

Selective Attention and the Control of Binocular Rivalry



Psychological Studies

11

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Selective Attention and the Control of Binocular Rivalry

LEON COLBURN LACK

*The Flinders University
of South Australia*

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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' (1908:173).

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, 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' (1908:2). 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 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' (1908:5).

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

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of attention is practically constant, and cannot be applied to one object without affecting the clearness of others' (1908:9). 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' (1908:25). 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' (1908:61–62).

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 'immediate' and 'derived', and of the third, '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' (1891:421). 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' (1891:434).

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 book. 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

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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 1925:497). 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 1925:499).

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 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' (1925:500). 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 1873:294–295). 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' (1873:295).

Other experimenters also used BR as an example of the attention process. Breese (1899:17) 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 states that 'one of the most satisfactory ways of studying many of the phenomena of the attention is by means of a simple stereoscope' (1908:32). 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 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 1950s were references to the phenomena [attention] again made explicitly by name' (1969:2–3).

Several recent publications have given a short history of the decline

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and renewal of interest in attention (Santos, Farrow and Haines 1963; Bakan 1966; Norman 1969; McGhie 1969; Moray 1969; Swets and 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 behaviourism 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 and 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 revival 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.

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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 book, included 87 references to publications using or studying binocular rivalry. Except for an anomalous 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 ascendancy 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 and Myro (1959) using tachistoscopically presented faces. Bagby (1957) found culturally meaningful stimuli to be dominant in rivalry. Toch and 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 and 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 and Svendsen (1968) in a series of studies used BR to compare associative and syntactic meaningfulness of words. Goryo (1969) found that faces predominated 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 and Bricker (1952), Mull, Armstrong and Telfer (1956), Kakizaki (1960), Kaplan and 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 effect of movement on pattern dominance in BR was studied by Springbett (1961) and Grindley and Townsend (1965, 1966).

Three comparatively recent studies (Treisman 1962; Hochberg 1964a, b; Ogle and 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 and 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 (1964a, b) investigated spreading suppression in the visual system with the use of BR.

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Aafjes, Hueting and Visser (1966) and Cogan and 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 (1968) compared it with image fragmentation of stabilized images and afterimages. Whittle, Bloor and 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 and Serman (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 and Lindsay 1965; Mast and Watson 1968; Eason, Harter and White 1969; Kopell, Wittner and Warrick 1969; 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 and Morton (1967), Lawwill and Biersdorf (1968) and Donchin and 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 1961:273).

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' (1964:335). He concludes that rivalry 'reflects a genuine perceptual process which involves a temporary inhibition of response' (1964:335). 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' (1963:14). 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. Treisman states that binocular rivalry 'may be taken as one limit on divided attention' (1969:288). 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 spatial location' (1969:288). Thus, because she assumes

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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 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' (1969:150). He bases his conclusion of the lack of control of rivalry on the assumption of 'general agreement'. Since neither Treisman (1969) nor Moray (1969) refers 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 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' (1969:101-2). 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 suggests that 'aural rivalry' (1969:102) may occur with perfect auditory synchrony.

In his last chapter, Moray 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' (1969:193). 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' (1969:5). 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; 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 expressed the view that 'most previous observers agree that attention has no influence on retinal rivalry, (1947:298). 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.)' (1925:500).

However, Helmholtz believes that like all other examples of selective attention and voluntary processes the control of rivalry is a 'mediate, not an immediate, volition' (1925:500). 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 orientated 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 1899:25). 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 fluctuations 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 1899:46). 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 and 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