness or with right eye open to the flashing light. JT understood the instructions and the importance of maintaining the correct fixation point for the entire 45 second induction period. He knew "what to look for" since he had previously participated in BR experiments in which afterimages were used. These previous afterimages had been induced with a flash gun rather than with prolonged fixation of a pattern. JT was not incapable of fixating for a period of time since he could observe reasonably robust MAEs. One explanation for this curious anomaly could be that JT had a rather large amplitude flick component in his saccadic eye movements or some sort of eye tremor that was just large enough to move the image of the induction stimulus across the retina to the extent that it failed to produce an AI. This hypothetical eye movement in subject JT, if it is assumed to have been operating at all times, was not large enough, however, to eliminate the induction of the MAE. If this is the correct explanation it would be a dramatic illustration of the greater effect of eye movements on the induction of the AI than on the MAE. In any case, subject JT was precluded from taking part in the AI part of the experiment.

The experiment was composed of two parts. In the first part, the three subjects were tested over a series of three experimental sessions usually on three consecutive days. In each session the subjects followed the same sequence of twenty trials, the first ten for the AI condition and the second ten for the MAE condition. Subject JT was tested only with the ten trials of the MAE condition in each of the three sessions. For any sequence of ten trials the same order was followed. The order was monocular condition, BR Instruction 1, BR Instruction 2, BR Instruction 3 and monocular condition. The second five were these same conditions in reverse order. There were 3 minute rests between trials and 5 minute rests between the first five and second five trials. For each block of five trials the first monocular trial served as the standard for magnitude estimates whose maximum intensity was given a value of 100.

On the third experimental session the subjects followed exactly the same procedure as on the previous two sessions except that 15 minutes prior to the commencement of the session the subjects were administered with cycloplegic and mydriatic eye drops. This was the same drug, Mydrilate, that was used in Experiments 8 and 9. The purpose of the Mydrilate was twofold: 1. to examine again whether the loss of peripheral ocular motor activity affects the degree of BR control, and 2. if variation of BR suppression affects the MAE under normal conditions, to test if it also affects the MAE strength when the intrinsic eye muscles are paralyzed.

Following the first part of the experiment all subjects were given twenty trials of spaced practice of the BR Instructions 2 and 3 with the left eye stimulus and MAE induction stimulus in rivalry. The purpose of these practice trials was to build up the subjects' degree of BR control with these rivalry patterns. In the second part of the experiment the subjects were given twelve trials in one session for the test of the MAE only. All trials were in the rivalry condition in which only Instructions 2 and 3 were used. The two instructions were alternated on consecutive trials with the first Instruction 2 trial serving as the standard for the first six trials and an Instruction 3 trial serving as the standard for the second six. The purpose of this second part of the experiment was to maximize the BR control variation to increase the likelihood of getting positive results from the effect of control.

It appeared to the author that the decay of MAE velocity with time was of a different function for the monocular and rivalry conditions. For this reason at the end of Part 2 the three subjects viewed several MAEs alternating conditions on successive trials. To facilitate the association of the decay of angular velocity with time the experimenter called out the elapsed seconds as the subjects watched the MAEs. Then each subject drew a curve best representing the function of angular velocity over time. The curves for both the monocular and binocular stimulation MAEs were drawn with a standard of 100 representing the initial angular velocity of the monocular condition. This is similar to the technique used by Sekuler & Pantle (1967). They had subjects make magnitude estimates of the MAE at several different delay intervals following movement cessation. Their method overcomes problems of inaccurate memories which may arise when subjects have to reproduce the whole curve. However the present method was probably adequate to investigate rough descriptive differences which may exist between the conditions.

Results and Discussion

Subjects participated in the third session of the first part of the experiment with paralyzed intrinsic eye muscles. There were no differences between the normal and paralyzed eye sessions in BR control, nonsuppression time of the induction stimulus, or either of the strength measures of the MAE or AI. As a result, the data from all three sessions were combined in the data analysis. Table 5.9 shows the MAE and AI duration means and standard deviations for each of the subjects from the monocular induction trial.

TABLE 5.9

MEANS AND STANDARD DEVIATIONS (S.D.) IN SECONDS OF THE MAE AND AI FOLLOWING MONOCULAR INDUCTION PERIODS IN THE FIRST PART OF THE EXPERIMENT (THREE SESSIONS COMBINED).

Condition		Subjects		
		CC	LL	JT
MAE	Mean	27.6	31.3	28.9
	S.D.	2.8	5.8	5.3
AI	Mean	25.7	24.4	--
	S.D.	8.7	1.4	--

All three subjects have fairly robust MAE and AI durations with comparatively small standard deviations. This indicates the large amount of consistency of these values from session to session.

To compare changes in nonsuppression time with changes in durations and magnitudes the raw data was converted into the raw score percentage of the respective monocular mean score. For instance, nonsuppression time was converted to percentage of 45 seconds (presumably the amount of nonsuppression time of the monocular induction period). Both the duration values and magnitude estimates were also converted to percentages of their respective monocular condition means. Figure 5.4 illustrates the percentages for the MAE and AI conditions separated into the three different instruction conditions for each subject. The conditions are arranged from left to right in the order 3, 1, 2 because Instruction 3 was to suppress the induction stimulus time, Instruction 1 was for passive viewing, and Instruction 2 was to maximize the right eye nonsuppression time.

As can be seen from Figure 5.4 the results of Experiments 10 and 11 gain further support in this experiment. In the MAE condition the combined BR conditions for each subject were markedly less than their monocular conditions. For instance the magnitude measures of the three BR conditions of subject CC were significantly less than his monocular condition measures

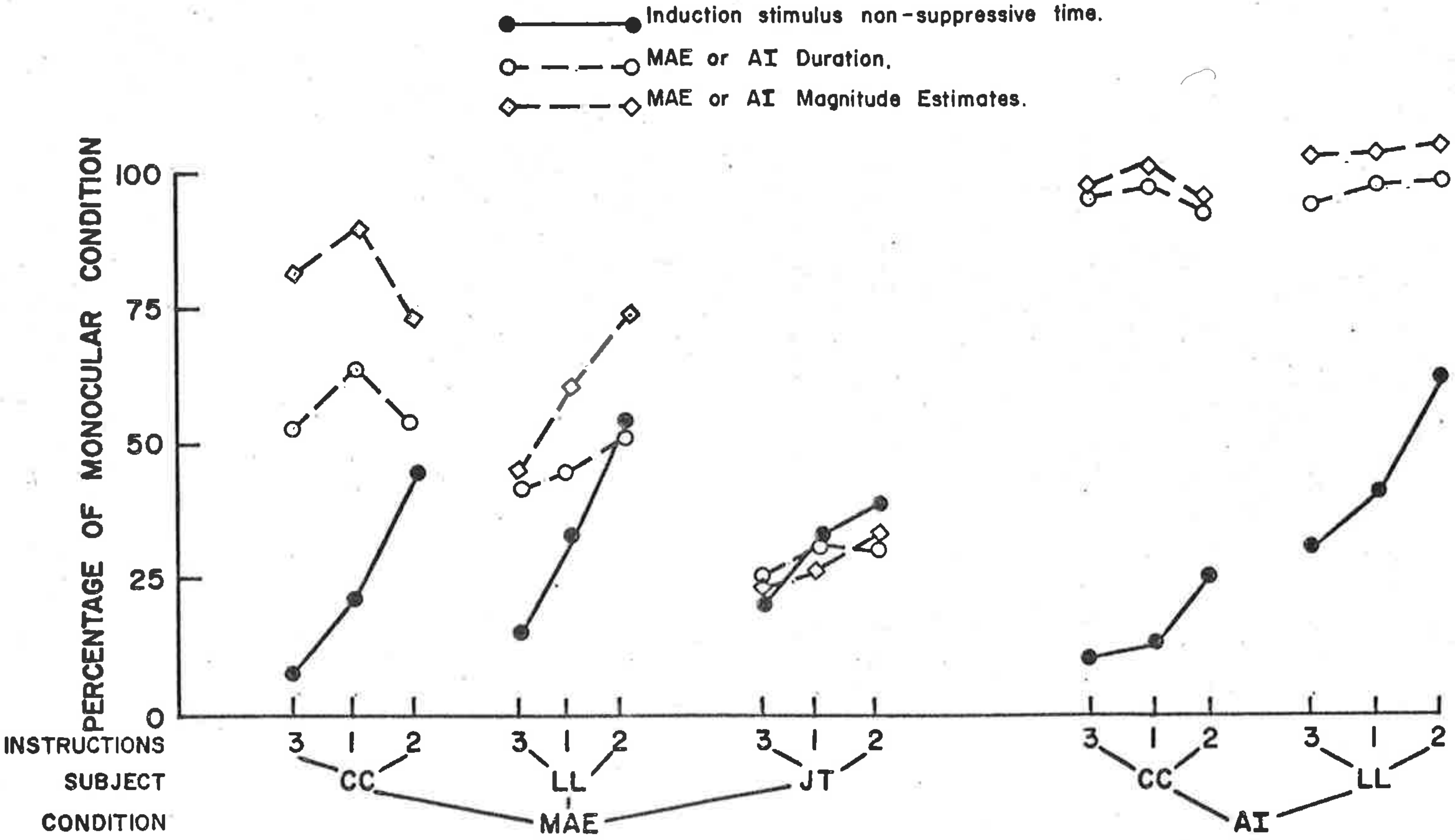


Fig. 5·4. Experiment 12. Right eye non-suppression time, durations, and magnitudes of MAE for 3 Ss and of AI for 2 Ss for the BR instructional conditions of 3, 1, and 2 expressed as a percentage of the respective monocular condition values.

at a high confidence level ($t = 5.42$, $df = 28$, $p < .001$). Subject CC had the highest percentage duration measures in the BR conditions (57.3%), but these measures were less than the respective monocular condition at a high significance level ($t = 9.68$, $df = 28$, $p < .001$). Compared with CC the duration and magnitude measures of LL and JT showed even greater decreases as a result of rivalry stimulation. There is no question of the reality of the effect of rivalry stimulation on the MAE.

The MAE curves of MAE velocity for each condition and each subject are shown in Figure 5.5. The most apparent difference between the two curves for all subjects seems to be in the initial rate of decay of the MAE. The movement velocity following monocular stimulation seems to sustain itself somewhat better than the rivalry condition MAE. Although the velocity following rivalry stimulation starts at a comparatively high level, it seems to decay very rapidly to a low level. This would suggest that the greatest difference between the monocular and binocular MAE is not in the initial magnitude but in the magnitudes after 2-5 seconds and in final durations.

Experiment 11 using naive subjects showed a slight reduction of AI magnitude in the binocular condition. It was concluded that this difference probably did not indicate a real effect of BR stimulation on the induction of the AI.

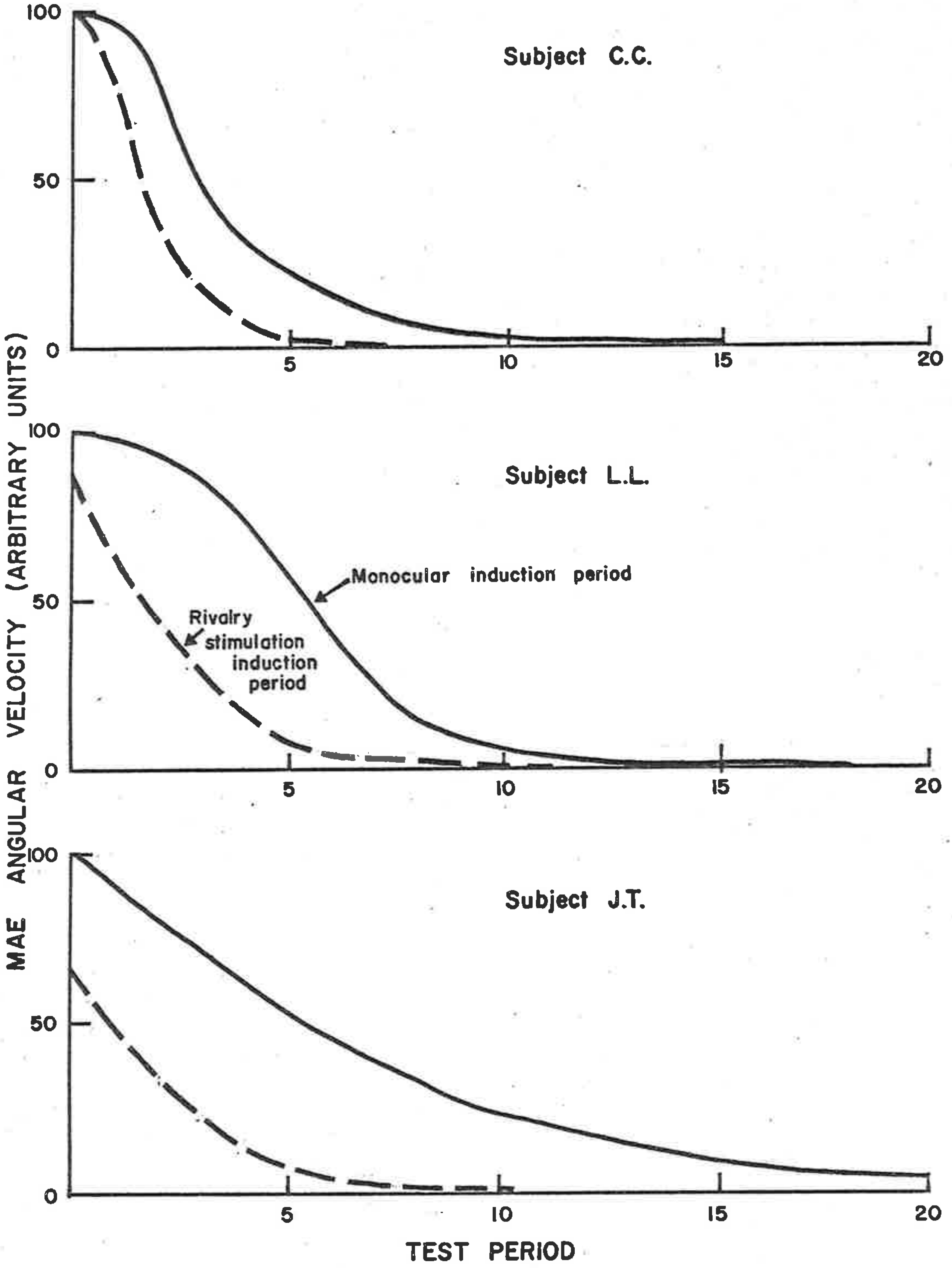


Fig. 5·5. Angular velocity estimates of the MAE for three Ss.

The results of the present experiment support that conclusion. Subjects CC and LL show virtually no difference in magnitudes or durations between the monocular condition and any of the three rivalry conditions. Although the horizontal bar patterns were in rivalry nonsuppression a minority of the 45 seconds induction period (especially for CC), the resultant AIs are unchanged in maximum intensity and duration as compared with the monocular induction condition. Therefore, it seems reasonable to conclude that rivalry stimulation and considerable rivalry suppression during an induction period does not affect the subsequent strength of an AI.

The main question of the present experiment was whether variation of BR suppression time would result in variation of the MAE strength. This can be investigated by testing the differences between BR Instruction 2 and Instruction 3 of non-suppression time for both MAE durations and MAE magnitudes. These differences for the three subjects with associated t-values and significance levels are shown in Table 5.10.

The effect of instructional conditions on the MAE duration and magnitude seems to be mixed. For CC there is virtually no difference of duration percentage between Instruction 2 and 3 and there is a slight decrease in MAE magnitude. Neither of these differences for CC approach a significant level. However LL shows a slight but not significant increase of duration and a larger increase of magnitude which is

TABLE 5.10.

PART 1 PERCENTAGE NONSUPPRESSION (NS) TIME OF RIGHT EYE INDUCTION STIMULUS, DURATION (D) AND MAGNITUDE (M) OF THE MAE WITH THE BR INSTRUCTION CONDITIONS 3 AND 2 AND THEIR DIFFERENCE WITH ASSOCIATED t-VALUE AND SIGNIFICANCE LEVEL (p).

Subject	Measure	Instr.3	Instr.2	(2-3) Diff.	t	p
CC	NS	7.1	45.0	37.9	10.00	$<.0001$
	D	53.3	54.0	0.7	0.12	N.S.
	M	80.0	75.0	- 5.0	- 0.61	N.S.
LL	NS	15.4	54.3	38.4	12.70	$<.0001$
	D	42.5	52.4	9.9	1.23	N.S.
	M	45.0	75.3	30.3	2.65	$<.05$
JT	NS	21.0	37.8	16.8	6.70	$<.0001$
	D	24.4	30.1	5.2	0.83	N.S.
	M	22.7	31.1	8.4	1.34	N.S.

significant ($t = 2.65$, $df = 10$, $p < .05$). JT shows slight increases of MAE strength but neither of them are significant. Of six differences of MAE strength one is opposite to the predicted direction and only one reaches a significant probability in the predicted direction. Hence, a confident conclusion about the effects of BR suppression cannot be drawn from the present results.

Following the first part of the experiment subjects were given practice trials in order to increase the degree of control with the rivalry stimuli of the experiment. With greater control and hence greater NS differences it was hoped that a more definite conclusion could be made regarding the effects of NS time on MAE strength. In the second part of the experiment twelve trials were given in which Instructions 2 and 3 were alternated on successive trials. No passive instruction trials or monocular trials were included. As in the first part, the percentage NS time was based on 45 seconds. Since there was no monocular condition the percentage durations had to be based on the monocular condition of the first part and the magnitude estimates were based on a standard from a BR trial, each instruction serving as a standard for six trials. In order to derive percentage values of the monocular condition, merely for illustrative purposes, the mean magnitude of this part was given the mean percentage value of Part 1. This did not alter the percentage difference, the crucial value to be tested.

The results of the second part of the experiment are illustrated in Figure 5.6. Subjects were again successful at producing a difference in NS time between Instruction 2 and 3. However in the MAE measures CC shows slight differences opposite to the predicted direction. LL and JT show small differences in the predicted direction. The percentage values of NS time, MAE duration and magnitude for Instruction 2 and 3 and the differences are shown in Table 5.11.

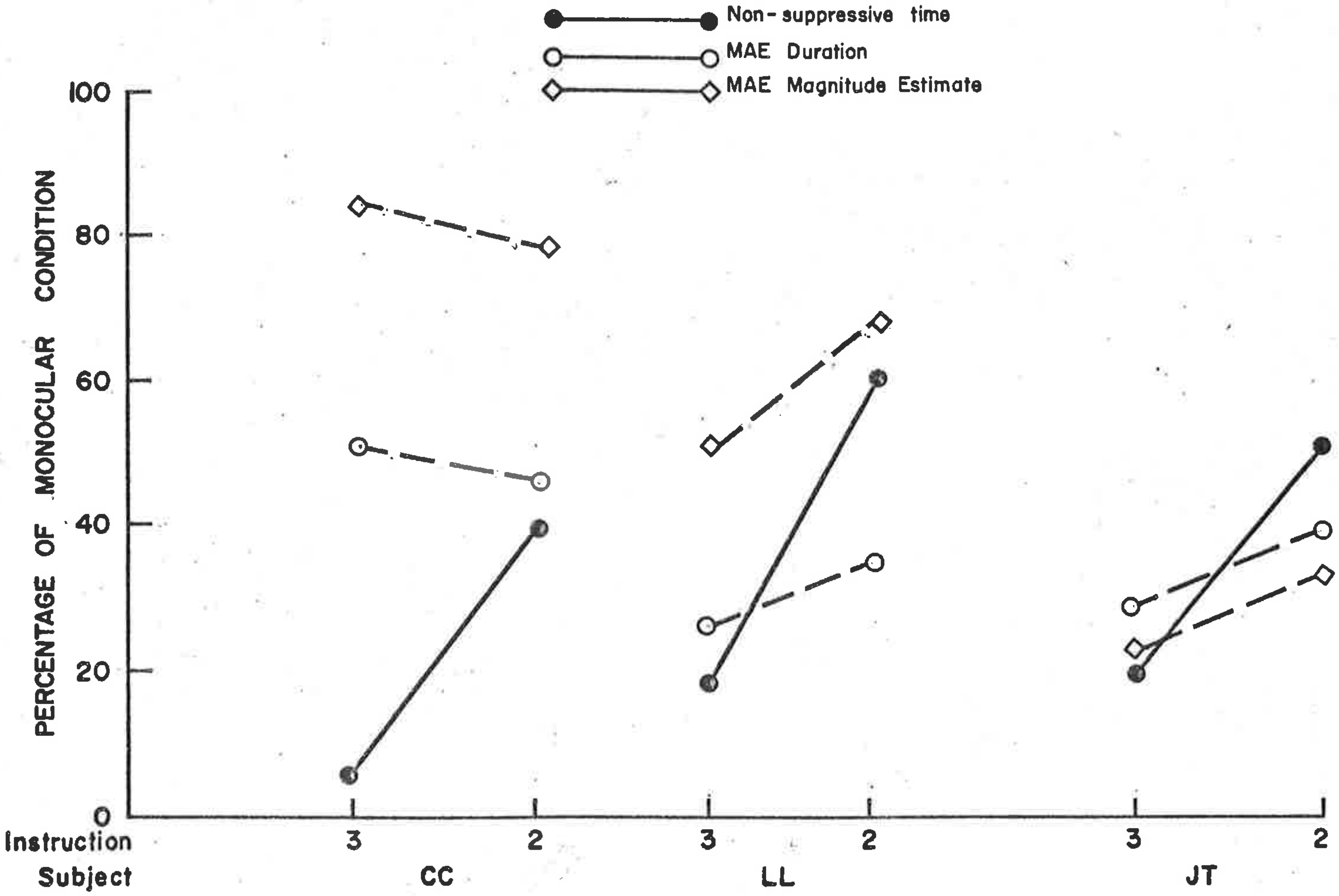


Fig. 5·6. Part 2 of Eperiment 12. Right eye nonsuppression time and MAE strength measures from BR instructions "Left Dominant" (3) and "Right Dominant" (2)

TABLE 5.11.

PART 2 PERCENTAGE NONSUPPRESSION (NS) TIME OF THE INDUCTION STIMULUS, MAE DURATION (D) AND MAE MAGNITUDE (M) WITH BR INSTRUCTION 3 AND 2 AND THEIR DIFFERENCE WITH ASSOCIATED t-VALUES AND SIGNIFICANCE LEVELS (p).

Subject	Measure	Instr.3	Instr.2	(2-3 Diff.)	t	p
CC	NS	7.0	39.6	32.6	26.70	.0001
	D	51.4	46.7	- 4.7	0.51	N.S.
	M	92.0	85.0	- 7.0	0.91	N.S.
LL	NS	19.0	59.6	40.6	16.20	.0001
	D	26.6	35.1	8.5	3.27	.01
	M	75.0	92.0	17.0	1.62	N.S.
JT	NS	21.0	51.2	30.2	7.50	.0001
	D	28.8	38.4	9.6	2.21	.05
	M	112.0	124.0	12.0	0.79	N.S.

The effect of practice between the two parts seems to have had a decided effect only on subject JT who showed an increase of BR control from 16.8% to 30.2%. CC showed a slight decrease and LL a slight increase in control from Part 1 to Part 2. In any case in Part 2 all three subjects showed NS differences between Instruction 3 and 2 which were significant at a high confidence level. However, again the differences in MAE strength are not consistent between subjects. Both measures decline slightly for CC. Both measures for LL and JT show differences in the predicted direction. The magnitude difference for LL is less in this part than in Part 1 and is not significant. On the other hand, the duration difference for LL, although it also is less than in Part 1, does reach a significant probability. Both the percentage differences for JT in this part are somewhat larger than in Part 1 of which the duration difference is significant.

If the results of Part 1 and Part 2 are combined perhaps a more reliable conclusion can be obtained regarding the main hypothesis. There is no appropriate way to combine magnitude estimates between the parts since they were relative judgments based on different types of standard trials. There is no basis to assume that the mean magnitude estimates of the two parts are, in fact, equal. However, the duration measures may be combined for the two parts in order to test the difference between Instruction 2 and 3. The mean duration difference for subject CC was -0.54 seconds or -2.7% of the monocular condition duration. The mean duration difference for LL was 2.86 seconds or 9.7% and was significant ($t = 1.726$, $df = 22$, $p < .05$). The mean difference for JT was 2.1 seconds or 7.4% and was significant ($t = 1.90$, $df = 22$, $p < .05$).

The duration measures of LL and JT show small but significant differences with changes in nonsuppression time resulting from BR control. On the other hand, CC showed no differences in the predicted direction of MAE duration or magnitude. Thus, the effects of varying nonsuppression time of the induction stimulus while keeping rivalry stimulus intensity constant are still equivocal.

What does seem clear from the results is that the difference of MAE strength is certainly smaller than the percentage variation of nonsuppression time. The effect of BR control on the NS difference for LL was a mean of 39.7%. On the other hand the mean duration and magnitude differences for LL were only 9.2% and 23.6%. Similarly the mean NS difference for JT was 18.5%, but JT's mean duration and magnitude differences were only 7.4% and 10.2% respectively. The percentage duration difference for LL was only 23% of his NS difference, and the percentage duration difference for JT was only 40% of his NS difference. For Part 2 in which the duration differences were significant for both LL and JT these differences were only 21% and 32% of their respective NS percentage differences. With two well-practiced subjects producing a considerable variation in the amount of NS time between conditions only a small variation of MAE durations resulted.

If MAE strength is dependent only on the phenomenal nonsuppression time of rivalry and not necessarily on the strength of the rivalry stimulus, then variation of NS time should have produced comparable variation of MAE strength. However, in this experiment the subjects' control of BR to vary NS time between conditions either had no effect or produced an effect which was only a fraction of the NS time variation.

This is fairly consistent with the results of Experiment 11 of the lack of positive correlation within intensity conditions between NS time and MAE strength. This indicates that if phenomenal nonsuppression time by itself has any effect on MAE strength it is only a minor effect.

The most dramatic effect on MAE strength is produced by the introduction and variation of binocular rivalry stimulation. The introduction of even a weak rivalry stimulus during induction markedly reduces the MAE strength compared with that following a monocular nonrivalry induction period. Increases of rivalry stimulus intensity produce marked and highly significant variation of MAE strength. In Experiment 11 the difference between Intensity 1 and 3 produced a difference of 27.7% in MAE duration, 22.6% in MAE magnitude, and 20.7% difference in nonsuppression time. From Experiments 11 and 12 it seems that both NS time and MAE strength are markedly affected by rivalry stimulus intensity. On the other hand, variation of NS time alone can produce, at the most, only a relatively small variation of MAE strength.

In terms of a physiological model the results would suggest that rivalry stimulation operates on the physiological mechanism responsible for the origin of the MAE at a level below that which is the basis of phenomenal rivalry. On the other hand, if rivalry stimulation is producing a constant inhibitory effect at some low level in the perceptual pathway, why is it that the rotating induction stimulus appears perfectly normal in the nonsuppression phases of rivalry? In addition, referring to Chapter III and to the work of Fox & Check (1966), why is it that information transmission during the nonsuppression phase of rivalry seems to be equal to the nonrivalry condition? These inconsistencies will be discussed following the discussion of the origins of the MAE and AI.

Discussion of the Evidence for the Origin of Afterimages

Most investigators have assumed that afterimages (AI), whether they are negative and induced by prolonged fixation of a visual pattern or positive following a brief intense flash, arise from a photochemical mechanism in the retina (Ruch, 1960, p.444). However, it would seem theoretically possible that a neural component to the origin of the AI, (especially negative AIs) may exist at the retinal or even higher levels. It is interesting that the assumption of the retinal origin of AIs seems to be held so strongly given the actual paucity of crucial experimental evidence relevant to the question. This discussion will focus on the few more recent studies concerned with the origin of AIs.

Brindley (1959) measured AIs from brief flashes and found that the strength of the AI (excluding the first 15 seconds) was dependent on the total energy transmitted in the flash whether the energy was transmitted in 0.016 seconds or

1.68 seconds. This was consistent with a photochemical basis of the AI but not a neural basis. Brindley (1962) also investigated the effects of progressive blurring of flash induced AIs and the green "halo" effect which appeared under some conditions with a pink AI. He felt that the only explanation consistent with all his results was one in which the AI is the product of photolysis of cone pigments. In this case the blurring and green "halo" were the result of the diffusion of these photochemical products. Barlow & Sparrock (1964) used the AI from a brief flash and stabilized retinal images to plot the absolute thresholds of the AI to light stimulation during dark adaptation. They found that the receptors of the AI are not unresponsive but only more "noisy" thus increasing the threshold relative to surrounding retinal areas. Their results also strongly suggested the retinal origin of AIs.

Recently, however, the increased use of stabilized retinal images and the comparison with AIs has led some experimenters to suggest a cortical component in AIs. Gerrits, de Haan & Vendrick (1966) suggest that the periodic fading of stabilized retinal images more closely fits the known neural characteristics of cortical cells than it does retinal cells. In addition Mackinnon, Forde & Piggins (1969) found the nonrandom, all-or-none fragmentation characteristics to be very similar to stabilized retinal images, steadily fixated low intensity figures, and prolonged afterimages. They conclude that a "single mechanism in the central nervous system underlies fragmentation."

On the other hand Smith (1968) found that the fragmentations occurring in binocular rivalry were less structured than those occurring with the same pattern viewed as an afterimage. Since BR was assumed to be a cortical phenomenon, he concluded that AI fragmentation may have a pre-cortical component. Matthews (1970) found that an AI, viewed monocularly against an opposite contoured background, fragmented in an unstructured way to a much greater extent that if the opposite background was viewed dichoptically. This supported a retinal origin of the AI. However, because the total fragmentation time was the same regardless of the background, he felt that some central factor was involved in fragmentation. Piggins (1969) summarized the experimental evidence by suggesting that "whilst the gradual decay and final disappearance of the prolonged afterimage may be explained in terms of retinal photochemistry, it is more probable that the locus of fragmentation lies altogether outside the retina (p.287)." However, because the initial intensity of the AI and the total time of AI presence were used as measures of AI strength, the presence of any fragmentation phenomena would not have affected the results of Experiments 11 and 12.

Other psychological experiments concerned solely with the origin of AIs also support a retinal site. Kolehmainen & Toumisaari (1969) flashed three small bright lights to produce the "tau-effect" and three AI spots. The lights were equidistant in a horizontal line. When two adjacent lights were flashed simultaneously followed shortly by the third light, the two simultaneous flashes were perceived as closer together in space than the centre flash and the third flash. The "tau-effect" is attributed to a central mechanism since the three lights are equidistant on the retina. On the other hand, the AIs produced by the three lights were perceived as equidistant. They concluded from this result that AIs were retinal in origin.

It would seem that a more convincing way to establish the retinal origin of AIs would be to employ some technique to eliminate retino-cortical transmission either during or following the induction of an AI. The technique of pressure blinding the eye may fulfill this function. Pressure applied to the eyeball produces partial retinal anoxia resulting in an increase in threshold to light after 5-15 seconds and effective blindness after 15-30 seconds (Craik & Vernon, 1941). Presumably pressure blinding interrupts synaptic transmission in the retina.

Craik (1940) described the results of a short experiment in which he pressure blinded one eye until vision faded entirely. The light from a 60-watt bulb was then projected on the blinded eye using the unblinded eye to establish fixation. After 2 minutes of exposure he looked away and viewed a homogeneous background. A clear AI from the normal eye was first visible. Then, when Craik (1940) closed that eye and released the blinded eye, vision returned along with an AI presumably from the blinded eye that had never transmitted stimulation to the higher visual centres. The similar strength of the blinded AI and the normal AI strongly suggested a retinal origin. An AI could also be produced in the blinded eye with the normal eye closed during the 2 minute exposure period. This presumably ruled out the possibility that the AI in the first case was due to a transferred AI from the normal eye. Therefore, because retino-cortical transmission was effectively blocked during induction, the subsequent AI must be originating in the retina.

However, it would seem that some improvements could be made to increase the conclusiveness of Craik's demonstration (1940). Because his induction period extended over a full 2 minutes and because pressure blinding is a somewhat uncomfortable procedure, it would seem possible that the effectiveness of pressure blinding may have varied considerably over the 2 minute period. Also, in his first experiment it seems possible that the viewed AI or part of the strength of the resultant AI was transferred from the normal eye. Even when the normal eye is closed stimulation would continue to be transmitted centrally possibly to contribute to any AI from the blinded eye. Craik (1940) presumably controlled for this possibility in a second test by keeping the normal eye closed during the induction period. On the other hand this would create the problem of maintaining constant fixation during the induction period with any eye movements resulting in a reduction in AI strength. However, this condition also produced "the same result."

Since Craik (1940) was more interested in demonstrating the usefulness of pressure blinding as an investigative tool than in undertaking a definitive study of the AI, his short report lacks quantitative support. Because Craik's (1940) conclusion would benefit from an improved replication of his short experiment and because the method of pressure blinding would seem to provide such a simple and conclusive demonstration of the retinal origin of AIs, the following short experiment was undertaken.

A Demonstration of the Retinal Origin of Afterimages

A simple way to overcome most of the criticisms of Craik's (1940) procedure is to use a brief intense flash as the AI induction stimulus rather than a stimulus requiring prolonged fixation. This would only require adequate pressure blinding during the instant of the flash. The AI would be sharp because eye movements would essentially be stopped during induction. If the much more intense flash stimulus was not perceived, it would be a more convincing check of the adequacy of the pressure blinding. Since the nonstimulated eye would be completely occluded there would be no possibility of a transferred AI contributing to the induced AI.

Since a positive AI results from the intense flash, it can be observed in a dark room without any background stimulation. This fact would allow the test of a central component of the AI. If, after induction, pressure blinding the stimulated eye but not the unstimulated eye had the effect of eliminating the AI, it would suggest that there is no central component to its origin. This was not tested by Craik (1940) and, therefore, needs confirmation. One difficulty in using a brief flash induction stimulus as far as the evaluation of Experiments 11 and 12 are concerned is whether the results could be generalized to negative AIs from prolonged fixation. It will be shown that the results using either method of AI induction are identical.

The first test was conducted to replicate Craik's (1940) results using a brief, intense flash as the induction stimulus with the stimulated eye pressure blinded. For this purpose the subject first dark adapted for 5 minutes in a very dimly lit room with an ambient illumination producing about 0.01 ft-L luminance from white surfaces. The induction stimulus was provided by a cut-out stencil of a vertical bar on a white background. 10 cm behind the cut-out stencil a Blaupunkt flashgun was mounted which produced a 100 joule flash of approximately a 1 msec duration. The subject positioned his head on a chin rest mounted 30 cm from the stencil pattern and fixated the centre of the vertical bar. With this arrangement the vertical bar measured 4 degrees of visual angle in height and one degree in width. The subject covered his left eye with the palm of his left hand and could pressure blind his right eye using the right index finger before triggering the flashgun on any trial.

Two conditions were tested using four trials following an ABBA design. 10 minutes separated the trials to allow complete AI fading. Condition A was right eye normal before right eye stimulation. In Condition B the subject applied pressure while maintaining fixation at the centre of the vertical bar as long as vision remained and for a further 10 seconds following the loss of vision. The flash was then triggered with a microswitch pressed by the small finger of the right hand. As soon as the flash occurred pressure was released. In all trials the initial strength of the AI was judged with respect to the first trial AI which was given a value of 100. In addition the time elapsed from the induction stimulus until the AI faded completely was measured with a stop watch and represented a duration measure of the AI.

The results showed no significant difference of AI strength between the conditions. The mean AI duration of condition A was 110 seconds and for condition B was 100 seconds. The mean initial magnitude for condition A was 95 and for condition B was 85. It must be noted in this last case that the AI appeared only when vision returned following the release of pressure from the blinded eye. Since this was usually about 10 seconds after the flash, it may be expected to yield a somewhat lower initial intensity than that in condition A which is observed almost immediately after the flash. Although it was difficult to compare the initial AI in condition B with that at the 10 second point in condition A, they seemed to be of equal strength. Therefore, the results suggest that equally strong AIs result whether an eye is normal or whether it is pressure blinded to block cortical stimulation. A retinal component of the AI is unquestionable. The fact that both conditions are essentially equal suggests that there is no cortical component.

A more conclusive demonstration of the lack of a cortical component would be to test the effect of pressure blinding after AI induction. In this case the same experimental conditions and stimuli were used as in the previous test. Instead of pressure blinding before AI induction, pressure was applied immediately after AI induction in the right eye. A positive AI could be observed clearly in the dark room with effectively no retinal activity resulting from distal stimulation. If there were a cortical component of the AI it should be unaffected by the retino-cortical blockage from pressure blinding and some AI should still be present. The results were quite dramatic. When the stimulated eye was pressure blinded immediately after AI induction, the AI faded entirely within 5-10 seconds. The AI did not reappear as long as pressure was maintained. When pressure was released the AI would usually return within 10-15 seconds. Since the AI under these conditions was clearly present for up to 100 seconds, pressure could alternately be applied and released to make the AI disappear and reappear several times. Pressure blinding did not seem to affect the overall rate of decay or total duration of the AI.

It may be that pressure blinding, instead of eliminating retino-cortical transmission, produces a low level noise which disrupts low level cortical activity. In other words, perhaps a cortical component of the AI exists but is disrupted by random activity from pressure blinding. If this were the case, then pressure blinding the unstimulated eye would be expected to diminish the intensity and duration of the AI as compared with a normal condition A trial of the first test. However, the AI during pressure blinding of the unstimulated eye was indistinguishable from that during a normal trial without pressure blinding. Therefore in the case of the positive AI following an intense, brief flash of light, the results of the present experiment indicate that the origin of the AI is in the retina without any component contributed from nonretinal levels.

In the case of negative AIs following prolonged fixation of the induction stimulus Craik (1940) has already shown that the AIs are induced during the pressure blinding of the stimulated eye. The question is whether it is also the case with negative AIs as it is with positive AIs that pressure blinding the stimulated eye after induction will cause the AI to disappear along with vision in the blinded eye? The same procedure was followed here as in the previous tests except that the stimulus was provided by a black vertical bar on a white background with the luminances of 1.0 ft-L and 20 ft-L respectively.

Constant fixation for 60 seconds produced a clear negative AI which lasted about 20 seconds. However, if the stimulated eye were pressure blinded at the end of the 60 second induction period with fixation being maintained as long as vision remained, no AI was observed with the unstimulated eye covered or uncovered and viewing a homogeneous illuminated field. Pressure was released soon after blindness had been attained and vision in the stimulated eye along with a weak AI returned within a few seconds. Because the total time to attain blindness and to retain vision after pressure release was about 15 seconds, it was understandable that only a weak

AI remained. The fact that the AI decayed regardless of retino-cortical transmission is further support for a photochemical origin of the AI. At least this fact fails to support a hypothesis that the AI is stored if it is not allowed to "discharge".

In summary, the results of the present experiments support and elaborate the earlier results of Craik (1940). Pressure blinding the stimulated eye during the induction period does not affect the subsequent strength of either a positive or a negative AI. However following a normal induction of either a positive or negative AI, pressure blinding the stimulated eye eliminates the AI. These simple experiments in addition to the evidence discussed earlier provide what seems to be conclusive evidence that the origin of AIs is in the retina.

Discussion of the Evidence for the Origin of the Movement After Effect

Sekuler & Pantle (1967) recently proposed a model for the MAE which generally fits the scheme thought to underlie all aftereffect phenomena (Sutherland, 1961; Woodworth & Schlosberg, 1954). The main points of their model are:

1. The existence of cells or analyzers which respond exclusively or at least optimally to movement in a preferred direction.
2. Adaptation of these cells with continued stimulation.

3. When the movement ceases these cells are suppressed in activity.

4. The amount of suppression depends on the amount of prior stimulation.

5. The amount of time to recover the baseline activity level is a function of the amount of suppression.

6. The final duration of the MAE is the time required to recover the baseline level.

It would also be generally accepted that it is the imbalance of stimulation between analyzers sensitive to movements in opposite directions which results in the MAE. That is, the suppression of 'analyzers' for movement in one direction will result in a greater net activity from the 'analyzers' for movement in the opposite direction.

Sekuler & Ganz (1963) described psychophysical results consistent with this model. They found that continued movement stimulation raised the luminance threshold for detecting stripes moving in the same direction compared with the threshold for detection of opposite moving contours. There is some physiological evidence to support the existence of such 'analyzers'. Barlow & Hill (1963) reported the existence of retinal ganglion cells in the rabbit retina that would fit the requirements of the Sekuler & Pantle model (1967). The retinal ganglion cells showed maximum activation to moving contours in its retinal field in a 'preferred' direction. With continuous movement stimulation for 57 seconds the cell showed an exponential decay of activity from about 60 impluses per second to about 25/second. At the end of 57 seconds the motion was stopped and the frequency of impulses dropped to zero which was below the normal baseline of about 5/second. During the next 30 seconds the level of activity climbed slowly back to its normal spontaneous level. Presumably cells that are maximally sensitive to movement opposite to the stimulation movement would be unaffected during the stimulation period and would continue to show baseline activity following stimulation when the activity of the stimulated cell was still suppressed. This imbalance should then give the perceived MAE. It is interesting that the time course for these movement detectors of adaptation and recovery of baseline activity corresponds fairly well to the MAE that would normally result from a 57 second stimulation period. Of course, the Barlow & Hill (1963) study only verified the existence of the required mechanism for the MAE in one species of mammal. In an associated study Barlow & Brindley (1963) point out that it is unlikely that such units exist in the retina of humans. The evidence for this will be discussed later.

Physiological studies in mammalian species with visual systems more similar to humans have produced other evidence relevant to the origin of the MAE. Hubel & Wiesel (1959) found neural cells in the primary visual cortex of cats that responded maximally to stimuli moving in one direction across the retinal receptive field. These cortical cells responded at a much reduced level to stimuli moving in the opposite direction. In a more detailed analysis of the primary visual cortex of monkeys Hubel & Wiesel (1968) found a large number of their 'complex' cells to be activated by contours moving only in one direction and not in the opposite direction. These results have been confirmed by Wurtz (1969) working with awake, nonparalyzed monkeys.

On the other hand Kuffler (1953) found the retinal ganglion cells of cats to have concentric receptive fields and to respond to the onset or termination of a spot of light in a specific retinal area. He failed to find cells continuously activated by constant movement in one direction. Hubel & Wiesel (1962) also found concentric receptive fields in the lateral geniculate nucleus of cats. Thus, if we assume that the human visual system is more similar to that of the cat and monkey than to that of the rabbit it seems most likely that the units responsible for the origin of the MAE are located on higher levels than the retina, perhaps in the primary visual areas in the cerebral cortex.

Before complicating the physiological picture any further it may be appropriate to consider some of the psychological evidence relevant to the origin of the MAE. The debate between peripheral and central origins of the MAE is an old one. Adherents of the peripheral theory usually depend for support on the fact that the 'transferred' MAE from the stimulated to the unstimulated eye is rarely as strong as the MAE in the stimulated eye, and that it is impossible to know which eye is being stimulated so that 'transference' may not be occurring at all. At the same time the fact that there is usually considerable interocular transfer of the MAE has been used by some experimenters as conclusive evidence of a central origin (Holland, 1957). However, as Day (1958) and Pickersgill & Jeeves (1964) correctly argue, evidence of 'transfer' does not rule out a retinal origin of the MAE since the effects of a continuing retinal process of the induced eye may be what is seen in the other eye.

On the other hand, the fact that the 'transferred' MAE is rarely as strong as the ipsilateral MAE and sometimes is absent entirely is not conclusive evidence for the existence of a retinal component since it may be the result of cortical cells that show ocular dominance to one eye. Electrophysiological evidence (Hubel & Wiesel, 1962, 1968; Blakemore & Pettigrew, 1970) and anatomical evidence (Hubel & Wiesel, 1969) now exists demonstrating that most cortical neurons in the striate cortex of cats and monkeys are ocular dominant. This means that when only one eye is receiving constant movement stimulation during an induction period, it is stimulating a large number of neurons that can respond to either eye but those that are most strongly stimulated are those that are ocular dominant to the stimulated eye. That could explain why 'transfer' occurs but is rarely as strong as the ipsilateral MAE. Thus the evidence of 'transfer' may be consistent with any theory of the origin of the MAE and, therefore, provides no crucial support for any one theory.

An interesting attempt to localize the origin of the MAE was undertaken by Anstis & Moulden (1970). They presented results which they feel support both retinal and central components. In their first experiment the subjects observed opposite rotating sectored disks in binocular rivalry during the induction period. In the test period, their subjects reported no movement when both eyes were open and in the case of only one eye being tested the MAE for that eye only was observed. They do not report if the separate MAE's were reduced as compared to nonrivalry monocular stimulation but only that there was movement in the appropriate direction. They conclude that this evidence would be consistent with a retinal origin of the MAE, or an origin peripheral to the point of binocular fusion (Anstis & Moulden, 1970). This assumes that binocular fusion occurs on cortical cells that are activated equally by both eyes and ignores the previously mentioned findings of cortical neurone ocular dominance. If it is assumed that the organization of the human striate cortex is similar to that of the monkey then most cortical neurons are differentially sensitive to one eye or the other. In that case, the Anstis & Moulden (1970) evidence is consistent with a cortical origin of the MAE and is not necessarily evidence for a retinal origin.

On the other hand, the subsequent experiments of Anstis & Moulden (1970) necessarily support a central origin of the MAE. They arranged a ring of lights and switched them on and off in such a way that each eye saw only a random flashing oscillation but so that with dichoptic presentation subjects saw rotating phi movement. Their subjects reported the opposite rotating movement of the MAE during the test period. In another experiment the switching of the lights was arranged so that each eye saw phi movement rotating in a clockwise direction but so that with dichoptic viewing subjects saw anticlockwise rotation. Following an induction period of this type of stimulation, subjects saw a clockwise MAE whether the test period was with binocular or monocular viewing of a stationary field. This MAE, although it was short (2-3 seconds) must have been produced by central and not retinal mechanisms.

Another technique that has been used recently to analyze the components involved in the MAE has been that of pressure blinding the eye as described in the previous discussion of the AI origin. This provides a technique for eliminating an MAE if it is retinally produced. If the MAE is still 'transferred' to the nonstimulated eye when the stimulated eye is pressure blinded, then it must have a nonretinal origin. Barlow & Brindley (1963) did just that and found that pressure blinding did not affect the apparent strength and duration of the 'transferred' MAE.

On the other hand, Pickersgill & Jeeves (1964) conducted a series of experiments using pressure blinding with a larger number of subjects and concluded that the MAE was dependent on the state of the stimulated eye during the aftereffect. It may be instructive to consider their results in more detail to determine which theory is more heavily supported. Pickersgill & Jeeves found that no MAE resulted if the stimulated eye was pressure blinded during the entire induction period but released during the test period. This result would only be consistent with a retinal origin if the effect of pressure blinding was to interfere with retinal synaptic transmission rather than optic nerve transmission. In either case the results are consistent with a central origin of the MAE.

In a further experiment Pickersgill & Jeeves (1964) essentially replicated the Barlow & Brindley (1963) experiment by comparing their condition "1a" ("transfer" without pressure blinding) with condition "2a" ("transferred" MAE with stimulated eye pressure blinded during the test period.) Their results (Pickersgill & Jeeves, 1964) were consistent with those of Barlow & Brindley (1963) in that there was no difference in the 'transferred' MAE duration between the two conditions. This seems to be the strongest evidence available against a retinal origin and evidence for a more central origin of the MAE. Pickersgill & Jeeves (1964) only conclude from this that "it is not possible to draw any conclusions from this result about the effects of anoxia (p.99)."

One part of this last experiment of Pickersgill & Jeeves (1964) does seem less easily explicable in terms of a nonretinal origin of the MAE. After the MAE had come to an end in the contralateral eye with the ipsilateral eye pressure blinded during the test period, the pressure was released but the eye was covered to occlude any light stimulation and subjects continued to view with their contralateral eye. In this case 7 out of 12 subjects showed a renewed MAE with an average duration of about 10 seconds. The fact that 5 subjects did not see any further MAE was not important, they felt. What was important to them was the demonstration that resumption of the aftereffect could occur when pressure blinding was terminated. They made the fairly safe conclusion that the MAE in the contralateral eye "is, therefore, dependent on the state of the stimulated eye during the aftereffect (p.99)."

However, the conclusion that the origin of the MAE or even a component of the MAE was in the retina is not necessary from the findings of Pickersgill & Jeeves (1964). The renewed stimulation of spontaneous activity from the ipsilateral eye following the release of pressure may produce activity in cortical cells for which the ipsilateral eye is dominant. This may 'discharge' any remaining MAE that is less effectively 'discharged' by the contralateral eye. It would seem that even the result which Pickersgill & Jeeves (1964) feel is most convincing for a retinal component of the MAE is consistent with a cortical origin if one assumes that most striate cortical neurones are ocular dominant. Thus, it seems that the experiments of Pickersgill & Jeeves (1964) do not present any evidence which necessarily implicates the retina as the origin of the MAE, or which is inconsistent with a cortical origin.

Scott & Wood (1966) in an impressively controlled study investigated some of the same conditions tested by Pickersgill & Jeeves (1964). Using a "null" technique rather than duration measure they found that pressure blinding produced a slight but significant reduction of MAE in the stimulated eye. This result was found regardless of whether the stimulated or contralateral eye was the one being pressure blinded. They also found robust 'transfer' of the MAE when the stimulated eye was pressure blinded. Pressure blinding appears to affect the MAE strength but "no retinal theory would have predicted the diminution of the aftereffect resulting from applying pressure to the nonparticipating eye (p.442)."

They conclude that "if there is a retinal component in the aftereffect of motion, it can account for only a very small fraction of the aftereffect (Scott & Wood, 1966, p.442)." Although pressure blinding may interfere minimally with the MAE, this interference may be occurring in the retina and/or the cortex. Thus there is still no evidence that necessarily substantiates the retina as providing even a component of the origin of MAE.

There is some evidence which would be consistent with a retinal component. However, in general the available psychological evidence strongly supports a cortical or non-retinal origin of the MAE and throws doubt on the existence of any retinal component of the MAE origin.

There has been considerable recent electrophysiological evidence of directionally sensitive neurons in the optic tectum (superior colliculus) of different mammals (Humphrey, 1968; Sterling & Wickelgren, 1969; Wickelgren & Sterling, 1969).

This research motivated Richards & Smith (1969) to attempt to separate effects of cortical activity from that of the superior colliculus. Their attempt was based on the assumption that changing convergence affects the 'mapping' of the retinae onto the cortex and effectively expands or contracts the apparent size of the whole visual field (Richards, 1968). If an 'image' from the MAE of a rotating spiral is not due to the geniculo-cortico mapping but due to a fixed cortical 'fatigued' area, then convergent eye movements should not affect the apparent size but would change the objective angular size of the MAE. This would presumably occur because the visual world would shrink in cortical extent with convergence movements and the MAE would remain constant in cortical extent and apparent size, but relatively larger with respect to the visual world. They ingeneously used a spiral whose inner disk produced contraction with an outer annulus that produced expansion. This provided a nonmoving circular boundary that could only be perceived when the spiral was rotating or when the aftereffect was being observed. The objective angular diameter of this boundary in the aftereffect showed no change with a degree of convergence that should have altered the objective size by about 30% if it had been of a cortical origin. They also felt that previous experimental evidence eliminated the retina as a possible site of the MAE. They conclude that "the most likely location for the motion aftereffect in man would be the most prominent midbrain structure receiving retinal input, the superior colliculus (Richards & Smith, 1969, p.534)."

The neurophysiological investigations of the superior colliculus of the cat by Sterling & Wickelgren (1969) would strongly suggest the involvement of the superior colliculus in the MAE. Single units in the superior colliculus are even more selectively sensitive to retinal movement and less sensitive to contour characteristics than are cortical cells.

They adapt more rapidly to stationary stimuli. Their 'null' direction of movement is opposite to the preferred direction rather than perpendicular as for cortical cells. 97% of the units were binocularly driven with over half of the units showing no ocular dominance. The topographic map of the visual field shows an even greater predominance of the area centralis than the retino-cortical mapping.

Although the superior colliculus receives input from both the retina and the striate cortex, the units have response characteristics most similar to the cortical cells described as 'hyper-complex' by Hubel & Wiesel (1962). Wickelgren & Sterling (1969) failed to find any directionally sensitive fibers in the retino-collicular tract which, incidentally, suggests that the cat does not have retinal movement detectors. However, by using ablation studies and reversible cooling effects they demonstrated that the directional sensitivity of the collicular units is dependent on cortical input. They also found that monocular closure from birth produces almost complete dominance of all units to the normal eye. Therefore, if the superior colliculus of humans functions similarly to that of cats, it would appear to be a likely candidate for the origin of at least some component of the MAE.

However, the conclusion of Richards & Smith (1969) to rule out the striate cortex as a location of the MAE must be treated very tentatively. Their conclusion is based on a series of sequentially contingent assumptions with empirical support in each case from no more than one experiment. They first assume that a 'remapping' must occur in the lateral geniculate body or before retinal input reaches binocularly driven cortical units. This is based on the finding that the change in perceived size of constant sized retinal images which accompanies vergent eye movements also changes the absolute minimum visual angle which can produce binocular rivalry. This, of course, assumes that binocular rivalry occurs on the first cortical level to receive binocular input (an unsubstantiated premise). It also assumes that the changes of perceived size accompanying vergent eye movements is a result of this 'remapping' process.

Next, Richards & Smith (1969) demonstrate that convergence changes the apparent size but does not change the objective visual angle size of an image that can only be perceived in a movement aftereffect. This is contrary to the effects of convergence on the visual scotoma from a cortical lesion. Presumably, then, the area of 'fatigue' underlying a MAE is not the same as an area of a fixed cortical lesion. Based on their earlier assumptions they conclude that the MAE originates in the superior colliculus since it must not be coming from the cortex. However, it would seem difficult to evaluate the relevance of the effects of convergence on cortically produced visual scotomas. It is certaintly questionable whether one can conclude that the 'fatigued' cells producing the MAE do not occupy a fixed cortical area just because the perceived MAE size does not operate like a perceived scotoma size.

Besides the tenuousness of most of their earlier assumptions, their conclusion seems to disregard the Wickelgren & Sterling (1969) results which attribute the movement response characteristics of the superior colliculus not to retinal input but to input from the visual cortex and probably from 'hypercomplex' cells at that. How can the geniculo-striate system be by-passed during the production of the MAE in the superior colliculus when motion sensitivity is dependent on the cortico-collicular system? There are too many weak links in the chain of their argument to agree with their conclusion of the lack of cortical involvement in the MAE. Indeed, the Wickelgren & Sterling (1969) study would strongly suggest cortical involvement.

In summary, the neurophysiological evidence provides no support for a retinal origin of the MAE in higher mammals and primates. On the other hand, cells in the striate cortex and superior colliculi of cats and monkeys show ocular dominance and motion sensitivity in a 'preferred' direction. This evidence would strongly suggest the involvement of the superior colliculus and perhaps to a lesser extent the involvement of the primary visual cortex in the origin of the MAE. Psychological evidence exists which necessarily implicates nonretinal mechanisms in the MAE. But it seems that none of the discussed psychological evidence provides necessary support for a retinal involvement in the origin of the MAE. In other words,all the psychological evidence is consistent with a nonretinal origin.

Discussion regarding the 'level' of Binocular Rivalry

The fact that binocular rivalry stimulation during induction had a minimal effect on the afterimage strength indicated that contralateral inhibitory effects of BR occurred mainly on a higher 'level' than the origin of the AI. The physiological and psychological evidence discussed earlier points to the retina and more specifically to the photoreceptor cells of the retina as the origin of prolonged AIs. This leads to the conclusion that there is no contralateral effect from BR stimulation on the retinal level. The results of Experiment 12 would also suggest that BR control is not exerted even partially on the photoreceptor level. This rules out a centrifugal effect from BR control as far out as the photoreceptor level.

Assuming that the first level of binocular interaction in the primary human visual system is in the striate cortex, these are not surprising conclusions. Indeed, based on the assumption of cortical binocular interaction the lack of a BR effect on the AI would be sufficient evidence to assign a pre-cortical origin to the AI. This would imply that the negative AI resulting from prolonged fixation as used in Experiments 11 and 12, if it has a neural component, would be confined to pre-cortical levels.

On the other hand, the mixed results of BR stimulation and BR control effects on the MAE and the imprecise determination from the evidence of the MAE origin require a rather more complicated conclusion about the effective level of BR stimulation and control. From Experiment 12 it was concluded that the MAE arises from a lower "level" than that which is the basis for the phenomenal suppression of BR since phenomenal suppression itself, did not affect the MAE strength. The physiological evidence and the investigation by Richards & Smith (1969) suggested the involvement of the superior colliculus in the MAE origin.

The findings of Wickelgren & Sterling (1969) suggest that the superior colliculus receives its movement sensitive stimulation from the striate cortex, probably from 'complex' or 'hyper-complex' cells. If it is assumed that no binocular interaction exists prior to the visual cortex and if the superior colliculus provides a component of the MAE, the findings in this chapter indicate that it is the striate cortex, rather than the retina, that supplies the superior colliculus with movement stimulation. Thus, if some component of the MAE arises from the superior colliculus, it may be presumed that collicular cells receive movement input from the striate cortex during the induction period and feed back MAE stimulation to the striate cortex during the test period. Since it is not the phenomenal suppression which affects the MAE, the superior colliculus would presumably receive its cortical input from levels below that of phenomenal rivalry.

The inhibitory effects of BR stimulation may operate on cortical cells that supply the superior colliculus with its input or on the superior colliculus alone. In the first case it would mean that the inhibitory effects would be operating continuously on cortical levels below that of phenomenal rivalry. These effects, if they are continuous as they appear to be with the MAE, should be detectable even during non-suppression phases. As mentioned earlier, the fact that non-suppression seems subjectively and behaviourally to be free of inhibition is inconsistent with the conception of a continuous lower level inhibitory effect.

The second possibility, that the contralateral inhibitory effect only operates on the superior colliculus, provides a convenient resolution to this inconsistency. This possibility also seems to be the more plausible one in view of the physiological evidence that a minority of collicular units are ocular dominant but that 80% of cortical units are ocular dominant. This allows the possibility that binocularly incompatible contour and movement information may coexist to some extent in the same cortical region in different populations of cells each dominant to different eyes. However, in the superior colliculus coexistence of binocularly incompatible information would be much less possible with its much greater binocular convergence on to nondominant populations of cells. Binocular inhibitory effects would be much less avoidable in the superior colliculus. Thus, the consideration of the superior colliculus as the origin of at least a major component of the MAE allows the possibility that the contralateral inhibitory effects of BR stimulation can reduce the MAE without affecting information transmission during the phenomenal nonsuppression phase.

The phenomenal alternations of rivalry which are subject to voluntary control would then operate mainly on a higher level than that which provides collicular input. Information transmission during the nonsuppression phase may in reality be less efficient than during nonrivalry. Under the present model the extent of information loss during nonsuppression would indicate the extent to which some contralateral inhibition exists on cortical levels prior to the cortical level that supplies the collicular input. In addition, if in fact BR control does affect the MAE strength it would indicate the extent to which phenomenal rivalry results from the same cortical levels that supply collicular input. Alternatively, an effect of BR control on the MAE strength would indicate the extent to which the level of phenomenal rivalry is at or below the origin of a possible cortical component of the MAE.

In summary, it appears that the superior colliculus may be the origin of at least the major component of the movement aftereffect. The superior colliculus receives its movement stimulation probably from 'complex' or 'hyper-complex' cells in the striate cortex. The presence of binocular rivalry stimulation during an induction period markedly reduces the MAE strength. Variation of rivalry stimulus intensity but not of phenomenal dominance using voluntary control has the effect of varying MAE strength. Previous findings in Chapter III and from other experimenters suggests a lack of inhibition of contour information during the nonsuppression rivalry phase. Therefore a possible model to incorporate the present evidence would suggest that the inhibitory effect of rivalry stimulation on the MAE operates mainly on the superior colliculus. The phenomenal alternations of rivalry would then operate from activity mainly in levels beyond those of the 'complex' and 'hypercomplex' cells providing the colliculus with input. Wherever this higher level of phenomenal rivalry exists has yet to be determined.

CHAPTER VI.

THE EFFECT OF THE VOLUNTARY CONTROL ON THE MEAN PHASE DURATIONS OF BINOCULAR RIVALRY.

Introduction

It has been known for a considerable time that dominance in binocular rivalry can be dependent upon the relative stimulus strengths of the rivalry stimuli (Breese, 1899). An increased strength of one stimulus results in an increase in its relative dominance in rivalry. Stimulus strength may be in terms of overall luminance (Breese, 1899), sharpness of contour or blurredness (Levelt, 1968), concentration of contours (Kaufman, 1963), movement of contours (Grindley & Townsend, 1965), or contrast of contours (Kaplan & Metlay, 1964). The effect of stimulus strength variation has always been measured in terms of overall predominance during the experimental period. This may be taken simply as the percentage of the total period that the stimulus is recorded as being in the nonsuppression phase of rivalry. Past experimenters have not investigated the effects of stimulus strength on the individual phase durations. As Levelt points out (1968, p.83) most experimenters have assumed that the mean nonsuppression phase durations of a stimulus would be positively correlated with its strength.

However, the increase in dominance may result from any one of three possible changes in mean phase durations: 1. the stimulus with increased strength shows an increased mean nonsuppression duration and the constant strength stimulus shows no change in nonsuppression duration. 2. the stronger stimulus shows no change in phase duration but the constant strength stimulus shows a decreased duration of nonsuppression phase. Or 3. the stronger stimulus shows an increased nonsuppression duration and the constant stimulus shows a decreased nonsuppression duration. At the present time only two investigations (Levelt, 1968 and Fox & Rasche, 1969) have measured the effects of variation of stimulus strength on mean phase durations.

Levelt (1968) kept the right eye stimulus strength constant and varied the left eye stimulus strength in two different ways. In his Experiment 11 (Levelt, 1968, p.88) kept all parameters constant in the left eye stimulus except the introduction of a certain amount of blur of the contours. Under the sharp contour condition the left eye stimulus was in nonsuppression phase for 50.9% of the time. Blurring the left eye stimulus significantly reduced its dominance to 26.5% of the time. On the other hand, there was no change in the mean duration of the left eye nonsuppression phase. The mean left eye phase durations were 2.50 seconds and 2.48 seconds for the two conditions respectively. The result must have been an increase in mean duration of the right eye nonsuppression phase.

In the second method of varying stimulus strength Levelt (1968, p.90) varied the degree of contrast between the black and white of the left eye stimulus. Two high contrast (7.35) conditions but at different overall luminances produced 41.9% and 46.6% nonsuppression time for the left eye stimulus. A reduction of contrast to 0.18 reduced the left eye nonsuppression time to 27.6%. Again there was no variation of the mean duration of the left eye nonsuppression phase. The means from the three conditions were 2.62 seconds, 2.56 seconds and 2.59 seconds respectively. The result of decreasing stimulus strength of the left eye apparently was an increase of the duration of the nonsuppression phase of the right eye with no change in the duration of the left eye nonsuppression phase. This result supported the second of Levelt's four propositions (1968, p.76) relating stimulus strength to predominance and rate of rivalry alternation. The proposition was that an increase of stimulus strength in one eye will not affect the mean dominance phase for the same eye but will only affect the mean dominance phase for the opposite eye.

Fox & Rasche (1969) used essentially the same rivalry stimuli as that of Levelt but varied contrast values over a much wider range. The right eye rivalry stimulus was provided by a black disk 40 min of angle surrounded concentrically by a white annulus extending to a visual diameter of 3 deg 14 min. The left eye rivalry stimulus was provided by a foveally located white disk 40 min in diameter surrounded by a black annulus with a visual diameter of 2 deg 48 min surrounded in turn by a concentric white ring with an outer diameter of 3 deg 14 min of visual angle. These rivalry stimuli were the same as used by Levelt (1968) except that they occupied slightly less than half the visual angle of Levelt's stimuli. The black area of the rivalry stimuli was at a constant 0.001 ft-L so variation of the white area luminance produced a variation in contour contrast. The luminances for the variable stimulus ranged from 0.1 ft-L to 100 ft-L in equal log unit steps. The four variable stimulus values were tested with two different constant stimulus values. They found that the mean nonsuppression phase durations of the varied stimulus eye showed no significant change. On the other hand, the mean duration of the constant stimulus eye did show a significant ($p = .01$) variation between the two extreme luminance values. Thus, these results (Fox & Rasche, 1969) supported Levelt's proposition.

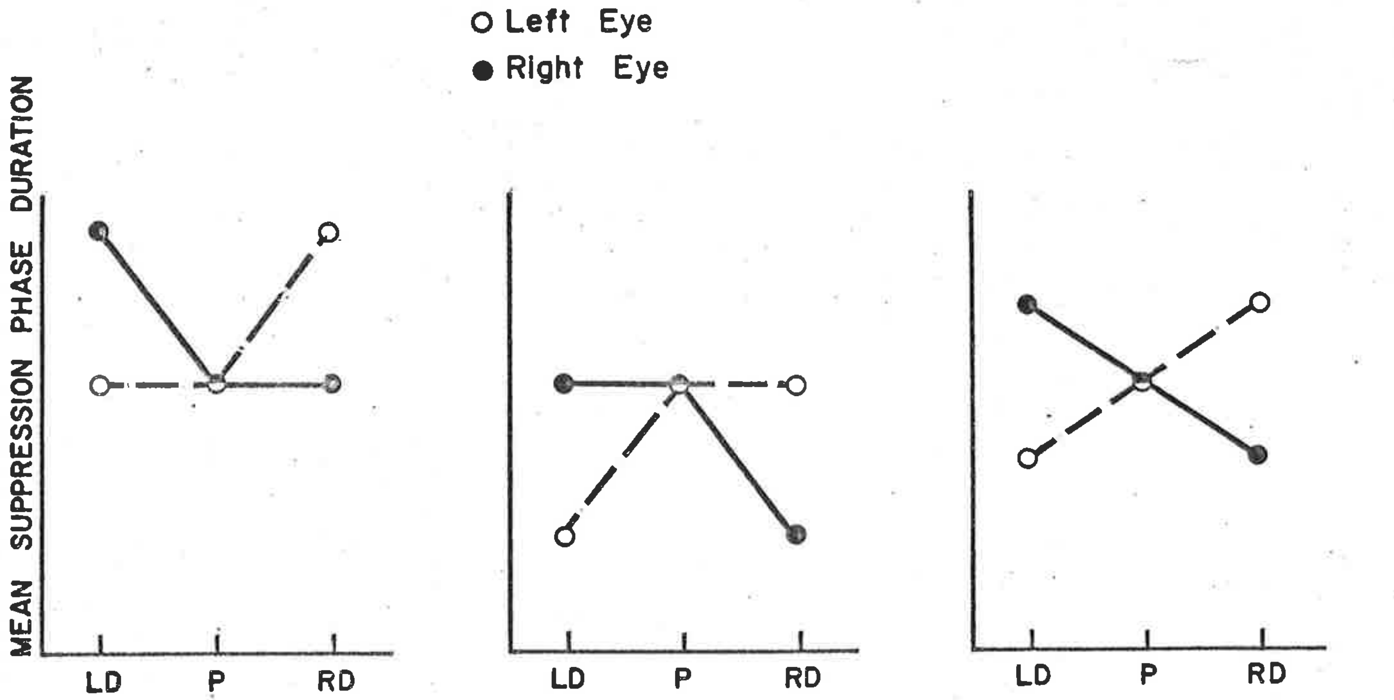
For the purpose of simplicity it would be advantageous to restate Levelt's proposition. Because he concentrates solely on the dominance or nonsuppression phase durations his proposition has to be stated in a negative and rather nonintuitive manner, i.e. there is no change of phase duration in the varied stimulus eye but there is an inverse change of phase duration in the opposite eye. If it is assumed that rivalry is a dichotomous phenomenon (an assumption supported by the results of Experiment 4), then the dominance phase of one eye is also the suppression phase of the opposite eye. Since Levelt does not propose any underlying physiological mechanism as a basis for his results, his Proposition II serves only a descriptive function. Presumably then, he would not object to a simplification of his Proposition by substituting the suppression phase of the varied stimulus eye for the nonsuppression phase of the opposite eye.

Levelt's Proposition would then read--variation of the stimulus strength in one eye produces variation of the suppression phase duration in that eye and no change in the suppression phase duration of the opposite eye. For example, an increase of stimulus strength produces a decrease of suppression duration in the affected eye and no change in the opposite eye. In fact Fox & Rasche (1969) state the relationship in these terms since they suggest a model which relates rivalry stimulus strength in an eye only to the suppression phase of that eye.

The confirmation of Levelt's Proposition II by Fox & Rasche (1969) may provide a basis on which to investigate further the mechanism of the control of BR. Both the variation of stimulus strength and the exercise of control of rivalry affect the phase durations. Thus it may be possible to speculate about the nature of the mechanism of rivalry control. If control produces effects which are equivalent to an increase of stimulus strength it may be considered 'excitatory'. If control produces effects which are equivalent to a decrease of stimulus strength, the control mechanism may be considered 'inhibitory'.

It has been shown in earlier chapters that by using voluntary control the rate of rivalry may be increased or decreased as compared to the passive rate and that the predominance of one rivalry stimulus may be increased or decreased compared with the passive viewing condition. The second of these, dominance control, may be exercised by; 1. increasing the suppression phase duration of the unwanted eye, 2. by decreasing the suppression duration of the attended eye, or 3. by a combination of both effects. The first effect could also be produced under passive viewing conditions by a decreased stimulus strength of the suppressed eye, the second by an increased stimulus strength of the attended eye, and the third could be produced by a combination of both effects. These three possibilities and their effects on the mean suppression phase durations are illustrated in Figure 6.1. Figure 6.1a represents the possibility of an increased suppression duration of the nondominant or suppressed eye and would suggest an 'inhibitory' mechanism of control. Figure 6.1b represents the possibility of decreasing suppression durations of the dominant eye and would suggest an 'excitatory' mechanism. The third possibility represented in Figure 6.1c would suggest the presence of both 'inhibitory' and 'excitatory' effects.

It has already been clearly established that the control of the rate of rivalry alternations can produce either a decrease or an increase of rate. An increase of rivalry rate



a. NONDOMINANT EYE IS 'INHIBITED'

b. DOMINANT EYE IS 'EXCITED'

c. NONDOMINANT EYE IS 'INHIBITED AND DOMINANT EYE IS 'EXCITED'.

Fig. 6·1. Experiments 13 and 14. The three possible effects on mean durations of the suppression phase of the left and right eye under the dominance control instructions. "Left Dominant" (LD), "Passive" (P) and "Right Dominant" (R.D) necessarily produces a decrease in mean phase durations in one or both eyes. In terms of the above speculation this would suggest the presence of an 'excitatory' effect. On the other hand, a decreased rivalry rate must accompany an increased phase duration in one or both eyes--an effect which is equivalent to a decreased stimulus strength in one or both eyes. This would suggest the presence also of an 'inhibitory' effect. Since the dominance control and rate control methods usually yield highly correlated control measures (Experiment 5), it may be suggested that they are merely two methods of measuring the same ability. With this assumption it may be predicted that dominance control also employs an inhibitory and excitatory effect and would alter the suppression durations in the manner illustrated in Figure 6.1c.

It may also be predicted that if rate control and dominance control are correlated and if they both employ excitatory and inhibitory mechanisms, then there should be similarities of mean suppression durations between the modes of exercising control. The mean suppression durations for the left and right eye during 'Rapid rate' should be the same as those when the left and right eye respectively are being held dominant during dominance control. Similarly, the mean suppression durations for the left and right eye during 'Slow rate' should be the same as those when left and right eye respectively are being held in the suppression state during dominance control. In the following experiments, these predictions will be tested for naive, unpracticed subjects and for two subjects well practiced in BR control.

Experiment 13

It was shown in Chapters II and IV that naive, unpracticed subjects could exercise a very significant degree of voluntary control of rivalry by reducing the rate under the 'Slow rate' instructions and increasing it under the 'Rapid rate' instructions. It was also shown that the effect of practicing these conditions is an increase in the degree of control resulting from a decreased slow rate and an increased rapid rate. No suggestion was made that well-practiced control was qualitatively different than unpracticed control. It was assumed that practice merely extended the ability that was already present. However, it may be that with dominance control in particular the nature of the control mechanism is different for well-practiced subjects than for unpracticed subjects. For example, unpracticed subjects may exert control using basically an inhibitory mechanism but with practice may develop an excitatory mechanism. It would be necessary first to measure the mean durations of rivalry phases of naive, unpracticed subjects exercising voluntary control.

Experiment 9 showed that the high degree of BR control that was developed with the practice of single line rivalry stimuli was not entirely transferred to other types of rivalry stimuli. The fact that naive subjects had somewhat less control of afterimage rivalry stimuli than control of continuously illuminated stimuli suggests that the measure of rivalry control may be dependent to some extent on the specific rivalry stimuli used. Thus, in the present attempt to relate the effects of control to the results of Levelt (1968) and Fox & Rasche (1969), it would be appropriate to use the same rivalry stimuli.

There has been some question in the past of the role of peripheral mechanisms in the control of rivalry. Although it was found in Chapter IV that peripheral mechanisms could make, at best, only a minor contribution to measured control, it would, nevertheless, be informative to test the effect of the control of afterimage rivalry stimuli. In addition to eliminating any possible role of accommodation or eye movements in BR control the use of a different type of rivalry stimulus would test the generality of the results from the conventional rivalry stimuli. Thus both the illuminated rivalry stimuli used by the other experimenters and the afterimage stimuli used in Experiment 9 were used in the present experiments.

Method

Subjects

Twelve subjects (6 males, 6 females) with uncorrected normal vision were obtained from an introductory psychology course. No subject had any previous experience of binocular rivalry and all were naive to the purpose of the experiment.

Stimuli

Two types of rivalry stimuli were used in the present experiment. The first type was the same as that used by Levelt (1968) and Fox & Rasche (1969). The right eye rivalry stimulus consisted of a centrally located dark grey disk 1 deg in diameter. This was surrounded by a white annulus with an outer diameter subtending a visual angle of 3 deg 30 min. The left eye rivalry stimulus essentially had these contours reversed. It consisted of a centrally located white disk 1 deg in diameter. This was surrounded by a dark grey annulus with an outer diameter subtending a visual angle of 3 deg. This in turn was surrounded by a white ring with an outer diameter of 3 deg 30 min and which served as a fusion contour for the two rivalry stimuli.

Since it was the experience of the author that these rivalry stimuli had some tendency to lose corresponding retinal projections through vergent eye movements, it was decided to use additional contours in the surrounding field to facilitate fusion. For this purpose an additional black ring 15 min in width surrounded the white annulus and white ring in the right and left eye rivalry stimulus respectively. In addition the two stimuli were placed in identical positions on identical random dot fields similar to the pattern used in Chapter V for the production of the MAE. The black dots were

15 min in diameter and accounted for about one third of the total area of the fusion fields. The random dot fields extended peripherally to subtend a visual angle of 25 deg. The fusion rings and random dot fields provided such a large number of high contrast fusion contours that it was almost impossible to lose fusion. The use of random dot patterns also discouraged any discrete incremental convergence movements that might occur with regular repeating fusion contours.

Uniform illumination was provided by overhead fluorescent lamps. The luminance of the white areas of both fusion fields and right and left rivalry stimuli as measured with an S.E.I. spot photometer was 25 ft-L. The luminance of the black random dots of the fusion fields was 2 ft-L. The luminance of the grey disk in the right rivalry stimulus and grey annulus in the left rivalry stimulus and the grey ring in both stimuli was 5 ft-L. This provided a contour contrast of 4.0 for both rivalry stimuli. This contrast value was intermediate to the two values used by Levelt (1968) and less than those of Fox & Rasche (1969). In addition, a comparison of retinal projection sizes showed that the subtended visual angle of the present rivalry stimuli was intermediate to those of these two previous investigations.

The afterimage rivalry stimuli were produced by the same method as described in Experiment 9. A Blaupunkt photoflash gun was mounted behind a stereocard placed in the stereoscope.

The stereocard was opaque to light except for cut-out slots which allowed the passage of light and production of positive afterimages. The slots were rectangular bars and subtended 4 deg of visual angle in length and 1 deg in width. The left eye bar was oriented horizontally and right eye bar, vertically. Surrounding random dot fusion fields insured that the vertical and horizontal bars bisected each other prior to the induction of the afterimages.

Following a flash the positive afterimages were viewed with eyes open in total darkness. Although the afterimages would normally remain for at least 2 minutes, trials commenced 5 seconds after the induction flash and were terminated 30 seconds later. This initial delay of 5 seconds was required to allow the afterimages to appear and rivalry to commence which normally occurred 2-3 seconds following the flash.

Using the S.E.I. spot photometer it was possible to measure approximately the equivalent luminances of the afterimage stimuli. Instead of matching the test spot with an objective luminance the author matched the spot with an afterimage bar while viewing into the photometer in a totally dark room. The afterimage strength 5 seconds after the flash was equivalent to a luminance of about 0.2 ft-L. Because afterimages decay in strength over time, it was not surprising to find that the afterimage strength 35 seconds following the flash had dropped to an equivalent luminance of about 0.05 ft-L. Nevertheless, this low equivalent luminance still provided an afterimage which subjectively was reasonably bright and easily discernable. The rivalry resulting from the two opposing afterimages was easily measured since it was almost completely dichotomous with only one complete afterimage present at any one time.

Apparatus and Procedure

The apparatus consisted mainly of the Holmes/Brewster type stereoscope as described in Chapter V. The rivalry stimuli could be placed in the stereoscope and adjusted to a depth and interstimulus distance to provide maximum acuity with only a slight degree of convergence. A chin rest and nose slot were adjustable to help the subjects maintain a steady head position.

Rivalry phase durations and alternations were reported by subjects with the use of a telegraph key connected to a single channel event recorder. Subjects were instructed to fixate the centre of the rivalry stimuli and to depress the telegraph key when the centre dark disk on white background became dominant or in the case of the afterimages when the vertical bar became dominant. The key was to remain depressed as long as this stimulus was dominant. When the opposite or left eye rivalry stimulus became dominant the telegraph key was to be released. Depression of the key produced deflection of the pen to one position of the record paper and release of the key produced deflection back to the initial position. The recording paper was driven under the pen marker at a constant speed of 2 millimeters per second. Measurement was accurate to within 0.2 mm or in other words to within 0.1 second.

The subjects were tested first with the disk rivalry stimuli. To familiarize the subjects with the rivalry of these stimuli and method of reporting rivalry ten 1 minute practice trials of passive viewing were given before testing. Subjects were then given ten 1 minute test trials separated by 1 minute rest periods. The ten trials were conducted using two trials for each of five different instructional conditions in the order shown in Table 6.1. In the "passive viewing" condition the subjects were instructed to watch the rivalry in a passive manner and not to exert any voluntary control over the rivalry process. In the "right eye stimulus dominant" condition the subjects were instructed to maximize the amount of time in the trial period for which the grey centre disk was dominant. Similarly in the "left eye stimulus dominant" condition the subjects were instructed to maximize the amount of time in the trial period for which the white centre disk was dominant. No specific suggestions were given as to how the subjects should follow these instructions. They were not instructed to decrease suppression phase durations or increase the dominance phase durations of the rivalry stimulus instructed to be dominant. The "slow rate" and "rapid rate" instructions were the same as those used in previous experiments and described in Experiment 1.

TABLE 6.1

ORDER OF THE FIVE INSTRUCTIONAL CONDITIONS OVER TEN TEST TRIALS IN EXPERIMENT 13.

Test Trial	Instructional Condition
1	Passive viewing
2	Right eye stimulus dominant
3	Left " " "
4	Left " " "
5	Right " " "
6	Slow rate of alternation
7	Rapid " " "
8	Rapid " " "
9	Slow " " "
10	Passive viewing

The control of afterimage stimuli was tested using the same instructional conditions following the same order illustrated in Table 6.1. In Test Trials 2 and 5 the vertical bar was instructed to be dominant. In Test Trials 3 and 4 the horizontal bar was instructed to be dominant. Because of the possibility of cumulative retinal effects from the use of the afterimage stimuli, only one practice trial was given and intertrial rest periods were 4 minutes in length.

Results and Discussion

The effects of the instructional conditions on the mean durations using the disk rivalry stimuli are illustrated in Figure 6.2. It can be seen that the effects of "left eye

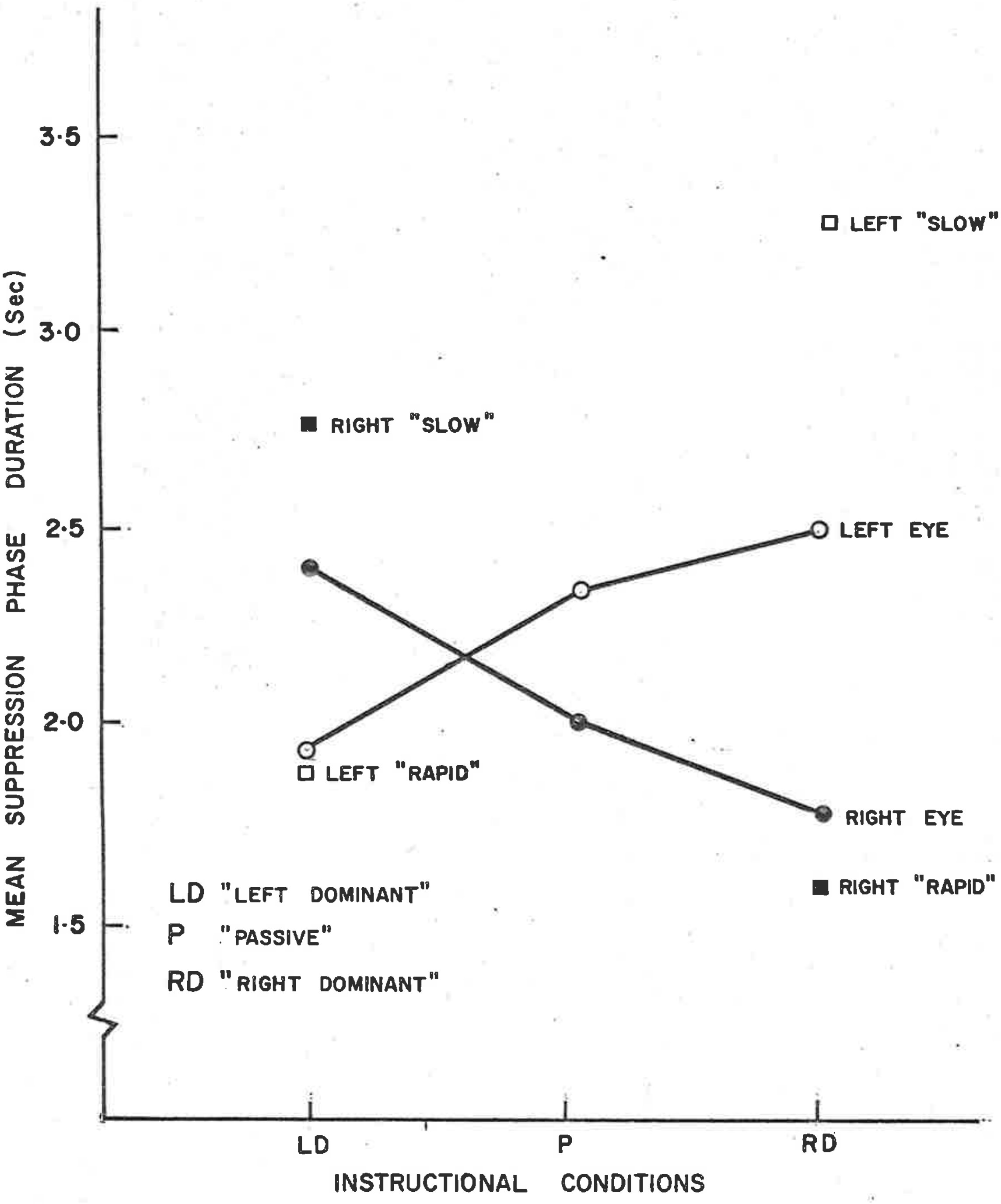


Fig. 6·2. Experiment 13. Mean suppression phase durations of the right eye and left eye disks rivalry stimuli under the instructional conditions (RD), (P), and (LD) and the rivalry rate instructions as indicated.

dominant" (LD) instruction compared with their respective passive viewing condition is an increase of right eye suppression phase duration ($t = 3.02$, $df = 11$, $p < .01$) and a decrease of left eye suppression duration ($t = 3.26$, $df = 11$, $p < .005$). The effect of "right eye dominant" (RD) instruction is less conclusive. The increase of left eye suppression phase is not significant and decrease of right eye suppression phase is significant only to a low confidence level ($t = 1.61$, $df = 11$, $p < .10$).

In terms of the three possible models discussed earlier, it appears that both 'inhibitory' and 'excitatory' effects are operating. An increase of mean suppression phases would indicate an inhibitory mechanism and decreases of suppression phases would indicate an excitatory mechanism. Since both effects are present to a significant extent, the third model seems to gain support. The relative contributions of each effect may be seen more concisely with the related sample t-tests ($df = 11$) presented in Table 6.2. The total effect of the hypothetical inhibitory and excitatory mechanisms are indicated in the "combined eyes" column. Although both mechanisms receive significant support, it appears that the excitatory effect may be stronger. However, when the total decreases of suppression phases are compared with increases of suppression phases the difference does not even approach significance ($t = 0.2$).

TABLE 6.2.

PREDICTED AND RESULTANT CHANGES IN MEAN SUPPRESSION PHASE DURATIONS COMPARED WITH PASSIVE VIEWING CONDITION FOR RIGHT AND LEFT EYES AND BOTH EYES COMBINED WITH DISK RIVALRY STIMULI IN EXPERIMENT 13.

Hypothetical Mechanism	Effect	Right Eye	Left Eye	Combined Eyes
Inhibitory	Increased duration	$t = 3.02$, $p < .01$	$t = 0.4$, N.S.	$t = 1.94$, $p < .05$
Excitatory	Decreased duration	$t = 1.61$, $p < .10$	$t = 3.26$ $p < .005$	$t = 5.17$ $p < .0005$

Thus, the dominance control of disk rivalry stimuli produced both decreased suppression phase durations of the "dominant" eye and increased suppression phase durations to about the same extent of the opposite or suppressed eye. This suggests the possibility of the operation of both an excitatory and an inhibitory effect in the mechanism of BR control.

Figure 6.2 also indicates the mean suppression phase durations of each eye under the "slow rate" and "rapid rate" instructions. For both eyes the suppression duration is similar but somewhat less under "rapid rate" than it is under the respective eye "dominant" instruction. Inversely, the "slow rate" instruction results in somewhat greater suppression durations than when the eyes are instructed to be nondominant. The mean percentage rate control measure was 29.5%. This agrees very closely with the mean percentage rate control value of a group of a group of 14 naive subjects using orthogonal single and multiple line rivalry stimuli in Experiment 9.

The results using the horizontal and vertical bar afterimages are illustrated in Figure 6.3. The right eye stimulus of the vertical bar afterimage appears to be more predominant with the 12 subjects under the present conditions than the left eye stimulus. The crucial comparison is the change of mean suppression duration from the passive condition. With the afterimage rivalry stimuli also the effect of "left dominant" instructions is a decrease in the left eye suppression duration and an increase in the right eye suppression mean. Conversely the "right dominant" instruction results in a decrease of right eye suppression duration and an increase in left eye suppression duration.

The related samples t-tests applied to these four differences and to the differences combining eyes to test the total increase of durations and total decrease of durations is presented in Table 6.3. As with the continuously illuminated disk stimuli, dominance control of the afterimage rivalry stimuli produced increased and decreased phase durations to about the same extent. Thus, both the hypothetical inhibitory and excitatory mechanisms again receive significant support and as before, there was no significant difference between them ($t = 0.66$).

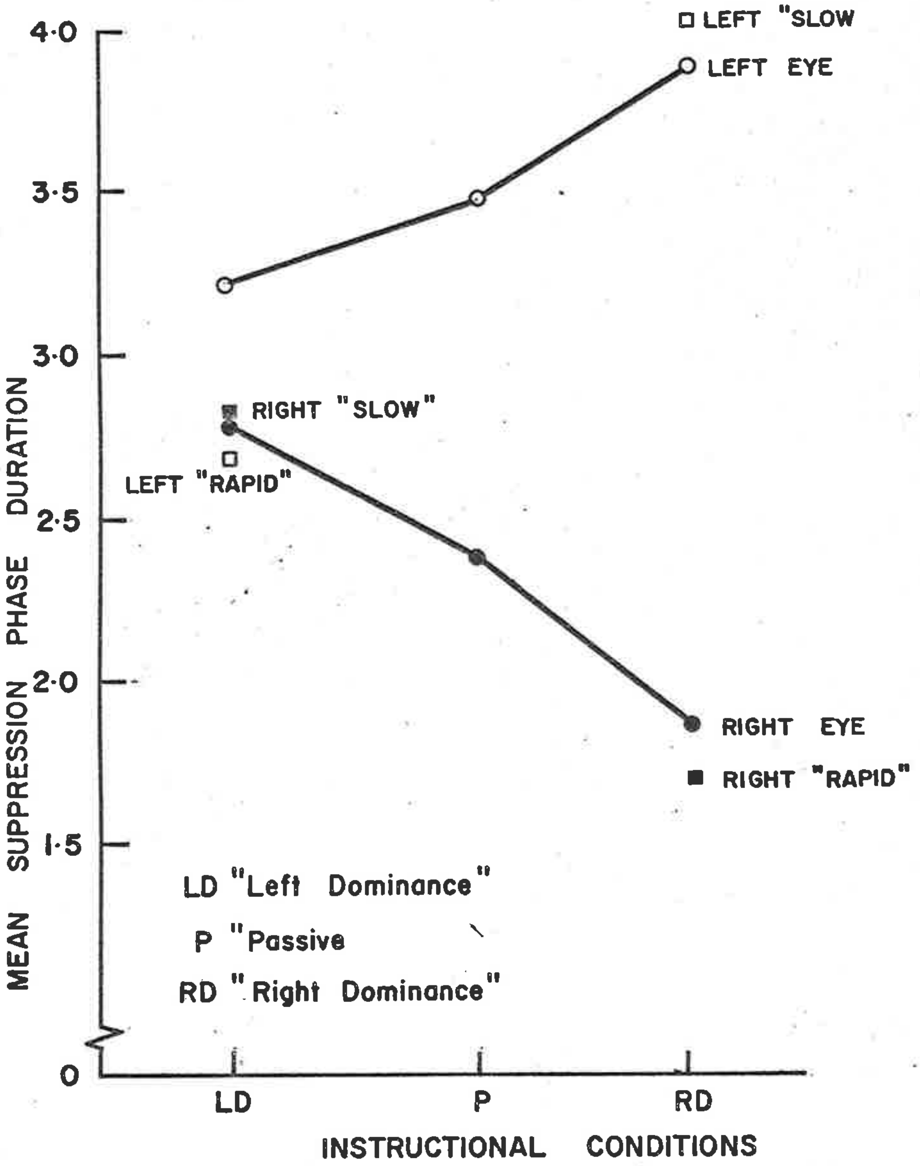


Fig. 6·3. Experiment 13. Mean suppression phase durations with afterimage stimuli under the instructional conditions LD, P, RD, and the rivalry rate instruction.

TABLE 6.3.

PREDICTED AND RESULTANT CHANGES IN MEAN SUPPRESSION PHASE DURATIONS FOR RIGHT AND LEFT EYES AND BOTH EYES COMBINED FROM DOMINANCE CONTROL INSTRUCTIONS WITH AFTERIMAGE RIVALRY STIMULI IN EXPERIMENT 13.

Hypothetical Mechanism	Effect	Right Eye	Left Eye	Combined Eyes
Inhibitory	Increased duration	$t = 3.29$, $p < .005$	$t = 1.91$, $p < .05$	$t = 4.34$, $p < .005$
Excitatory	Decreased duration	$t = 3.75$, $p < .005$	$t = 1.71$, $p < .10$	$t = 4.37$, $p < .005$

The rate control instructions produced a mean percentage control of 32.9. This is very similar to the mean rate control of unpracticed subjects in Experiment 9 who also used afterimage stimuli.

The effects of voluntary control of rivalry seem to be very much the same whether the illuminated disk stimuli are used or the afterimage stimuli are used. In both cases the dominance instructions produced a decreased suppression phase duration of the dominant eye and an increased suppression phase duration of the nondominant eye. Also in both cases the "slow rate" produced increases of suppression durations and the "rapid rate" produced decreases of suppression durations that were similar to those produced by the dominance control instructions.

It may be that these results are specific to the mechanism of control in subjects without previous practice or with low degrees of control. The next experiment will examine the control of these stimuli using more experienced subjects.

Experiment 14

In addition to the previously mentioned purposes the present experiment investigated a question concerning the effect of differences of types of rivalry stimuli on the degree of rivalry control. The two types of rivalry stimuli in Experiment 13 differ in two basic ways. One difference was the fact that the disk stimuli were continuously illuminated and the afterimage stimuli were essentially stabilized retinal images. The second basic difference is that the two disk stimuli had exactly the same dimensions with coincident contours with only the contrasts reversed. On the other hand the afterimage stimuli had mutually perpendicular contours.

Hubel & Wiesel (1968) have shown that the units in the striate cortex of monkeys are organized on at least two different dimensions, angular orientation and eye dominance. If rivalry may be considered in the physiological terms provided by Hubel & Wiesel, it may be assumed that all forms of binocular rivalry by definition produce a competition between two populations of units with opposite ocular dominance characteristics. In addition, rivalry stimuli that are mutually perpendicular would activate two populations of units that also differed in angular orientation specificity. For example, the right eye afterimage of the vertical bar would activate units that were selectively sensitive to vertical orientation and were also right eye dominant. The left eye afterimage would activate different units that were sensitive to the horizontal orientation and were different also in ocular dominance.

The disk stimuli, on the other hand, would result in a competition of opposite contrast stimulation in the same population of units with a specific angular orientation sensitivity. In this case the main difference in rivaling populations of units is in ocular dominance. Hubel & Wiesel (1968) also indicate that ocular dominance is usually not a discrete characteristic since most cells (80%) can be stimulated by both eyes to some extent. On the other hand, a population of cells specifically sensitive to one angular orientation is unaffected by a perpendicular orientation. There must then be virtually no units in common between mutually perpendicular orientations. Thus, angular orientation would seem to be physiologically a more differentiable attribute of stimuli.

This does not suggest that rivalry between the disk stimuli is difficult to report. It only suggests that the two active populations of units competing for the final common phenomenal pathway in rivalry are more independent with mutually perpendicular rivalry stimuli than with opposite contrasting but identically oriented rivalry stimuli.

Thus, mutually perpendicular rivalry stimuli may be more functionally discriminable by voluntary control and may be susceptible to a greater degree of control than stimuli having the same angular orientation.

A problem with comparing the previous types of rivalry stimuli is the possible confounding difference of illuminated versus afterimage stimuli. Because the afterimage rivalry stimuli offer the advantage of controlling for possible peripheral motor factors such as accommodation, eye blinks, and eye movements, they were used in a comparison with another pair of afterimage stimuli. The second pair differed only for the right eye afterimage. Instead of a vertical bar the right eye afterimage consisted of two half disks aligned in such a way as to provide horizontal contours coincident with the left eye afterimage but reversed in contrast. A comparison of the degree of control with these two pairs of afterimage stimuli may provide a tentative test of differences between the types of stimuli in their susceptibility to control.

Method

Subjects

Subjests JT and LL were used in the present experiment. They both had considerable previous experience of BR and control of rivalry as described in Experiments 5, 6, and 12. JT had normal vision without corrective lenses and LL had normal vision with corrective corneal lenses.

Stimuli

Three types of rivalry stimuli were used in the present experiment; 1. the opposite contrasting disk rivalry stimuli used in the previous experiment and which were similar to the stimuli used by Levelt (1968) and Fox & Rasche (1969), 2. the horizontal and vertical bar afterimage stimuli used in the previous experiment, and 3. afterimage stimuli that produced coincident but opposite contrasting contours.

In the third type the left eye rivalry stimulus was an afterimage of a foveally centred horizontal bar identical to that produced for the second pair of rivalry stimuli. The right eye rivalry stimulus consisted of two half disks with their respective straight edges aligned horizontally to be coincident with the upper and lower horizontal edges of the horizontal bar in the binocular condition. The positive afterimages were produced by a photoflash gun placed behind cut-out slots of the described configuration in the same way as in the previous experiment. When properly induced, the right afterimage provided a half disk above the fixation point with circular contour facing upward and a half disk equidistant below the fixation point with circular contour facing downward. In between the half disks was a black horizontal strip defined by the absence of a positive afterimage between the two half disks which was 1 deg of visual angle in width and 4 deg in length. This black strip coincided with the left eye horizontal bar positive afterimage in the binocular condition. These stimuli resulted in rivalry that was easily reported.

Apparatus and Procedure

The apparatus and procedure for the observing and reporting of rivalry phases and apparatus for recording rivalry phase durations were the same as in Experiment 13. In the case of the light versus dark horizontal bar afterimage stimuli the subjects pressed the telegraph key for the presence of the dark strip, right eye stimulus. The five instruction conditions and their order of presentation over ten trials for a given pair of rivalry stimuli was also the same as in the previous experiment (see Table 6.1).

The effect of practice was investigated by giving the subjects a series of five consecutive days of practice of control with knowledge of results following every trial. On each day the order of stimulus pairs was the disk stimuli first, followed by the horizontal-vertical afterimage stimuli followed by the horizontal-horizontal afterimage stimuli. Following the fifth practice day the two subjects were given a final test day in which they were tested with their intrinsic eye muscles paralyzed by the cycloplegic and mydriatic which was described in Chapters IV and V. JT and LL thus exercised dominance control and rate control on each of three different pairs of rivalry stimuli over a series of five practice days and a final test day with eyes paralyzed.

Results and Discussion

The effect of practice on the three types of rivalry stimuli is best illustrated in Figure 6.4. Both subjects show an increase of both the dominance control measure and rate control measure over the practice days on all three pairs of rivalry stimuli. A 4-way analysis-of-variance was applied to the control measures to test the main effects of practice days, type of control instructions, and stimuli. In each case the error term was the main effect by subjects interaction. Only the main effect of practice days was significant ($f = 51.24$, $df = 5/5$, $p \leqslant .001$). The effect of control instructions was not significant ($f = 15.07$, $df = 1/1$, $p \geqslant .10$), nor was the effect of stimuli ($f = 9.72$, $df = 2/2$, $p > .10$). All the interactions produced f-ratios less than 1.0. This suggests what is apparent in Figure 6.4, that the effect of practice is consistent with all stimuli and for both instructions.

On the Final Test Day both subjects had their intrinsic eye muscles paralyzed. From Figure 6.4 it can be seen that this treatment had no consistent effects to increase or decrease the measure of dominance control or rate control between Practice Day 5 and the Final Test Day. An examination of the mean suppression phase durations also failed to reveal any systematic effect of the paralysis treatment. The mean suppression phase durations were virtually the same on

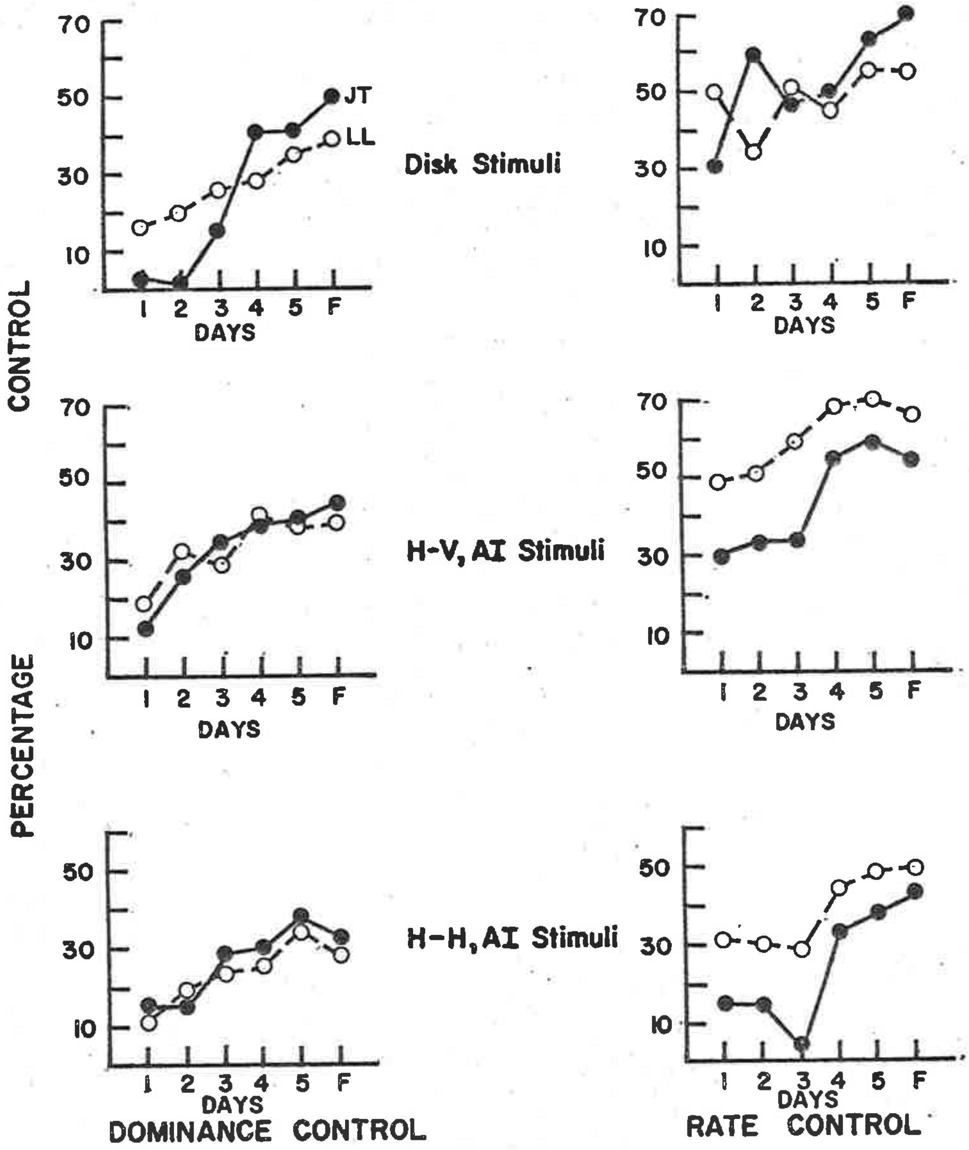


Fig. 6·4. Experiment 14. Percentage dominance and rate control measures for subjects JT (filled circles) and LL (empty circles).

Practice Day 5 and the Final Test Day for both subjects. This reconfirms the earlier findings described in Experiment 9 and in Experiment 12, that intrinsic eye muscle paralysis has, at the most, a minor effect on the increased measure of BR control established as a result of practice.

Although it appears in Figure 6.4 that rate instructions produce greater control than dominance instructions and less control results with the H-H stimuli than the other stimuli, these two effects are not significant in the analysis-of-variance. This lack of significance could be due to the fact that only two subjects were used. More direct comparisons of the rate and dominance instructions may be applied to their respective mean suppression phase durations.

Figure 6.5 shows the mean suppression phase durations of subject JT for each eye separately resulting from the dominance control instructions and rate control instructions on Practice Day 1 and on the Final Test Day with eyes paralyzed. In each of the six graphs the resultant suppression phase durations of slow rate for right eye and rapid rate for left eye are presented in the left Dominant (LD) column for dominance control. The suppression phase durations of slow rate for left eye and rapid rate for right eye are presented in the right Dominant (RD) column of the dominance control instructions. The purpose of this superimposition of rate control durations on dominance control instructions was the same as in Experiment 13, to enable a

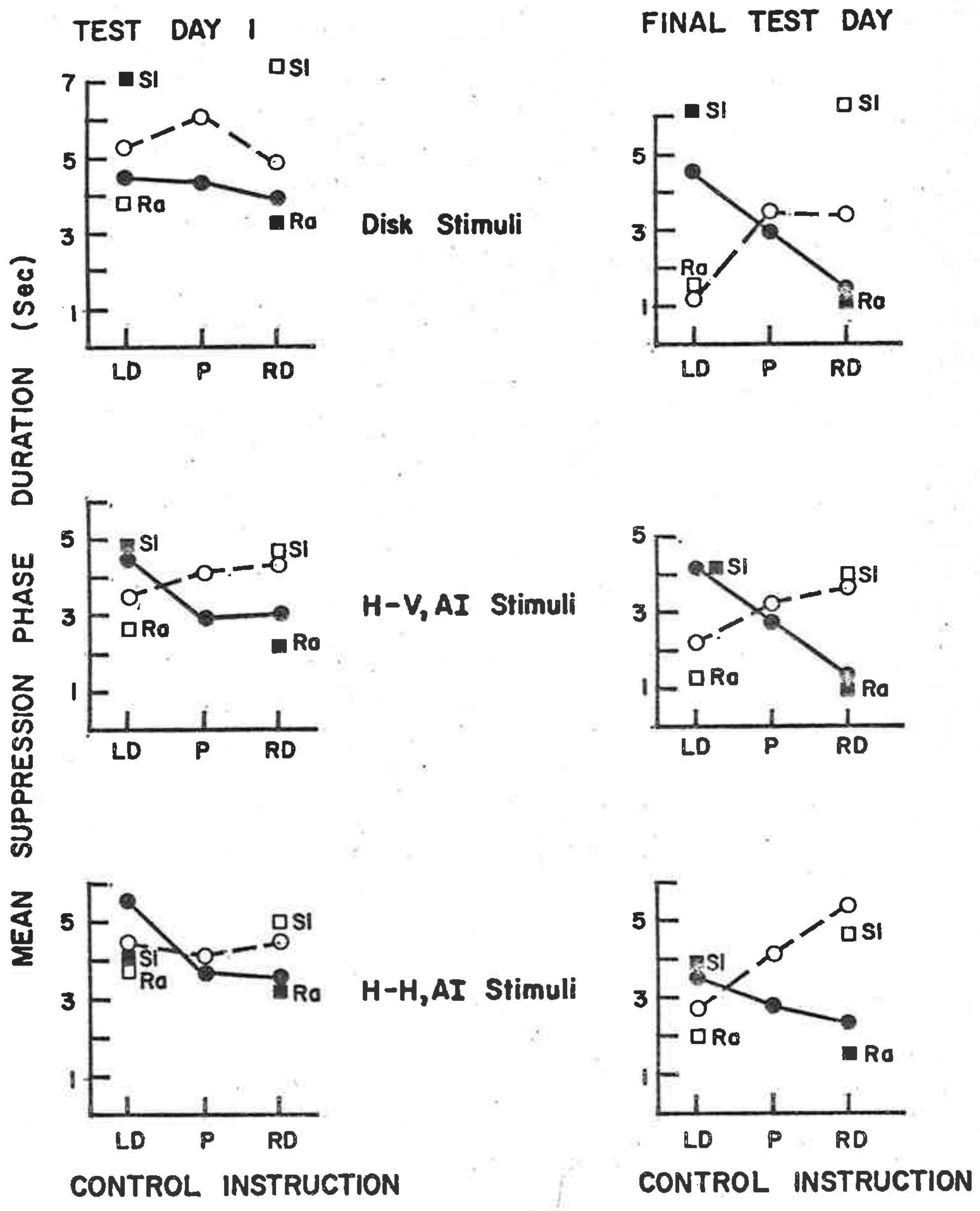


Fig. 6·5. Experiment 14. Subject JT mean suppression phase durations of left eye (open figures) and right eye (filled figures) following instructions Left Dominant (LD), Passive (P), Right Dominant (RD), Slow (Sl), and Rapid (Ra) visual comparison of the relative effects of the two types of control instructions. In this way the effects of increased suppression durations from dominance control instructions are appropriately compared with the increased durations from the slow rate instructions, and the decreased suppression durations from dominance control are compared with the Rapid rate instructions. In the same way Figure 6.6 shows the mean suppression durations for subject LL.

For any pair of rivalry stimuli the effect of control instructions can be tested for each eye. For example the effect of rate control on the left eye can be tested by comparing the slow rate suppression duration with rapid rate suppression duration. Similarly dominance control for the left eye can be tested by comparing the left eye, LD suppression duration with the left eye, RD duration. With the disk stimuli only, JT lacks significant dominance control on Practice Day 1. With the H-H afterimage stimuli JT lacks significant dominance and rate control in both eyes and LL lacks significant dominance control in his left eye on Practice Day 1. All other differences for both subjects on Day 1 are significant ($p < .025$) and all differences on the Final Test Day are significant ($p < .005$). Thus both subjects generally indicate a significant degree of control on Day 1 and very significant control in all conditions on the Final Test Day.

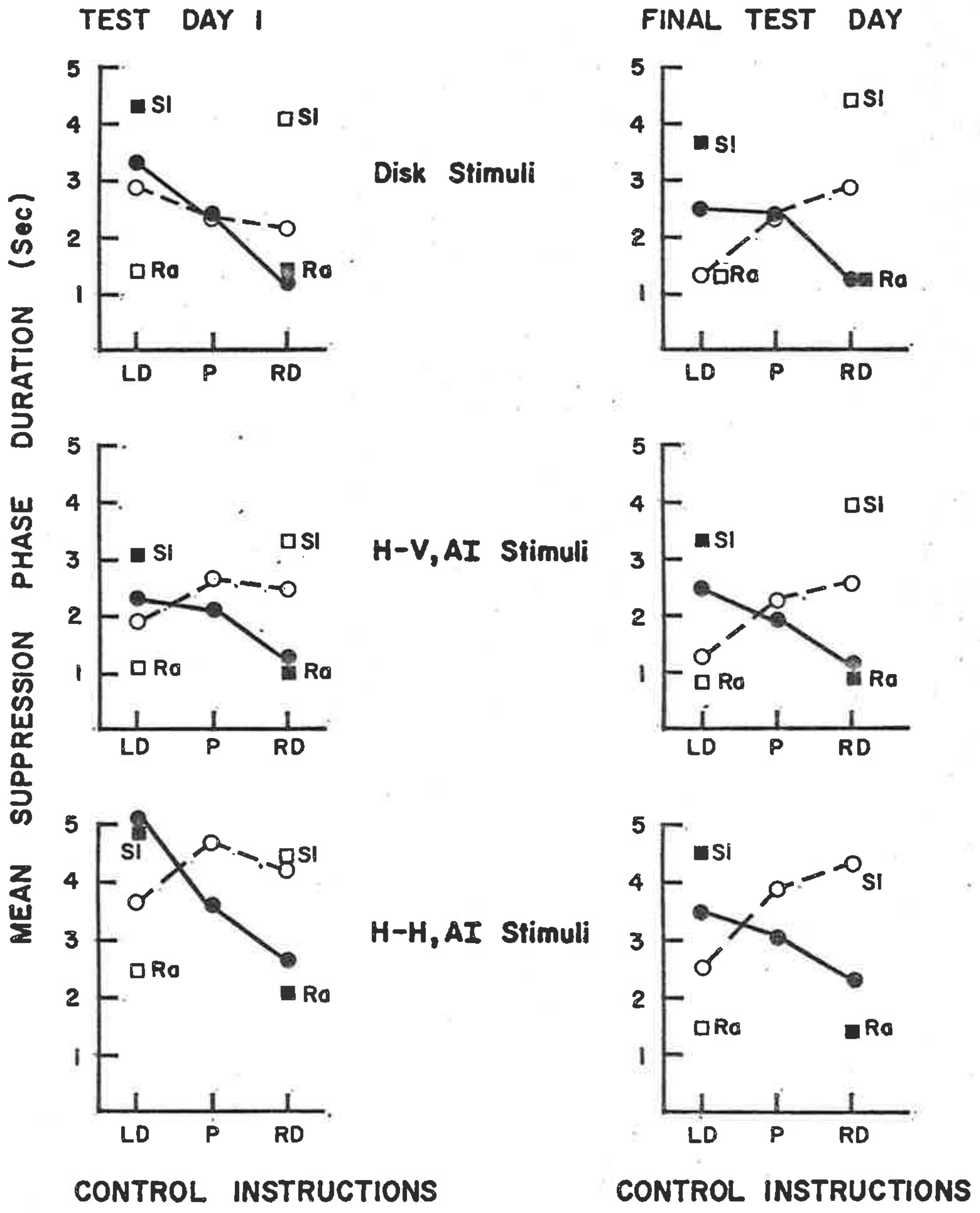


Fig. 6·6. Experiment 14. Subject LL mean suppression phase durations of left eye (open figures) and right eye (filled figures) following instructions Left Dominant (LD), Passive (P), Right Dominant (RD), Slow (Sl), and Rapid (Ra).

In Experiment 13 it was found that dominance control instructions had the effects to decrease the suppression duration of the dominant eye and to increase the suppression duration of the suppressed eye. Based on the results of earlier investigations (Levelt, 1968; and Fox & Rasche, 1969) these results would be analogous to increased stimulus strength on the dominant eye and a decreased stimulus strength on the suppressed eye and were accordingly designated as 'excitatory' and 'inhibitory' respectively. The 'excitatory' comparison or decreases from the passive condition are for the Right eye, Passive minus Right Dominant (R, P-RD) and for the Left eye, Passive minus Left Dominant (L,P-LD). The 'inhibitory' comparisons are for the Right eye, Left Dominant minus Passive (R, LD-P) and for the Left eye, Right Dominant minus Passive (L, RD-P).

These four comparisons with the three types of rivalry stimuli on Practice Day 1 and the Final Test Day are illustrated in Figure 6.5 for JT and Figure 6.6 for LL. Of twelve 'inhibitory' comparisons ten ($p < .02$) are differences in the predicted direction for JT and nine ($p < .10$) are in the predicted direction for LL. Of twelve 'excitatory' comparisons ten ($p < .02$) are in the predicted direction for JT and eleven ($p < .01$) are in the predicted direction for LL. The significance levels of the forty-eight individual comparisons are shown in Table 6.4. Of twenty-four 'inhibitory'

TABLE 6.4.

EXPERIMENT 14. TESTS OF 'INHIBITORY' AND 'EXCITATORY' EFFECTS. OBTAINED LEVELS OF SIGNIFICANCE FROM t-TESTS APPLIED TO DIFFERENCES IN MEAN SUPPRESSION PHASE DURATIONS FOR LEFT (L) OR RIGHT (R) EYE BETWEEN LEFT DOMINANT (LD) OR RIGHT DOMINANT (RD) AND PASSIVE (P) CONTROL INSTRUCTIONS.

			'Inhibitory' Comparison		'Excitatory' Comparison	
Stimuli	Subject	Test Day	R,LD-P	L,RD-P	R,P-RD	L,P-LD
Disk	JT	1	N.S.	N.S.	N.S.	N.S.
		F	.05	N.S.	.025	.005
	LL	1	.025	N.S.	.0005	N.S.
		F	N.S.	.10	.0005	.025
AI,H-V	JT	1	.005	N.S.	N.S.	.05
		F	.01	N.S.	.005	.025
	LL	1	N.S.	N.S.	.025	.05
		F	.025	N.S.	.0005	.005
AI,H-H	JT	1	N.S.	N.S.	N.S.	N.S.
		F	.10	.10	N.S.	.025
	LL	1	.05	N.S.	.10	N.S.
		F	N.S.	N.S.	.10	.10

comparisons six are individually significant to at least the .05 level. Of the twenty-four 'excitatory' comparisons thirteen are significant to the .05 level. Thus both subjects shown an 'inhibitory' effect or increases of suppression duration for the suppressed eye and an 'excitatory' effect or decreases of suppression duration for the dominant eye. This is consistent with the results from the naive, unpracticed subjects of Experiment 13 and confirms the predicted model illustrated in Figure 6.1c.

The effects of practice on the 'inhibitory' and 'excitatory' effects may be crudely examined by comparing Practice Day 1 with the Final Test Day. In Figure 6.5 JT shows neither a predominance of 'excitatory' effects nor 'inhibitory' effects on either Practice Day 1 or the Final Test Day. The effect of practice in most cases merely enhances the differences with the passive condition that already exist. Of six 'inhibitory' comparisons with the three stimulus pairs four of the differences are increased. Of six 'excitatory' comparisons for JT all six differences are increased between Day 1 and the Final Day. The examination of Figure 6.6 shows the same general results for subject LL, a lack of predominance of 'excitatory' or 'inhibitory' effects before or after practice. Of six 'excitatory' comparisons four show increased differences from Day 1 to Day F. Of six 'inhibitory' comparisons four show increased differences from Day 1 to Day F. Thus, neither the 'excitatory' effect nor the 'inhibitory' effect predominates for either subject before or after practice. Practice of control seems to increase both effects by about an equal amount.

It was suggested in the introduction to this experiment that a greater degree of control may be exercised with rivalry stimuli that differed in angular orientation than with stimuli having the same orientation but differing in contrast. More specifically it was predicted that a greater degree of control would be possible with the H-V afterimage stimuli than with the H-H afterimage stimuli. Although the differences in control for the three types of stimuli were not significant in the analysis-of-variance, there seems to be greater control of the H-V stimuli than of the H-H stimuli. The lack of the significance of the earlier analysis may arise from the use of only two subjects and from the additional variance contributed by the disk stimuli. A more appropriate way to test this specific prediction would be to compare directly the control values arising from these two types of stimuli.

For each subject under each type of control instruction the percentage control values were matched between the H-V and H-H stimulus conditions for respective practice days. This procedure resulted in related samples t-tests between the stimuli for each subject with each type of control instruction. The results of these tests are presented in Table 6.5.

TABLE 6.5.

RELATED SAMPLES t-TESTS (df = 5) APPLIED TO THE DIFFERENCES IN PERCENTAGE CONTROL BETWEEN THE HORIZONTAL-VERTICAL AND THE HORIZONTAL-HORIZONTAL AFTERIMAGE RIVALRY STIMULI IN EXPERIMENT 14.

Subject	Type of Control	t	p
JT	Dominance Control	1.97	.10
	Rate Control	4.50	.005
LL	Dominance Control	4.81	.005
	Rate Control	12.0	.0005

The results indicate a greater degree of control with the H-V stimuli than with the H-H stimuli for both subjects. This seems to confirm the earlier prediction of the existence of greater control with rivalry stimuli differing in angular orientation.

However, it is also the case that practice results in an increase of both dominance and rate control with the H-H stimuli. In fact, the increase of dominance control over the six days is only slightly less and the increase of rate control actually somewhat greater for the H-H stimuli than for the H-V stimuli. Thus, control of the H-H stimuli is definitely present and is increased as much by practice as is control of the H-V stimuli.

If there were a physiological limitation or disadvantage in the control of the H-H stimuli, as suggested earlier, one would expect either the complete lack of control or a smaller increase as the result of practice. Neither of these occurs. The only way in which control of the two types of stimuli differ is in the initial control values. Therefore, it seems most likely that the greater measure of BR control with the H-V stimuli is mainly a function of the amount of practice with these respective types of stimuli.

In summary, this experiment confirms the results of the previous experiment and of Experiment 9. The two experienced subjects showed both the 'excitatory' and 'inhibitory' effects in exercising dominance control both before and after five days of practice of control. As was the case in Chapters II, III and IV the effect of practice was an increase in the measure of control. The increased control was qualitatively the same as unpracticed control. Practice resulted in an enhanced ability to shorten and lengthen the suppression phase durations of rivalry.

CHAPTER VII CONCLUSION

Relevance of Rivalry Control to Selective Attention

Recognition of Relevance

The introductory chapter pointed out that in early theories binocular rivalry had an important role as a paradigm of selective attention, a role which has not been sufficiently recognized in recent years. The major obstacles preventing the recognition of the importance of BR are: 1. the general assumption that subjects do not normally have control over rivalry, 2. the conclusion that peripheral mechanisms such as blinking, eye movements and accommodation are a necessary component in BR control, and 3. the lack of an objective measure of the control of rivalry. The experimental evidence provided by this thesis should remove these obstacles.

Possible Extent of BR Control

Evidence from Washburn & Gillette (1933), Meredith & Meredith (1962), and the results of Experiments 1, 2, 3, 7, 8, 9, and 14 have shown that unpracticed subjects possess a highly significant degree of BR control. This control can be measured as the extent to which rivalry dominance can temporarily be altered or the extent to which the rivalry rate can be reduced and increased. Experiment 5 found that these two measures of control are highly correlated.

In addition, although the measures of BR control are reliable (Experiment 5), they are not permanently fixed. The degree of control is increased with practice, especially if the practice is spaced and if knowledge of results is given. The degree of BR control responds to practice in a way similar to that of the control of reversible figures, and may, therefore, be considered a perceptual skill that can be learned.

It was suggested that the initial difference in degree of control of BR and selective listening may be only a function of the previous amount of practice in these selective attention situations. Practice in selective listening occurs relatively frequently whereas binocular rivalry of the type in the laboratory situation does not normally occur in vision. The retinal disparity of objects in very near vision may result in observable rivalry, but attempts to control this rivalry would probably be rare.

Even with the relatively small amount of practice in the present experiments subjects produced marked increases in BR control. Although well-practiced subjects JT and LL did not exert complete control of the rivalry stimuli in Experiments 12 and 14, it was not the purpose of these experiments to test the upper limits of BR control with these stimuli. One may only speculate on the effects of providing as much practice in BR control as is normally obtained in selective listening.

Individuals suffering from strabismus, a condition in which normal binocular fixation and fusion are absent, must cope with what is essentially binocular rivalry in every day life. In the strabismic, corresponding retinal points receive conflicting contour information, the cause of "double images" or binocular rivalry in normal subjects. Although most strabismic patients show no dysfunction in either eye, they are not bothered by double vision (Duke-Elder, 1949).

It would be tempting to suggest that because of constant practice, strabismics possess complete control of rivalry. This may be the case with those who become strabismics late in life, but may not apply to congenital strabismics. Hubel & Wiesel (1965) found that if kittens were deprived of normal binocular vision from birth, either by surgically inducing a squint or by alternately occluding each eye, there was a progressive decrease with time of the percentage of binocularly driven cells, so that after 3 months only 20% of the cortical cells could be stimulated binocularly. If it is assumed that visual function in humans is similar to that in cats, then these results suggest that congenital strabismics would effectively lack binocularly driven cortical cells. In that case binocular rivalry would not exist in the normal way.

In Chapter VI it was suggested that the H-V rivalry stimuli would be easier to control than the H-H stimuli since the former differed both by eye and angular orientation resulting in competition between more disparate populations of cortical cells. The H-H stimuli would produce competition between two subpopulations differing only in ocular dominance. The logical extension of this argument would suggest that selection between populations of cells differing in angular orientation and differing completely in eye sensitivity would be much easier than control of normal rivalry. If congenital strabismics possess a different visual system, they cannot necessarily be considered to possess a greatly increased ability to control rivalry as a result of continuous practice.

On the other hand, the individual who later becomes strabismic possesses a normal percentage of binocular cortical cells and is faced immediately with the problem of double vision (McLaughlin, 1964). The strabismic slowly adapts to this confusing condition as one of the two images is increasingly suppressed. Eventually the double vision disappears although clear vision with either eye alone is still reported (McLaughlin, 1964). This would seem to be a case of extraordinary control of BR which is presumably a result of practice. With enough practice then, the degree of BR control may be at least as great as is the control of selective listening.

Role of Peripheral Mechanisms in BR Control

Although past experimental evidence was inadequate, it led most psychologists to conclude that peripheral mechanisms play a crucial role in the control of rivalry. The mechanisms of blinking, eye movements (fixation changes), accommodation (retinal image blurring and intraocular pressure changes) and pupillary activity have been proposed as necessary components of the control of rivalry. The nonperipheral factor of criterion distortions has also been suggested as a method whereby subjects may enhance their measures of control.

Experiment 2 found no difference in rate of blinking between the slow and rapid rate instructions. Subjects generally did not blink during the 30 second trials. Thus, blinking could be discounted as a factor in the control of rivalry rates.

The results of Experiment 3 which found that the use of very small artificial pupils did not reduce BR control, precluded the possibility of a retinal image blurring mechanism of BR control. The findings of Experiment 8 questioned the existence of any accommodation mechanism in BR control. The slight effect of the paralysis of intrinsic eye muscles was probably the result of a general performance decrement rather than the loss of a specific mechanism of rivalry control. Experiment 9 confirmed the unimportance of accommodation in unpracticed control and also found that well-practiced control is mainly retained with paralysis of the intrinsic eye muscles. The significant reduction of well-practiced control with eye paralysis could be more than accounted for by the general performance decrement and the reduced knowledge of results in the final test session.

A more crucial test of the role of peripheral mechanisms was provided by the use of afterimage rivalry in Experiments 9 and 14. In Experiment 9 the subjects observed the positive flash-induced AIs with eyes closed and intrinsic eye muscles paralyzed. In this condition blinking was eliminated in addition to retinal image movements (fixations), accommodation, and pupillary activity. For unpracticed subjects there was very little difference of BR control between the illuminated and AI rivalry stimuli. Well-practiced subjects showed a highly significant increase of BR control of AIs as a result of practicing with illuminated stimuli in Experiment 9 and with AI stimuli in Experiment 14. The lower degree of control of AIs as compared with illuminated stimuli may be the result of differences in stimulus intensity. Thus, it still cannot be ascertained whether peripheral mechanisms play any part in the control of rivalry. What is clear from these results is that peripheral mechanisms are certainly unnecessary and, at most, would play a minor part in unpracticed and well-practiced BR control.

It was also the experience of subjects that afterimage rivalry was dichotomous and unambiguous thus leaving little room for criterion distortions. From a comparison of Experiments 7 and 8 it would seem that misreporting accounted for very little, if any, of the measure of BR control. When criterion distortions and all peripheral mechanisms are virtually eliminated, there still exists very considerable BR control in unpracticed subjects and even greater measures of control in well-practiced subjects. Therefore, this remaining control must be mediated by central or neurophysiological mechanisms.

An Objective Measure of BR control

The third major obstacle to the recognition of the relevance of BR to attention has been the lack of an objective measure of BR control. The development of behavioural correlates to phenomenal rivalry has been pioneered by Fox (1963). The test stimulus method requiring recognition responses from subjects (Fox & Check, 1966) provided a useful measure of the effect of rivalry suppression under passive viewing conditions. The application of this method in Experiment 4 found that the magnitude of suppression was not changed by actively viewing rivalry. This method used in Experiments 5 and 6 found that subjects could control to some extent which eye would be in phenomenal suppression. The degree of control was reflected in the difference between instructed and noninstructed eye performance. The (I-NI) difference was correlated with the measures of rate control and dominance control. As predicted, subjects with faster rapid rates performed better when given only a 1 second delay to follow instructions and subjects with lower slow rates performed better at the 5 second delay. Thus the use of the test stimulus method has established the objective validity of BR control and has found that the effect of control is to select which eye will be suppressed.

The questions about the existence of BR control, the role of peripheral mechanisms, and the behavioural meaningfulness of BR control should now be answered and should no longer be obstacles to the consideration of BR control as an example of selective attention. The question may now be raised whether the findings of the study of BR control can be generalized to the field of attention.

Findings Relevant to Selective Attention

There are four main ways in which the results in this thesis may be relevant to selective attention: 1. in the controversy of intensity equivalents of attention, 2. in the investigation of switching time between channels, 3. in the question of the temporal limits of single acts of attention and 4. in the construction of a general model of attention.

Intensity Equivalent of the Effects of Attention

Pillsbury (1908) discussed the controversy of whether attention was the result of an increased intensity of the attended stimulus or a decreased intensity of all nonattended stimuli. Of the two alternatives Pillsbury (1908) favoured the latter view. The case of binocular rivalry would generally seem to correspond to Pillsbury's predictions (1908). The findings of Fox (1963), Fox & Check (1966, 1968), Wales & Fox (1970), and of Experiment 4 in this thesis would suggest that BR nonsuppression is equivalent to nonrivalry and is mainly free of the inhibitory effects of suppression. On the other hand, suppression represents a nonspecific inhibitory state which effectively results in a decrease of visual sensitivity or an increased threshold. This inhibition would be equivalent to a reduced stimulus intensity.

The report of one recent experiment has raised doubts about the nonsuppressed state of rivalry. Collyer & Bevan (1970) found recognition performance in the nonsuppressed state to be lower than that during nonrivalry. They found a somewhat greater nonrivalry-nonsuppression difference than was found by Fox & Check (1966) or in Experiment 4. Collyer & Bevan (1970) used rather more complicated rivalry patterns of noncontinuous line segments that may have resulted very rarely in complete suppression or dominance. They also suggested that subjects may have been less attentive to target stimuli in the rivalry condition. In addition their nonrivalry condition was monocular viewing with the opposite field darkened (Collyer & Bevan, 1970), while nonrivalry in the Fox & Check experiment (1966) and in Experiment 4 was produced by removing only the rivalry contours of one eye. It may be that monocular nonrivalry results in better performance than binocular nonrivalry. In any case it is clear that rivalry suppression is an inhibitory state and nonsuppression is not an excitatory state or does not represent an increased intensity compared with nonrivalry. The extent of possible inhibitory effects in the nonsuppressed state of rivalry has yet to be determined.

The time taken to Switch Channels in Attention

Broadbent (1958) suggested a value of about 1/6 second for the minimum time taken to switch between channels. The measurement of this figure was complicated by the necessity of measuring the time for a complete cycle between channels including a recognition response in one channel. Since the recognition time was difficult to establish, it was difficult to determine the switching time. A more convenient measure of the minimum switching time, at least in binocular rivalry, may be obtained from the rapid rate measure. The recognition times required for these comparative simple rivalry stimuli should be much less than that required for digit recognition and storage in short term memory. The mean phase duration under the rapid rate instructions should then be close to the minimum switching time in rivalry.

The fact is that there was considerable variation of rapid rates between subjects and a large increase of rapid rate with practice. The mean rapid rate for unpracticed subjects was about 35 alternations/min resulting in a mean phase duration of about 1.7 seconds. Practiced subjects decreased their mean durations to about 0.92 seconds and two well-practiced subjects in Experiment 2 reduced their durations to 0.22 seconds and 0.67 seconds. Thus it is not unusual to find practiced subjects with mean durations less than 1.0 seconds under the rapid rate instructions. What part of this duration is required to recognize a rivalry stimulus and what part is required to shift attention to the other stimulus is indeterminable from this data. In any case the minimum time to shift attention in BR is less than 1 second for moderately practiced subjects.

It may be misleading to suggest that some absolute minimum switching time exists in BR. Since rapid rate increases with practice with no apparent limit, it seems to be that the minimum time to switch attention in BR decreases with practice. This may also apply in other modalities. Moray & Jordan (1966) found that subjects improved markedly with practice in the alternating condition of a dichotic listening task. The minimum switching time in a dichotic listening task must be inferred from recall performance and presentation rate. BR offers the advantage of measuring the switching time more directly from the alternation rate.

The method of Experiment 5 could be used to eliminate any recognition time from the calculation of switching time in BR. The ability to follow instructions after the shortest delay of 1 second in Experiment 5 was correlated with the subjects ability to produce a high rapid rate. Since the task for the

1 second delay requires only a shift of attention, it eliminates the recognition times included in the rivalry alternations of the rapid rate. Subjects showed significant ($p < .01$) ability to shift to the instructed eye by the 1 second delay. It remains to be investigated how short the delay could be and still result in a significant difference between instructed and noninstructed eye recognition performance.

The Maximum Time of a Single "Act" of Attention

Pillsbury (1908) suggests that attention may dwell on one stimulus from 3 seconds to 24 seconds but that the normal span of attention is about 5-8 seconds. This seems to be rather an arbitrary choice with little experimental support. Recent experimental evidence would suggest that there is probably no absolute maximum attention time. Shadowing experiments and the selective vision of alternating strabismus would suggest nearly indefinite attention time, at least times much greater than 24 seconds.

In the case of binocular rivalry a maximum attention time may be calculated directly from the subjects' slow rates. Unpracticed subjects have a mean slow rate of about 12 alternations/min or a mean duration of about 5 seconds. The practiced subjects of Experiments 1, 2 and 3 reduced their slow rates to about 8/min or increased their mean durations to about 8 seconds. Further practice by subjects CT and RG increased the mean duration to at least 30 seconds. Experiment 5 showed a significant decline of the (I-NI) measure by 7 seconds following the instruction stimulus which suggested that at least some subjects lost the dominance of the instructed pattern after 7 seconds. In binocular rivalry between two equally dominant stimuli the average maximum attention time of about 5-7 seconds conforms well to Pillsbury's estimate (1908). However, this maximum attention time for BR shows large individual differences and is very much affected by practice.

Support for Current Theories of Attention

The results of Experiment 4 confirmed the results of Fox & Check (1966, 1968), Wales & Fox (1970) and Collyer & Bevan (1970) that rivalry suppression was correlated with an inhibitory state of limited effect. No experimenters found a reduction of suppressed state recognition performance to chance level. The difference between suppressed and non-suppressed state performance was usually in the region of 15-20% or a d' difference of about 0.6. Hence, these results would not support Broadbent's filter theory (1958) which proposed an all-or-none effect of attention.

On the other hand, phenomenal rivalry does seem to be an all-or-none alternation. When one rivalry stimulus is completely suppressed it subjectively does not exist. The limited degree of inhibition present in rivalry suppression only becomes evident when a probe stimulus is presented to the suppressed eye. Most experiments in selective listening have also used the probe stimulus method and have obtained results similar to those in BR. Lawson (1966) found no difference in reaction times between the ears to simple stimuli that were very different from the shadowed and rejected messages. However, when words are used as target stimuli embedded in speech messages, there is a very significant difference between attended and rejected channels. Even here there are more intrusions from the rejected message than one might expect from the very great phenomenal suppression of the rejected message. It seems that the performance difference between selected and rejected channels increases as the probe stimuli become more and more similar to the attended and rejected stimuli. Thus, the controversy between an all-or-none or attenuation model of attention may be reduced to a description of the way the effects of attention are measured.

According to the theory of Deutsch & Deutsch (1963), which proposes that all stimuli undergo a full cortical recognition analysis, there should not be any difference in recognition performance between the instructed and noninstructed eyes in Experiments 5 and 6. The differences in d' but not confidence criteria in the immediate recognition task of Experiments 5 and 6 would tend not to support this theory.

The results of Experiments 10, 11 and 12 are more damaging to the Deutschs' theory, at least with respect to binocular rivalry. These experiments found that the movement aftereffect was reduced as a result of rivalry stimulation during the induction period. This implies that BR stimulation must exert an inhibitory effect on or prior to the level which is the origin of the MAE. If it is assumed that the origin of the MAE is on the input side, this is also where the effects of BR suppression must occur.

Although some of the present results may be relevant to the attention model proposed by Treisman (1969), her theory does not generate many predictions specific to the control of rivalry. The fact that information is reduced or attenuated and not completely blocked by rivalry suppression is consistent with her model. She recognizes the effectiveness of instructions in producing transient changes in stimulus importance and thus in selective attention but she does not consider in detail the dynamics of the control of attention. It is clear that her theory proposes the attenuation of a rejected message in opposition to an all-or-none switching between accepted and rejected messages with the accepted message predominating. It is not clear, however, if the theory could incorporate the possibility of an "all-or-some" switching with the accepted message predominating--this latter notion being that of BR.

Thus, of the three main current theories of attention the theory of Deutsch & Deutsch (1963) would seem to receive least support from the present investigation of BR control. Broadbent's theory (1958) seems to be appropriate to phenomenal rivalry but not to the effect of rivalry suppression on target stimuli. Treisman's attenuation theory (1969) seems to be most appropriate to the effects of BR control. However, none of the theories are specific enough regarding attention in vision or especially in binocular rivalry for the present results to provide a crucial test between them.

Physiological Concomitants of Binocular Rivalry

One advantage mentioned in the Introduction of studying the effects of attention in binocular rivalry is the accessibility of BR to a physiological investigation. Because the experiments in Chapter V provided some indirect evidence regarding possible neural mechanisms involved in BR and BR control, it may be instructive to consider the investigations of the peripheral and central neural effects of binocular rivalry.

Peripheral Neural Effects

Effects of BR on Pupillary Activity

Bárány & Halldén (1948) found that 5 of their 7 subjects gave significantly more pupillary responses to a threshold light flash when the flash was presented to the dominant rather than the suppressed eye in rivalry. Wirth (1953) also reported that a pupillary response is more likely to be elicited when the stimulated eye is in rivalry dominance. Zuber, Stark & Lorber (1966) found a reduction in the amplitude of the pupillary response when the stimulated eye entered the suppression phase of rivalry. These results suggest either that rivalry suppression produces an inhibition that extends down to the retinal level or that suppression in some way operates through parasympathetic pathways to affect the pupillary response.

However, there were methodological problems associated with these studies which may vitiate their results. In a more controlled and thorough investigation of the pupillary reflex Lowe & Ogle (1966) could find no difference in the amplitude of response between nonsuppression, suppression and monocular conditions. When equally intense rivalry stimuli were used the amplitudes of pupillary responses were a function only of the flash stimulus intensities. However, Lowe & Ogle (1966) did find small pupillary responses during rivalry of a bright and dim pattern when the bright pattern emerged from suppression. Their results would support an indirect effect of rivalry on the pupillary response via the parasympathetic pathways, or a binocular brightness averaging mechanism, but would not support a mechanism of direct retinal inhibition.

Rather than measuring pupillary responses to photic flashes, Bradshaw (1969) measured baseline pupil diameters during rivalry of unequally illuminated patterns. Pupil diameters were measured under 4 binocular conditions: 1. plain dark versus plain bright, 2. plain dark versus patterned bright, 3. patterned dark versus patterned bright, and 4. patterned dark versus plain bright. The bright pattern would dominate in condition 2 and dark pattern would dominate in condition 4. If it is assumed that rivalry produces retinal inhibition, then condition 2 should produce smaller pupil diameters. However, there was no difference between these conditions.

One interesting aspect of Bradshaw's results (1969) is relevant to Experiment 4. The results of Experiment 4 showed no difference in recognition performance in the nonrivalry state between target stimulus presentations to the patterned eye and to the blank field. Although the pattern dominated over the blank field this condition seems to be free of rivalry suppression. If this is the case, then only condition 3 of Bradshaw's experiment (1969) would contain rivalry suppression. If pupillary baseline diameters are a function of the total amount of illumination in both eyes minus any inhibitory effect which would effectively subtract illumination, then condition 3 should produce the largest pupil diameters. This is, in fact, what is evident from Bradshaw's data (1969). Condition 3 diameters are significantly ($p < .05$) larger than those of condition 2 and

4 combined. Condition 3 is also larger than all three of the other conditions combined ($p < .025$). Thus, Lowe & Ogle's results (1966) and Bradshaw's data (1969) suggest that rivalry suppression affects pupillary diameter, although it is unclear how or where this effect operates. The lack of effect on flash evoked pupillary responses in Lowe & Ogle's experiment (1966) makes it doubtful that rivalry suppression produces an inhibitory effect on the retinal level.

Effects on the Electroretinogram

Viefhues & Müller-Limmroth (1958) found a reduction of the b-wave amplitude of the electroretinogram (ERG) in the squinting eye of alternating strabismics. In addition they found that the amblyopic eye of monocular strabismics showed the opposite effect--decreased ERG with fixation and increased ERG in the squinting condition. Besides the difficulty in interpreting these apparently conflicting results, it is difficult to assess reliability of the results from their brief, undetailed report.

Using more sophisticated techniques and more controlled conditions Burian & Lawwill (1966) found no difference in ERG amplitude or waveform between normal and amblyopic eyes. They point out, however, that the ERG may be too crude a measure to detect localized abnormalities or suppression effects in the central macular area of the retina. It may also be questioned whether strabismic amplyopia operates in a similar way to rivalry suppression. It can only be suggested that if no ERG changes are found with the very strong suppressive effects of strabismic amblyopia, it would seem unlikely that they would be found with normal rivalry suppression.

ERG responses were measured in normal subjects in essentially a rivalry situation by van Balen (1964). He measured the ERG to a flashing light from an eye in dominance (same eye reading printed text) or in suppression (opposite eye reading text). Using a computer of average transients van Balen (1964) found no difference between rivalry dominance or suppression in the average flash-evoked ERG. His techniques were sensitive to the effects of rivalry suppression because he did find differences in the evoked cortical responses to the flashing light. Thus, the more convincing studies of Burian & Lawwill (1966) and van Balen (1964) found no effects on the ERG response of normal rivalry suppression or of amblyopic suppression in strabismic patients. This suggests that if a retinal inhibition accompanies rivalry suppression, the inhibition is too weak to produce an effect on the ERG.

Effects of Rivalry and BR Control on Afterimages

The study by Craik (1940) and the demonstration in Chapter V of the effects of pressure blinding on the strength of afterimages indicate that AIs have their origin in the retina. More specifically Brindley (1959, 1962) concluded that AIs were basically a photochemical phenomenon arising from the receptor cell layer in the retina. Hence, even if rivalry suppression were accompanied by some inhibitory effect on the retinal level, it would not interfere with the formation of an afterimage during an induction period.

The results of Experiment 11 found only a slight but significant reduction of AI strength following a rivalry induction period. It would seem likely, given a receptor cell origin of AIs, that this reduction of AI strength resulted from a physical disruption of the retinal image rather than from retinal neural inhibition during the induction period.

With experienced subjects in Experiment 12 there was no difference in AI strength following a monocular or BR induction period. If a photochemical basis of AIs is accepted, this result confirms the fixation steadiness of subjects CC and LL rather than precluding the possibility of neural inhibition in the retina. The results of Experiment 12 are important in that there was also no effect of BR control on the strength of AIs. This suggests that the change of rivalry dominance induced by voluntary control was not produced by a physical disruption of the retinal image which would occur with eye movements or accommodation changes. This result supports the earlier conclusions from Chapters IV and VI of the unimportance of peripheral mechanisms in BR control.

In summary, there are mixed findings regarding the effect of rivalry suppression on pupillary responses and diameters. Some studies found inhibition of pupillary responses while others found no effect of rivalry suppression on pupillary activity. It seems evident that rivalry suppression does not affect the ERG. Thus no definite conclusions can be made regarding the possible neural effects of rivalry suppression on the retinal level. However, the growing amount of evidence of the existence of centrifugal fibers in the retina (Brooke, Downer & Powell, 1965 and Honrubia & Elliott, 1968) as well as centrifugal activity in the visual system (Granit, 1955; Dodt, 1956; and Spinelli & Weingarten, 1966) would make it prudent to leave open the possibility of some neural inhibitory effect on the retinal level from rivalry suppression.

Central Neural Effects

Effects of Rivalry on Cortical Evoked Potentials

There has been an accelerating interest lately in the physiological correlates of the attention process (Worden, 1966). Most investigators have measured the cortical evoked electrical potentials (EP) to light flashes, auditory clicks or tactile shocks under different conditions of attention. This technique has also been applied to the study of the effects of binocular rivalry on flash evoked responses in the striate cortical area. Van Balen (1964) found that the EP amplitude was reduced by 20-40% when the subjects read printed text with the eye not being stimulated by the flashes. Apparently, then, rivalry suppression produced an effect measurable in the cortical EP.

Lansing (1964) measured flicker driven electroencephalogram (EEG) responses as subjects reported alternations in rivalry between a flashing light on one eye and a pattern of parallel diagonal lines on the other eye. He found that the amplitude of the flicker driven EEG was highly correlated with the reported suppression and dominance of the flickering light in rivalry.

Cobb, Ettlinger & Morton (1967) were unable to replicate the earlier results using flicker stimuli. They argued that their experiment, which used flickering illumination of both eyes each with its own rivalry stimulus, provided a real rivalry situation and thus a better test of the effects of rivalry on the cortical EP. However, when Cobb, Morton & Ettlinger (1967) used pattern reversals of black-white bar patterns instead of flickering light as stimuli, they found very clear reductions of the cortical EPs with rivalry suppression. They also found that EPs during nonsuppression were at least as great as during the monocular condition.

In an experiment similar to that of Cobb, Ettlinger & Morton (1967), Riggs & Whittle (1967) found no change in flicker EPs between rivalry dominance and suppression. However, Lawwill & Biersdorf (1968) using vertical and horizontal bar patterns as rivalry stimuli each presented with a different frequency of flicker found marked differences in cortical EPs correlated with rivalry phases. They found differences in peak amplitudes and differences of peak latencies of as much as 50 msec between rivalry dominance and suppression phases.

Donchin & Cohen (1970) reported a short experiment in which the subjects viewed rivalry between perpendicularly oriented grid patterns on which flashes of light occurred randomly in time and randomly to either eye. They found that the average EP to the light flash was almost nonexistent when the subjects were reporting on rivalry alternations and ignoring the superimposed flashes. But when the subjects attended to the flashes and ignored the rivalry alternations, the cortical EPs to the flashes became very prominent. This suggests that intramodality changes of attention have a large effect on the cortical EPs. Hence, the attempt to measure the effects of rivalry by superimposing nonattended photic flashes on the rivalry stimuli would very likely be unsuccessful. This may explain the negative results of Cobb, Ettlinger & Morton (1967) and Riggs & Whittle (1967).

The positive results of van Balen (1964) and Lansing (1964) and especially of Cobb, Morton & Ettlinger (1967) and Lawwill & Biersdorf (1968) provide strong support for the existence of cortical effects of binocular rivalry. However, the EPs provide little evidence of what cortical levels are involved. It is even possible that the changes in averaged EPs indicate neural inhibition at precortical levels, e.g. the lateral geniculate nucleus. What can be stated from the evidence is that the effects of rivalry can be measured electrophysiologically from scalp electrodes over the cortical visual areas.

Summary of Physiological Concomitants

From the results of experiments with afterimages the receptor cell layer of the retina can be eliminated as the site of rivalry suppression or of the effects of BR control. Although ERGs are not responsive to changes in rivalry, there is some effect of rivalry in pupillary activity. This is not conclusive evidence, but it does suggest the possibility of some retinal inhibition.

The movement aftereffect is strongly affected by rivalrous stimulation during an induction period. Most evidence requires a nonretinal component of the MAE and indicates that a retinal component, if it exists at all, could contribute to MAE strength only to a minor extent. The evidence also suggests that the interference of a hypothetical retinal component could not account for the extent of MAE reduction that occurs following rivalry stimulation. Therefore, the main effect of rivalry stimulation on the MAE must operate on nonretinal levels.

Chapter V concluded that a component of the origin of the MAE may be in the superior colliculus. Neurophysiological evidence suggests that the superior colliculus obtains its visual movement stimulation from a level of the visual cortex. If this level is below the level at which phenomenal rivalry suppression originates, it could account for the fact that rivalry stimulation but not phenomenal suppression interferes with the induction of the MAE. The reduction of the MAE would thus be a result of neural inhibition mainly in the superior colliculus.

There is strong evidence from electrophysiological studies that rivalry suppression exerts an inhibitory effect on the level of the visual cortex. Suppression is correlated with a reduced evoked potential to light flashes or pattern reversals whereas nonsuppression produces EPs similar to those in a monocular nonrivalry condition. Therefore, at least some of the inhibitory effect of rivalry suppression which reduces EPs and test stimulus performance arises on cortical levels.

A Model of Control of Binocular Rivalry

A tentative model of BR control is suggested by the experimental findings of this thesis. It would appropriately be based upon the most recently proposed model of binocular rivalry. Wales & Fox (1970) found that rivalry suppression involved a decreased visual sensitivity or increase in threshold of about .5 log units compared with nonsuppression or monocular conditions. They concluded that "rivalry suppression is an inhibitory state that attenuates all classes of inputs falling within the spatial boundaries of the suppressed target (Wales & Fox, 1970, p.90)." Fox & Rasche (1969) extended this concept of suppression to account for alternations in rivalry. When a reciprocal inhibition model failed to be confirmed, Fox & Rasche (1969) suggested that each eye had separate and independent inhibition mechanisms that produced suppression phases. Since durations of suppression phases were dependent only on the stimulus strength of that eye, a greater stimulus strength would more quickly overcome the inhibition and result in reduced suppression phase durations.

To account for the dichotomous alternation between the eyes Fox & Rasche (1969, p.217) proposed a "flip-flop switching device that would trigger the suppression mechanism alternately for each eye whenever a signal from the other eye emerged from suppression." They stressed that "the only function allotted to the switching device would be to alternately trigger the suppression mechanism for the two eyes (p.217)." In other words the duration of the suppression phase would be a function only of its stimulus strength. When the duration is completed, the switching device triggers the suppression phase of the other eye. The two eyes do not interact directly but alternate by means of this separate switching device. Fox & Rasche (1969) have thus suggested the operation of two mechanisms, an inhibition mechanism to determine phase durations independently for the two eyes, and a selection device to provide the alternation of the suppression phases.

Experiments 13 and 14 found that the control of binocular rivalry has the effect of shortening or lengthening the durations of suppression phases. Based on the Fox & Rasche model (1969) one explanation of this effect would be that control effectively alters the strengths of the rivalry stimuli. This explanation, in fact, receives little support from the experimental results of this thesis. For instance, one convenient way to alter the effective stimulus strength would be to change the physical properties of the stimulus through the operation of some peripheral mechanism such as eye movements or accommodation. However, Experiments 2, 7, 8, 9, 13 and 14 found that these effects contribute very little to the measure of control.

Alternatively, it may be argued that control could be mediated by centrifugal neurophysiological inhibition and excitation of the rivalry stimuli. For several reasons this possibility also seems unlikely. First, the subjects reported that when they made one stimulus more dominant it did not alter in its subjective intensity. The only result was an increase in nonsuppression durations and a decrease in suppression durations. Second, the results of Experiment 4 showed that the magnitude of suppression was constant even when control was being exerted. Third, a centrifugal neural mechanism would operate in Experiment 5 to exert control for the 1 second delay by effectively increasing the intensity for the instructed eye, and for the 5 second and 7 second delays by decreasing stimulus strength for the noninstructed eye. Then overall recognition performance should be greater for the 1 second delay than for the 7 second delay. The fact that Experiment 5 showed no change in overall recognition performance between the 1 second and 7 second delays would argue against an inhibitory and excitatory neural effect which can be applied to the two visual inputs to control rivalry.

A second possible model of BR control based on the Fox & Rasche (1969) suggestions would be that control affects the rivalry switching device. Fox & Rasche (1969) imply that the switching device operates in some way to trigger the next suppression phase when one eye emerges from suppression. The switching mechanism may be innervated from more central levels allowing the possibility of an inhibitory or excitatory effect. An excitatory effect may trigger the suppression phase in the dominant eye before the suppressed eye would normally emerge from suppression. This would allow the other eye automatically to emerge from suppression. In addition, an inhibitory effect would delay the triggering of the next suppression phase and thus prevent the suppressed eye from becoming dominant. Thus, the 'inhibitory' and 'excitatory' effects found in Experiments 13 and 14 would operate on the switching device proposed by Fox & Rasche (1969) rather than on the relative strengths of the rivalry stimuli.

Experiment 12 found that altering the relative dominance of a rotating induction stimulus by voluntary control did not change the strength of the MAE. If the superior colliculus receives its movement stimulation from some level of the visual cortex, it would seem unlikely that BR control exerts a centrifugal neural effect at or below this level. The model of BR control based on a mediation of the switching device proposed by Fox & Rasche (1969) would be consistent with these experimental results. This model does not require the addition of any excitatory or inhibitory neural effects to that of the rivalry stimuli. The only inhibition of rivalry stimuli would be that from normal rivalry suppression since BR control would operate only on the switching device.

This model proposes neither an all-or-none switching of attention nor a constant attenuation of the rejected channel. It suggests, instead, an all-or-some switching in which the selected channel is "all" a majority of the time but switches of attention ("all") to unwanted channels, even if very brief, inevitably occur. The total proportion of time for which the selected channel is attended is the measure of control of attention, a measure which can be increased with practice.

The model proposed above is consistent with the results of Experiment 5, although the use of the overall (I-NI) measure for each subject disguises the all-or-some switching between the eyes. Most investigators (Broadbent & Gregory, 1963; Moray & O'Brien, 1967; and Treisman & Geffen, 1967) have also used overall performance differences between selected and rejected channels as the measure of the effects of selective attention. This overall difference measure is insensitive to transient lapses of attention to the selected channel and therefore cannot determine whether attention produces a constant attenuation of the rejected channel or a switching of an attenuation effect (all-or-some switching). Thus, the use of this performance measure may incorrectly lead to the conclusion of a constant attenuation. If the effect of attention is to be measured more precisely and if the specific effects of voluntary control are to be understood, the question of whether selective attention is a constant attenuation or an all-or-some switching needs to be investigated.

This model of BR control is consistent with the experimental findings of this thesis. The notion that control would operate on the switching device of the Fox & Rasche model (1969) is consistent with the findings of Chapters IV, V and VI that BR control is mediated basically by central rather than peripheral mechanisms. The results of Experiments 4 and 5 required, in fact, a model of control which directs the rivalry phases to the selected eye but does not affect the magnitude of suppression. An excitatory effect has never been found to be associated with dominance phases. This is consistent with the proposal that 'inhibitory' and 'excitatory' effects found in Experiments 13 and 14 would operate on the switching device rather than the rivalry stimuli. The model also incorporates the possibility that control of phase durations may be increased with practice by the increased inhibitory and excitatory innervation of the switching device from more central levels. Thus the model is consistent with the known effects of BR control.

As mentioned in Chapter III this model also conforms to the suggestions of Verhoeff (1937) that the effects of attention (rivalry suppression) are involuntary and of a constant amount while the voluntary control of attention directs these effects (BR switching mechanism). The model of voluntary control of rivalry would be applicable to selective attention in other modalities, and would generate testable hypotheses to provide a more detailed analysis of the effects of the voluntary control of attention. Thus, the experimental findings of this thesis and the proposals derived from these findings should increase the importance of BR control and may lead to the resumption of its former place in the study of selective attention.

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