RICE UNIVERSITY

THE EFFECT OF AROUSAL ON A SELECTIVE ATTENTION TASK

by

DEBORAH A. PEARSON

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE

MASTER OF ARTS

APPROVED, THESIS COMMITTEE:

David M. Lane
David M. Lane,
Assistant Professor

Sarah A. Burnett
Sarah A. Burnett,
Associate Professor

William C. Howell,
Professor

HOUSTON, TEXAS

APRIL 1982

Abstract

The Effect of Arousal on a Selective Attention Task

Deborah A. Pearson

In two experiments, subjects performed a luminance detection task under conditions of low arousal and high arousal. In the low arousal condition, subjects heard 70 dB(A) broadband noise, and in the high arousal condition they heard 100 dB(A) noise. Stimuli were presented on a cathode ray tube, and appeared at the center and along the perimeter of an imaginary circle. Two expectancy conditions were used: a central expectancy condition, in which most of the stimuli appeared at the center of the screen and a few appeared along the perimeter, and a peripheral condition in which the opposite was true. Subjects responded faster to central stimuli than peripheral stimuli; they also responded faster to expected stimuli than unexpected stimuli. Noise had no effect on the way in which subjects processed location or expectancy information . It was concluded that arousal has no effect on the breadth of attention in this task.

Acknowledgements

The author would like to express her gratitude to David M. Lane, who served as the thesis chairman for this project. His continued guidance in collecting and analyzing the data, and later in preparing the thesis, was invaluable. The advice and support of Sarah Burnett and William Howell, who served on the thesis committee, and Arthur Gottschalk, who prepared the noise tapes were also very much appreciated. Finally, the author would like to thank Mr. and Mrs. Harry Pearson, Jr. -- for everything.

Table of Contents

List of Tables

Page

The Effect of Arousal on a Selective Attention Task

From the time William James (1890) declared that "Every one knows what attention is," psychology has been attempting to discover just what it is and how it operates. James informed us that the immediate effects of attention allow us to "perceive, conceive, distinguish, and remember." (p. 424). This principle has been reformulated by modern researchers into the concept of selective attention. Selective attention allows us to select relevant information from our environment while at the same time ignoring irrelevant information. Such research has been directed toward the discovery of the mechanism by which selective attention operates, with particular interest being focused on the point in the information processing sequence at which relevant stimuli are separated from irrelevant stimuli. The first studies that will be reviewed placed it at an early stage of processing, while later studies suggested that a considerable amount of processing is performed on all incoming stimuli, with the selection process occurring later in the sequence.

The first major study in this area was performed by Cherry (1953). In this study, two spoken messages were delivered simultaneously, one to each ear, and subjects were instructed to shadow one of the messages, while ignoring the other message completely. When questioned about the ignored message, subjects could only volunteer the most basic information such as whether there was a switch from a male to a female voice. They were unable to report the content of the ignored message, and were even unable to determine whether or not the message had been delivered in English.

In 1958, Broadbent attempted to synthesize existing information concerning attentional ability, and proposed his "filter theory." According to this theory, stimuli from the environment pass through an attentional filter which sorts them on the basis of physical characteristics. Only stimuli which are selected and thus pass through the filter are processed beyond their obvious physical characteristics. This processing is done by a limited capacity system. In the case of the Cherry experiments, the message was selected on the basis of spatial origin (i.e., the left ear, or the right ear).

The original version of filter theory was challenged by a series of experiments performed in the early 1960's. Gray and Wedderburn (1960) found that subjects would follow a message from one ear to another in order to follow its meaning. For example, if "mice" is presented to the left ear, "eat" to the right ear, and "cheese" to the left ear, subjects follow it back and forth in order to obtain a meaningful phrase, rather than shadowing a meaningless string of words in one ear. Moray (1959) provided additional evidence that messages presented to the unattended ear are analyzed for speech content when he demonstrated that subjects were more likely to remember something from the unattended ear if it had been preceeded by the subject's name than if it had not.

Along this same line, Treisman (1964) found that the more similar two binaural messages were, the more difficult it was for subjects to separate them. Subjects had no trouble distinguishing between messages of vastly different physical characteristics, but had considerable difficulty when the physical characteristics of the two messages were similar. Subjects found it extremely difficult, for example, to distinguish between two messages that were read in the same language by the same voice.

Treisman proposed a modification of Broadbent's filter theory. According to this revised filter theory, all incoming stimuli are subjected to a series of preliminary tests. These tests analyze all inputs for physical characteristics, and more refined tests distinguish stimuli on the basis of syllabic patterns, individual words, and finally meaning. Relevant stimuli are selected from irrelevant stimuli by attenuating the channel carrying the irrelevant information. For instance, if messages can be distinguished on the basis of physical characteristics, the attenuation process will begin at this early stage of processing. However, since the stimuli are attenuated rather than being filtered out completely, significant stimuli such as the subject's name can pass through into the limited capacity system for further processing.

As an alternative to filter theory, Deutsch and Deutsch (1963) and Norman (1969) proposed models of selective attention that postulated that all competing inputs get analyzed to the point where they activate a representation in long term memory, thereby getting a simple analysis for meaning. The input that has the most "pertinence" will be selected to enter conscious awareness. It is only at this last stage that selection comes into play.

Instead of thinking in terms of "bottleneck" models of attention as did Broadbent and Deutsch and Deutsch, Moray (1967) proposed the existence of a limited capacity central processor, as opposed to a limited capacity channel system. The basic tenet of his hypothesis was that there is a central pool of capacity which can be allocated in different ways according to the task at hand. Each task requires a "plan," with a difficult tasks's plan using more of the central capacity than an easy task's plan. As a result, there is a greater amount of capacity left over for an easy task.

Kahneman (1973) expanded on the idea of a general capacity system by proposing that the general capacity is expandable according to the demands placed upon the system. The policy that dictates how capacity is allocated is controlled by four basic factors: enduring dispositions of involuntary attention (ex., orienting to a novel stimulus), momentary intentions, the evaluation of demands, and arousal.

The major concern of this paper is with the last of these four factors. The effect of arousal on attention has been the subject of considerable research in the past twenty-five years. Easterbrook (1959) extensively reviewed the literature in this area and, following Yerkes and Dodson (1908), hypothesized a curvilinear relationship between arousal and attention. According to Easterbrook, increases in arousal level result in a restriction in the range of cues that are used in performing tasks. At low levels of arousal, performance is poor because selectivity is low and the subject pays attention to irrelevant cues. As arousal increases, selectivity improves and more relevant cues are utilized so performance also improves. At very high arousal levels, selectivity is so narrowed that even relevant cues are ignored and performance declines as a result.

One of the sources that Easterbrook cited as an example of this relationship was Bursill (1958), who demonstrated the progressive narrowing of attention with increasing arousal levels. The central task in his experiment was a tracking task in which subjects were required to align the two pointers of a pursuit-meter. In addition to the tracking task, a detection task was introduced which required the subject to monitor the periphery for lights that flashed in a random order. Subjects responded to these lights by pressing a button which corresponded to the light that had just flashed. Before the actual procedure began, subjects were exposed to one of two experimental conditions: one hour spent in a 95°- 105°F room (the high arousal condition) or an hour spent in a 60°- 70°F room (the low arousal condition). The results for the tracking task and the peripheral lights task were analyzed separately. Subjects tended to show a slight decrement in performance on the tracking task under conditions of arousal. The results of the monitoring task supported Easterbrook's theory: more peripheral lights were missed in the high arousal condition. The further out from the center the lights were, the more likely they were to be missed, and this was more true for the subjects in the high than in the low arousal condition. Bursill concluded that there is a "funneling of the field of awareness" at high arousal levels.

Bahrick, Fitts, and Rankin (1952) obtained a similar effect when arousal was manipulated by incentive levels. Subjects in a high incentive condition received bonuses for high scores on their tasks and were presumably more stimulated as a result. Subjects in the low incentive condition received base pay only. The central task in this experiment was a tracking task, as in Bursill (1958). Two peripheral tasks were used in this experiment: monitoring flashing peripheral lights and realigning an instrument pointer than had deflected from its mark by turning a knob. Each subject performed only one of the peripheral tasks. Central task performance improved during incentive trials, whereas scores on the peripheral tasks were adversely affected by them.

In addition to the use of heat and incentives, the restriction in the range of cues can also be pharmaceutically induced. Callaway and Thompson (1953) increased arousal by administering amyl nitrate (an amphetamine) or by persuading subjects to submerge one foot in a bucket of ice water, thereby triggering the release of natural adrenalin.

The task used by Callaway and Thompson is known as the card size test. Subjects held a cardboard rectangle in front of them with one hand while controlling an instrument that projected rectangles onto a screen with the other hand. The card that was held by the subject was considered to be the central object and the rectangle on the screen was considered to be the peripheral object. The experimental task involved adjusting the projector so that the size of the rectangle on the screen equalled the size of the rectangle on the card in the subject's hand.

Callaway and Thompson found that subjects aroused by either amyl nitrate or a bucket of ice water overestimated the size of the projected rectangle. They hypothesized that this overestimation was probably an attempt to compensate for the shrinking peripheral field. Callaway and Thompson referred to this phenomenon as "decreased extroceptive input." It should be noted, however, that the interpretation of this effect in terms of a restriction in the range of cue utilization is somewhat speculative.

Subsequent experiments by Callaway and his coworkers also have not provided compelling evidence for this effect. In a study by Callaway and Dembo (1958), the criterion used for defining a task as central or peripheral is questionable. In the context of a probability learning task in which subjects had to guess which of two lights would flash next, "central" information concerned the current guess and current answer whereas "peripheral" information was defined as that information that was concerned with previous sequences. In the first sequence of a series of trials, the two lights flashed equally; in subsequent trials, one of the lights flashed 75% of the time whereas the other flashed only 25% of the time. Subjects who had been aroused using amphetamines were slower than subjects given a placebo at picking up on the probability cues, thereby giving more incorrect guesses. According to Callaway and Dembo, aroused subjects were less able than unaroused subjects to use "peripheral" stimuli, which presumably would have swayed them to predicting that the light that had flashed more previously would be a more likely choice to flash in the future. Again, it is not clear that the effect or arousal is on cue utilization. In fact, Callaway and Stone (1960) themselves questioned whether this was a proper interpretation.

Cornsweet (1969) noted that all the paradigms that had been used in this field had included peripheral tasks which did not impart task-relevant information. In the task used by Cornsweet, subjects focused on a fixation point two feet in front of them. Two central lights were located five degrees to the left and to the right of this point. On either side of the subject's head (90° from the fixation point), there were peripheral lights.

The experimenter signalled the start of a trial by making a clicking sound, which warned the subject that one of the central lights would be coming on in .8 seconds. Subjects had to respond by pressing a button corresponding to the appropriate light. On half of the trials, the peripheral light that was on the same side as the central light that would eventually flash came on .5 seconds before the central light. Thus, a subject using the peripheral cues should be able to respond sooner on trials in which the peripheral lights were presented than on trials in which they were not.

Arousal level was manipulated by electric shock. Cornsweet found a significant difference in reaction times between the trials which included the peripheral cue and those which did not for subjects in the high arousal condition but not for subjects in the low arousal condition. From these results, it would seem that aroused subjects were making more use of the peripheral cues that were unaroused subjects.

These findings are apparently in contradiction to the studies that had been reviewed previously. In these previous studies, there had been a reduction of the range of cues used under aroused conditions. Cornsweet pointed out that the peripheral cues in her experiment were relevant to the task at hand, and that subjects would be highly motivated to use those cues in an attempt to avoid shock in the high arousal condition.

A series of studies by Hockey provides insight into this problem. Hockey (1970a) first performed a replication of Bursill's (1958) paradigm using loud noise as an arousal agent. He found that both the performance on the central tracking task and the detection of central lights were facilitated by loud noise. Detection of peripheral lights, however, decreased in loud noise. Hockey suggested two possible explanations for the facilitation of central detections: (a) these sources were scanned more frequently due to their close proximity to the tracking task, and (b) these sources had a higher apparent probability of flashing (subjects detect more flashing in the central locations from the outset of the experiment, so as the experiment goes on, they expect more flashing to occur there and thus scan this area more thoroughly).

In an attempt to distinguish between these possibilities, Hockey (1970b) changed the experimental design by substituting "continuous hold" signals for the flashing lights of the previous experiment. In this case, the light would remain on until the subject detected it. In this way, the objective and subjective probabilities of a light going on were equated. Hockey used this substitution to create an unbiased condition in which signals were presented with equal probabilities at all locations, and a biased condition in which signals were heavily biased in probability of occurrence to the central locations in a 4:1 ratio. Reaction time was used as the dependent variable.

According to the location hypothesis, noise (arousal) should facilitate the detection of central lights in both the biased and unbiased conditions. On the other hand, since the probability hypothesis predicts facilitation of the most probable sources, it predicts that facilitation of the central lights should occur only during the biased condition.

The results support the probability hypothesis. There was no tendency for detection of central sources to improve under noise in the unbiased situation. In the biased condition, lights in the 50° and 80° positions had longer reaction times in aroused subjects, whereas the latency of response to the central lights (20°) was shortened in these same subjects.

From these results, Hockey suggested that there is a funneling of attention, not a funneling in the physical field of awareness, that occurs during high arousal. This logic can be applied to Cornsweet's (1969) results: attention was simply shifted to using the peripheral cues when they were salient.

This theory was extended by Hockey (1970c), who used sleep-deprived subjects as a low arousal group. The procedure was identical to that used in Hockey (1970b), except that in all conditions, the central lights were favored over the peripheral lights in a 4:1 ratio. These subjects showed decrements on the central tracking task and on detection of central light signals, but there was no decrement in detection of peripheral light sources. From these results it is possible to infer that low arousal produced impaired performance on high probability sources, while low probability sources do not suffer a decrement in detection. Hockey concluded that there is a monotonic relationship between arousal and attention such that selectivity increases under states of heightened arousal and decreases under states of lowered arousal.

Poulton (1977) reinterpreted the results of many noise experiments, including Hockey's, in terms of auditory feedback. According to Poulton, there will be a decrement in performance in noise as compared to quiet in tasks that use equipment which provides auditory feedback due to the fact that subjects will not be able to hear the auditory cues. In the Hockey experiments, the buttons that subjects pressed in response to a flashing light had a click. Subjects could hear this click in the quiet condition, and they were able to monitor their performance by using it. In the noise condition, subjects were unable to hear this click, thereby losing a valuable cue. Poulton explained the differential decline in peripheral monitoring performance in the following manner: under conditions of high arousal, subjects became more tense and adopted a strategy of keeping a finger near the two central light switches. As a result, reaction time to peripheral sources increased.

Broadbent (1978) disputed Poulton's claim that performance will be upset by noise only if it prevents the subject from using auditory cues. He reveiwed the studies which Poulton had used to make this claim, and showed that no cues had been masked by noise, hence, auditory masking could not have played a role in the outcomes of these experiments. Furthermore, he pointed out that Poulton was not aware of the fact that there are two physical scales of noise, the "A" scale and the "C" scale. The C-weighted scale is a purely physical measure of sound, whereas the A-weighted scale is primarily a subjective measure of sound. Since the numeric values of any given decibel level do not correspond for the two scales, it is necessary to clarify which scale is being used (Poulton frequently confused them). In this paper, unless otherwise stated, the decibel levels are stated in terms of the A scale.

Another line of evidence that provides support for arousal being the mediator of the effect obtained by Hockey is the fact that similar effects have been reported in a number of studies that used other arousal agents such as heat (Bursill, 1958), amphetamines (Callaway & Thompson, 1953), and shock (Cornsweet, 1969). Taken collectively, it is reasonable to assume that arousal as induced by noise was the mediating agent.

Forster and Grierson (1978) sought to extend Hockey's finding by introducing peripheral expectancies and intermittent noise into the original paradigm used by Hockey. In their first experiment, the biased sources were in the periphery, as opposed to the center. They wanted to see if the enhanced selectivity of expected sources over unexpected sources under conditions of noise would generalize to a situation in which the expected sources were peripheral. Although subjects were able to respond faster to expected sources than unexpected sources, this selectivity was not greater in noise than in quiet. When intermittent noise (which was hypothesized to be more distracting than a constant background of white noise) was used, similar results were found. The time on target for the tracking task showed no difference between noise and quiet in either constant or intermittant noise.

After Forster and Grierson were unable to extend Hockey's work, they tried to replicate it precisely to the original specifications, including conducting the experiment in Hockey's lab using the original equipment. They were unable to replicate his results: there was no significant difference in performance between the noise and quiet conditions.

In another variation of their study, Forster and Grierson compared performance using auditory and silent switches. The condition in which auditory switches were used provided auditory feedback, whereas the silent switches did not. According to Poulton, there would be an impairment in performance under noise conditions for the condition in which auditory feedback was provided. In fact, there was no evidence of impaired performance as a result of noise in either condition, which would suggest that masking of auditory feedback was not a factor in this experiment.

The Forster and Grierson (1978) experiments would seem to indicate that the arousing properties of noise may not be as robust as had originally been thought. Recently, several problems with these experiments have come to light. Hockey (1978) and Hartley (1981) have described some differences between the two sets of experiments that may account for the inability of Forster and Grierson to replicate and extend Hockey's results.

The first difference was that of noise level. Hockey used 70 dB for his quiet condition and 100 dB for his noise condition. Although Forster and Grierson used 80 dB for their quiet condition, they only used 92 db for their loud condition. Perhaps this lower decibel level did not arouse the subject as much, thereby diminishing the effect. This probably was not the case, however, since other studies (e.g., Hartley and Carpenter, 1974) have produced arousal with lower levels of noise.

A second difference in the two studies lies in the nature of the tracking task. Although Hockey's subjects were on target 60-70% of the time, Forster and Grierson's subjects only showed a 30-40% time on target. Later it was discovered that a mechanical alteration of the original equipment had been made between the time Hockey performed his original experiments and Forster and Grierson performed theirs. Under these circumstances, attention may have been deployed differently in the two studies. Hockey (1978) hypothesized that the more difficult tracking task of Forster and Grierson may not have retained its high priority throughout the experimental session because subjects became discouraged with their low success rate and simply lost incentive. At any rate, it is difficult to assess attentional selectivity when the true pattern of attention is questionable.

Hartley (1981) pointed out another potential problem with the Forster and Grierson (1978) experiments: they lacked power. In order for their experiments to have had a 85% chance of replicating Hockey, they would have had to have used 32 subjects. In fact, only eight subjects participated in the attempted replication, thereby greatly reducing the chance of finding a significant effect. Hartley proceeded to replicate Hockey using 95 dB noise, a tracking task of similar difficulty level to Hockey (as indicated by a 65% time on target) and no chin rest (which Forster and Grierson had included, although Hockey had not). The results of this attempted replication were mixed. Noise was found to have a detrimental effect on tracking (unlike Hockey), but monitoring performance mirrored Hockey's results in that latency of response to peripheral stimuli was increased while reaction time to central (biased) stimuli was reduced by noise. However, even this study was not a complete replication of Hockey, as Poulton (1981) pointed out, because Hockey's pursuitmeter was random whereas the path of Hartley's pursuitmeter was predictable.

At this point, the question of the effect of arousal on selective attention has hardly been answered. In particular, it has yet to be demonstrated that attention is focused on more probable sources in all positions of the visual field to a greater extent in noise than in quiet. It may well be that arousal in the form of noise serves to funnel attention to the center of the visual field because no one has ever found a greater selectivity under noise for stimuli that are expected in the periphery. Then again, there is inconsistent data as to whether there is any effect of noise on attentional selectivity at all.

If arousal serves to increase the extent to which stimuli appearing in expected locations are processed more efficiently than stimuli appearing in unexpected locations, then the actual placement of the location in the display in which stimuli are likely should not make any difference. When most of the signals occur in the center of the visual field, this theory would predict that aroused subjects would be better able than unaroused subjects to detect signals from this area, but less able to detect peripherally presented stimuli. When most of the signals occur in the periphery, aroused subjects should be better able to detect these stimuli but less able to detect central stimuli than unaroused subjects.

On the other hand, if arousal serves to decrease breadth of attention such that there is a funneling of attention to the center of the visual field, there should never be any facilitation of reaction time to peripheral sources, even when they are expected. The present study sought to discover which, if either, of these hypotheses could better explain the effect of noise on selective attention. In a paradigm that was completely removed from the Bursill task, conditions were established in which both the center and the periphery served as the prime source of information.

Detection ability was measured in terms of reaction time to a stimulus. Arousal was induced by white noise, and source priorities were established by informing the subject which sources would emit the most signals. If there is a funneling of attention toward the most probable sources, then one would expect that aroused subjects would display shorter reaction times to signals from sources of high priority (as defined by the instruction) in comparison to unaroused subjects. The aroused subjects might also experience a decrement in the low probability source locations as a result of shifting their attention to high priority areas. If on the other hand there is a physical contraction in the visual field during arousal, there would be only an enhancement of performance in the center, regardless of priorities, and no enhancement in the periphery ever.

The importance of this study lies in the fact that it integrates both the center and the periphery as the priority source of information. In order to truly clarify the distinction between the effect of arousal being to a) funnel the actual field of awareness (Bursill, 1958), or b) to promote a differential scanning of high priority signals (Hockey, 1970a, 1970b), there must be a manipulation of both high and low priorities in the visual field. This experiment incorporates both of these manipulations in an attempt to distingush between these hypotheses.

Experiment 1 used a task in which subjects were instructed to attend to different spatial locations in a variety of conditions. Similar paradigms have been used by many researchers, including Posner, Snyder, and Davidson (1980) and Egeth (1977).

In the Posner task, subjects were asked to respond to four lights that were arranged horizontally beneath a CRT (cathode ray tube). On some trials, they were cued on the screen as to the most probable location in which the stimulus would occur. If the stimulus actually appeared in the expected location, reaction time decreased relative to a neutral condition in which all four locations were equiprobable. If the stimulus appeared at one of the unexpected locations, reaction time increased relative to the neutral condition. From these results, Posner et al. concluded that subjects were able to establish expectancies and allocate their attention to the expected location.

Similar results were obtained by Egeth (1977), in which reaction time to a target letter was compared in two conditions. In the focused attention condition, the target letter was always presented in the middle of an imaginary circle whereas in the divided attention condition, the target appeared in the center of the circle 20% of the time and in the periphery the remaining 80% of the time. Subjects responded faster to the central target letter in the focused attention condition than when they had to divide their attention between the center and the periphery.

These paradigms influenced the methodology that was used in Lane and Pearson (in press) and in this presentation. In these cases, subjects were also presented with stimuli in locations that were either expected or unexpected, and reaction time to stimuli appearing at a location was compared in these two conditions. Noise was introduced in the present experiment in order to see what affect, if any, it would have on performance.

In summary, noise was used to induce arousal in order to see whether or not arousal led to a narrowing of attention, either in the sense of a visual contraction of the field, or in the sense of a differential scanning of more likely sources. Finally, as this task represents a departure from tasks used in previous experiments, this study sought to generalize the previous findings to a new experimental situation.

Experiment 1

Subjects. Eighteen subjects were recruited from introductory psychology courses at Rice University. There were nine men and women in the group, and they were compensated with class credit or money for their participation.

Each subject was tested in both the low arousal condition (70 dB(A) white noise) and the high arousal condition (100 dB(A) white noise). Half the subjects heard the 70 dB. noise first, and the other half heard the 100 dB. noise first. The two sessions for each subject were scheduled approximately one week apart.

Apparatus. The visual display was presented on a TRS-80 Radio Shack micro-computer. Subjects were seated in front of the computer and their heads were placed on a chin rest that produced a constant viewing distance of thirteen inches between the screen and the subject's eyes. A keyboard was placed directly in front of the subject; the subject responded to a signal by pressing one of the keys on this board.

White noise of 70 or 100 decibels was piped over earphones to the subjects from an AKAI 1722II stereo tape recorder. The 70 dB. tape consisted of broadband noise with a frequency range of 20-4KHz; the 100 dB tape consisted of broadband noise with a range of 10-4KHz.

Procedure. After the apparatus was adjusted in such a way that the subject's eyes would be level with the center of the screen, he was told that he would be seeing dots of light on the screen. Every time he saw a light, he was to press the space bar of a keyboard. Before a dot would come on, a focus point in the form of a number sign would appear in the center of the screen. The subject was told to look at the focus point whenever it appeared on the screen.

The dots appeared in either the center or the periphery of the screen. There were three sets of peripheral locations, composed of four possible positions along the perimeter of an imaginary circle. The perimeter of the small circle formed a 1.1° visual angle from the center, the medium size circle formed a 6.85° angle, and the large circle formed a 13.25° angle.

Subjects performed in each of six conditions during each session. Each of the circle sizes was used for two conditions, corresponding to a priority for the center and the peripheral locations. For example, in one pair of conditions, dots appeared in both the very center of the screen and in the four perimeter positions of the small circle. In one of the two conditions in the pair, most of the dots appeared in the center of the screen (120/144) whereas only a few (24/144) appeared in the periphery. In the other condition, the majority of the signals appeared in the periphery whereas only a few appeared in the center. Similar pairs of conditions existed for the medium and large size circles. The order in which the six conditions were presented was randomized individually for each subject.

Before the actual experiment began, subjects were given a block of practice trials to acquaint them with the task. The trial condition used as practice was randomly selected from the six possible conditions.
During this time subjects saw the two error messages that could be presented throughout the experiment. The first, which read "Anticipation Error" flashed when the subjects responded before 100 milliseconds (msec.) following presentation of the signal. As it would have been impossible to respond in this length of time, this message was used as a means of preventing haphazard responding. The second error message read "Please depress the bar when you see the light!" and it flashed when 750 msec had passed since a signal had been presented.

Table 1

Median Reaction Time (msec.): Experiment 1

	Center						Periphery					
	Expected			Unexpected			Expected			Unexpected		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
70 Decibels	261	270	258	256	273	295	253	268	288	266	316	323
100 Decibels	259	276	261	288	285	307	271	281	292	271	322	323

Results and Discussion

A four-way analysis of variance was performed on the data. The factorial design consisted of two levels of noise (soft and loud), two levels of location (center and periphery), two levels of priority (high and low; the high priority being the place where the subject expected to see most of the signals), and three levels of size of the peripheral circle (small, medium, and large). Only seventeen subjects were included in the analysis of variance; the eighteenth subject was not included because she had an excessively high error rate (exceeding ten percent).

The criterion used to assess performance was median reaction time. These reaction times are shown in Table 1. The major findings of this experiment were that there was no evidence of either a Noise x Location interaction, $\underline{F}(1,16) < 1.0$ or a Noise x Expectancy interaction, $\underline{F}(1,16) = 1.06$, $\underline{p} = .32$. Thus this experiment found no evidence of an effect of noise on selective attention. There were, however, a variety of significant effects. Signals that appeared in the center of the screen were detected more quickly than signals appearing in the periphery, $\underline{F}(1,16) = 25.63$, $\underline{p} < .001$.

The effect of expectancy was highly significant, $\underline{F}(1,16) = 106.02$, $\underline{p} < .0001$, reflecting the fact that subjects who expected a signal at a certain location were able to use this information in order to respond more readily to these expected signals than they were to signals that were unexpected. The size of the peripheral circle also played a significant role: the larger the size of the peripheral circle, the longer the latency of response, $\underline{F}(1,16) = 29.34$, $\underline{p} < .001$. The effect of noise was not significant, $\underline{F}(1,16) = 1.31$, $\underline{p} = .27$, although there was a slight tendency for subjects to respond more slowly under conditions of loud noise than under conditions of soft noise.

There were two significant interactions: Location x Size, $\underline{F}(2,32) = 30.44$, $\underline{p} < .00001$, and Expectancy x Size, $\underline{F}(2,32) = 25.44$, $\underline{p} < .00001$. In the first of these interactions, the difference in reaction time between central and peripheral signals grew steadily larger as the size of the peripheral circle increased. That is, the difference in reaction time between the central and peripheral signals for the small circle was less than the difference between the central and peripheral signals for the medium circle. In turn, the difference between central and peripheral scores was smaller in the medium size circle than in the large circle.

The Expectancy x Size interaction reflected the fact that the effect of expectancy (the difference between the unexpected and the expected scores) steadily increased as the size of the peripheral square increased. This was true for both centrally and peripherally presented stimuli. The Location x Size x Expectancy interaction was not significant, $\underline{F}(2,32) = 2.82$, $\underline{p} = .07$. The analysis of variance summary table is presented in Appendix 1.

Experiment 2

The second experiment was performed to attempt to replicate results of the first experiment and to extend these findings to a longer session. Specifically, Broadbent (1971) suggested that noise has its maximum effect in a prolonged session (over a half hour). For that reason, this experiment was lengthened to one hour, which is more in line with previous experiments.

Procedure. Twenty-four subjects were recruited from introductory psychology courses at Rice University, and were given extra course credit for their participation.

The apparatus was identical to that used in the first experiment. Subjects performed the same size conditions that were used in Experiment 1, and then performed an additional set of the same six conditions.

Table 2

Median Reaction Time (msec.): Experiment 2

	Center						Periphery					
	Expected			Unexpected			Expected			Unexpected		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
70 Decibels												
Trial 1	268	279	285	274	286	291	271	283	298	278	312	350
Trial 2	267	263	272	270	272	276	267	276	291	262	302	327
100 Decibels												
Trial 1	281	300	287	276	299	305	276	289	299	280	337	335
Trial 2	270	269	269	275	279	285	270	278	298	272	305	324

All conditions were randomized in order of presentation within each block. The first set of six conditions will be referred to as "Trial 1," and the second set as "Trial 2."

Results and Discussion

Although twenty-four subjects participated in this study, equipment failure resulted in the loss of data for four subjects. Data were recorded for the remaining twenty subjects, but four of them had to be discarded due to excessively high error rates. A subject was considered to have an unacceptable error rate if he missed more than ten percent of the signals.

Median reaction time was recorded, and the means of these medians were used in a five way ANOVA. These reaction times are listed in Table 2. As can be seen in Table 2, there was no evidence that noise interacted with either expectancy, $F(1,15) < 1.0$, or with Location, $F(1,15) = 2.32$, $p = .15$. Neither were the Trials x Noise x Location, $F(1,15) = 3.28$, $p = .09$ nor the Trials x Noise x Expectancy, $F(1,15) < 1.0$, interactions significant.

Subjects' response times in the first trial were significantly slower than they were in the second trial, $F(1,15) = 15.44$, $p < .01$. They were able to detect a stimulus in a location in which they were expecting it to occur faster than in a location in which it was unexpected, $F(1,15) = 127.22$, $p < .0001$.

The effect of size, $F(1,15) = 70.91$, $p < .001$ was highly significant, with subjects responding to the smaller circle faster than the medium circle, which in turn was faster than the large circle. Location was also highly significant, $F(1,15) = 44.70$, $p < .001$, such that stimuli appearing in the center of the visual field was detected faster than peripheral stimuli. There was no significant effect main effect of noise, although subjects once again had a slight tendency to respond more slowly in loud noise.

There were many significant interactions: Expectancy x Size, $F(2,30) = 34.67$, $p < .001$, and Location x Size, $F(2,30) = 40.94$, $p < .001$, displayed similar patterns as the results of Experiment 1. Location x Expectancy, $F(1,15) = 21.87$, $p < .001$, indicated that expectancy has a larger effect in the periphery of the visual field than in the center. There was a six msec difference between expected and unexpected stimuli in the center of the field, but a 24 msec difference in the periphery. This larger effect of expectancy in the periphery is clearly seen in the medium and large circles but not seen in the small circle.

The Location x Expectancy x Size interaction was significant, $\underline{F}(2,30) = 11.61$, $\underline{p} < .001$.

Reaction times for the second trial were generally faster than the first, and the medium and large size circles benefitted more than did the small circle, $\underline{F}$ $(2,30) = 4.41$, $\underline{p} = .02$. Reaction time to the small circle was decreased by seven msec, and reaction times to the medium and large circles was sped up by 17 and 13 msec respectively.

The Trial x Expectancy interaction, $\underline{F}(1,15) = 6.03$, $\underline{p} = .03$, reflects the fact that expectancy has a stronger effect in the first trial than in the second. In the first trial, subjects responded 17.3 msec faster to expected stimuli than to unexpected stimuli; in the second trial, this difference was 13 msec. These results become clearer when examined in terms of the Trial x Location x Expectancy interaction, $\underline{F}(1,15) = 5.3$, $\underline{p} = .03$. It is the periphery that accounts for the larger effect in Trial 1 as compared to Trial 2. In Trial 2, the expectancy effect shrinks to 18.2 msec in the periphery, while there is a slight increase in the center to a 7.8 msec difference in reaction time to unexpected versus expected stimuli.

There were no other statistically significant effects. Noise did not contribute significantly to any interactions. The analysis of variance summary table is reported in Appendix 2.

General Discussion

Subjects were clearly able to adjust the way in which they attended to the visual display set before them. When they were expecting something in a particular location, they were able to respond to it faster than they could if they were not expecting it at that location. Therefore, the expectancies that were established by a subject determined the way in which he focused his attention.

The ability to use expectancy information was influenced by physical dimensions. The biggest effect of expectancy was evidenced in the condition in which subjects saw signals in the middle of the screen and at the corners of a large peripheral square. It would seem that the further the distance between the two types of signals, the easier it is to set up an expectancy difference between them. Subjects can still do this at very small distances (the 1^{o} angle of the small square), although it gets progressively easier as the distances between expected and unexpected signals increases.

Noise did not influence this size of the expectancy effect or the size of the location effect. These results do not provide support for either of the hypotheses that were forwarded earlier. Noise did not produce more efficient processing of stimuli at expected locations and it did not funnel attention to the center of the visual system. These findings are consistent with Forster and Grierson (1978) as well as with Loeb, Jones, and Cohen (note 1), and Cason (note 2). They are not consistent with Hockey (1970a, b, c) or the previous research on the effect of arousal on attention.

There are several possible reasons why noise did not affect performance on this selective attention task. In the case of Experiment 1, noise may not have had sufficient time to exert its maximum effect. This possibility was diminished by extending the experimental session to a full hour as opposed to the half hour previously used. Even with this extension, there was no effect of noise on performance.

The angles which the peripheral stimuli formed to the mid-center were smaller than those that were used in previous experiments. The largest angle used in this task was 13.26°, whereas the smallest angle used in the Bursill (1958) and Hockey (1970a,b,c) tasks was 20°. However, the distances used in the present experiment were sufficient to reveal large effects of spatial expectancies.

The nature of the task was considerably different from the task which Hockey used, and may have influenced the outcome. In Hockey's paradigm, subjects performed two tasks simultaneously, whereas subjects in this experiment performed only one task. This argument looses force when one considers that a direct replication of the Hockey paradigm using the original equipment found no effect of noise (Forster & Grierson, 1978). Even when the procedure was improved (Hartley, 1981), the results were still mixed.

It would appear that this phenomenon is not as robust as was once believed. If noise really does affect performance as hypothesized by Easterbrook, Hockey, and others, it should generalize to a variety of tasks. This did not happen in the Forster and Grierson (1978) experiments, nor in the experiments by Loeb et al. (note 1), nor in a dual task experiment performed by Cason (note 2), nor in the present study. Furthermore, in another replication of Hockey's original paradigm (Loeb et al., note 1) which used continuous loud noise of 105-110 dB., with impact sounds of 136 dB., no effect of noise on monitoring performance was found.

This recent evidence suggests that arousal may not induce the narrowing of attention that Easterbrook proposed. Two of the strongest lines of evidence for this effect had come from arousal induced by noise and arousal induced by amphetamines. The effect of noise on attention has become increasing questionable in recent years, and this study provided no evidence for any effect of noise on attention. The effect of amphetamine-induced arousal yielded consistent results according to the definitions of narrowed attention imposed by Callaway and his co-workers in the 1950's, but their concept of narrowed attention does not fit with later concepts of narrowed attention. A clear example can be seen in the Callaway and Dembo (1958) experiment, in which aroused subjects were less likely to use probability information that was provided to them over a series of trials than were unaroused subjects. According to the concept of narrowed attention proposed by Hockey and Cornsweet, aroused subjects would be more likely to make use of relevant cues. Clearly the research in these different areas is inconsistent regarding the concept of the narrowing of attention, and Callaway and Stone (1960) suggested that this line of research could be better explained using Broadbent's filter model.

Although Easterbrook's 1959 theory is intuitively appealing, it is time to re-examine the hypothesis that arousal serves to restrict the range of cues used in selective attention. One thing that must be done is to measure the effect of different types of arousal on the same task. To date, there has been little consistency among the tasks used, although variations of the original Bursill task have been used with heat, incentives, and noise. Unfortunately, the replications of the Bursill task that have used noise have provided inconsistent results.

One issue that must be addressed concerns the type of arousal produced by a specific arousal agent. Callaway (1959) presented a list of amphetamines which were known to induce a variety of physiological changes. In order to understand the effect of arousal on attention, it is necessary to know the type and location of the arousal. To date, little attention has been focused in this area.

In conclusion, this study has suggested that the effect of arousal is not as robust nor as widely generalizable as previously thought. Moreover, a sufficient number of "negative" results have been published to call the whole phenomenon into question. It it now not improbable that increasing arousal has no effect on the breadth of attention.

Reference Notes

1. Loeb, M., Jones, P. D. and Cohen, A. Effects of noise on non-auditory sensory functions and performance. (Report No. HSM-99-73-22) Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1976

2. Cason, J. Personal communication, 1981.

References

Bahrick, H. P., Fitts, P. M., and Rankin, R. E. Effect of incentives upon reactions to peripheral stimuli. Journal of Experimental Psychology, 1952, 44, 400-406.

Broadbent, D. E. Perception and communication. London: Pergamon Press, 1958.

Broadbent, D. E. Decision and stress. New York: Academic Press, 1971.

Broadbent, D. E. The current state of noise research: A reply to Poulton. Psychological Bulletin, 1978, 85 , 1052-1067.

Bursill, A.E. The restriction of peripheral vision during exposure to hot and humid conditions. Quarterly Journal of Experimental Psychology, 1958, 10, 113-129.

Callaway, E. The influence of amobarbitol (amylobarbitone) and methylamphetamine on the focus of attention. Journal of Mental Science, 1959, 105, 382-392.

Callaway, E., and Dembo, D. Narrowed attention: A psychological phenomenon that accompanies a certain physiological change. Archives of Neurology and Psychiatry, 1958, 79, 74-90.

Callaway, E., and Thompson, S.V. Sympathetic activity and perception: An approach to the relationship between autonomic activity and personality. Psychosomatic Medicine, 1953, 15, 443-455.

Callaway, E., and Stone, G. Re-evaluating the focus of attention. In L. Uhr and J. G. Miller (Eds.), Drugs and Behavior, New York: John Wiley, 1960.

Cherry, E. C. Some experiments on the recognition of speech, with one and with two ears. Journal of the Acoustical Society of America, 1953, 25, 975-979.

Cornsweet, D. J. Use of cues in the visual periphery under conditions of arousal. Journal of Experimental Psychology, 1969, 80, 14-18.

Deutsch, J. A., and Deutsch, D. Attention: Some theoretical considerations. Psychological Review, 1959, 6, 183-201.

Easterbrook, J. A. The effect of emotion on cue utilization and the organization of behavior. Psychological Review, 1959, 66, 183-201.

Egeth, H. Attention and preattention. In G. H. Bower (Ed.), The psychology of learning and motivation (Vol. 11). New York: Academic Press, 1977.

Forster, P. M., and Grierson, A. T. Noise and attentional selectivity: A reproducible phenomenon? British Journal of Psychology, 1978, 69, 489-498.

Gray, J. A., and Wedderburn, A. A. I. Grouping strategies with simultaneous stimuli. Quarterly Journal of Experimental Psychology, 1960, 12, 180-184.

Hartley, L. R., and Carpenter, A. Comparison of performance with headphone and free-field noise. Journal of Experimental Psychology, 1974, 103, 377-380.

Hartley, L. R., Noise, attentional selectivity, serial reactions, and the need for experimental power. British Journal of Psychology, 1981, 72, 101-107.

Hockey, G. R. J. Effect of loud noise on attentional selectivity. Quarterly Journal of Experimental Psychology, 1970a, 22, 28-36.

Hockey, G. R. J. Signal probability and spatial location as possible bases for increased selectivity in noise. Quarterly Journal of Experimental Psychology, 1970b, 22, 37-42.

Hockey, G. R. J. Changes in attention allocation in a multicomponent task under loss of sleep. British Journal of Psychology, 1970c, 61, 473-480.

Hockey, G. R. J. Attentional selectivity and the problems of replication: A reply to Forster and Grierson. British Journal of Psychology,. 1978, 69, 499-503.

James, W. The principles of psychology. New York: Dover, 1950. (Originally published in 1890.)

Kahneman, D. Attention and effort, Englewood Cliffs, N. J.: Prentice Hall, 1973.

Lane, D. M. and Pearson, D. A. Attending to spatial locations: A developmental study. Child Development , in press.

Moray, N. Attention in dichotic listening: Affective cues and the influence of instruction. Quarterly Journal of Experimental Psychology, 1959, 11, 56-60.

Moray, N. Where is capacity limited? A survey and a model. Acta Psychologica, 1967, 27, 84-92.

Norman, D. A. Memory while shadowing. Quarterly Journal of Experimental Psychology,1969, 21, 84-92.

Poulton, E. C. Continuous intense noise masks auditory feedback and inner speech. Psychological Bulletin, 1977, 84, 977-1001.

Poulton, E. C. Masking, beneficial arousal and adaptation level: A reply to Hartley. British Journal of Psychology, 1981, 72, 109-116.

Posner, M., Snyder, C., and Davidson, B. Attention and the detection of signals. Journal of Experimental Psychology: General, 1980, 109, 160-174.

Treisman, A. M. Verbal cues, language, and meaning in selective attention. American Journal of Psychology, 1964, 77, 215-216.

Yerkes, R. M., and Dodson, J. D. The relations of strength of stimulus to rapidity of habit-formation. Journal of Comparative Neurology of Psychology, 1908, 18, 459-482.

Appendix 1

Analysis of Variance Summary Table

Experiment 1

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F-Ratio	Probability Level
Subjects	16	411222.66	25701.41		
Noise	1	8461.18	8461.18	1.31	0.269
Error	16	103294.73	6455.92		
Location	1	23950.67	23950.67	25.63	0.00
Error	16	14952.57	934.53		
NL	1	241.65	241.65	0.75	0.39
Error	16	5108.42	319.27		
Expectancy	1	58225.18	58225.18	106.02	0.0
Error	16	8786.89	549.18		
NE	1	404.00	404.00	1.06	0.32
Error	16	6123.57	382.72		
LE	1	1737.65	1737.65	1.05	0.32
Error	16	26430.25	1651.89		
NLE	1	3732.24	3732.24	2.82	0.11
Error	16	21148.17	1321.76		
Size	2	56538.72	28269.36	29.34	0.0
Error	32	30829.69	963.42		
NS	2	1145.54	572.77	0.86	0.43
Error	32	21266.53	664.57		
LS	2	13962.76	6981.38	30.44	0.0
Error	32	7338.48	229.32		
NLS	2	107.07	53.53	0.16	0.84
Error	32	10111.83	315.99		
ES	2	14219.60	7109.80	25.44	0.0
Error	32	8943.80	279.49		

Analysis of Variance Summary Table

Experiment 1 (cont)

NES	2	528.01	264.009	0.98	0.38
Error	32	8552.39	267.26		
LES	2	12009.49	6004.74	2.82	0.07
Error	32	68099.09	2128.09		
NLES	2	1598.25	799.12	1.18	0.31
Error	32	21589.32	674.66		

Appendix 2

Analysis of Variance Summary Table

Experiment 2

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F-Ratio	Tail Probability
Mean	1	63270298.47	63270298.47	1249.03	0.00
Error	15	759834.75	50655.65		
Trial	1	29812.79	29812.79	15.44	0.00
Error	15	28964.26	1930.95		
Noise	1	6469.32	6469.32	0.67	0.42
Error	15	145403.15	9693.54		
TN	1	467.18	467.18	0.21	0.65
Error	15	34164.62	2277.64		
Location	1	48689.09	48689.09	44.70	0.00
Error	15	16339.71	1089.31		
TL	1	211.47	211.47	0.89	0.35
Error	15	3546.84	236.45		
NL	1	636.19	636.19	2.32	0.15
Error	15	4114.36	274.29		
TNL	1	381.09	381.09	3.28	0.09
Error	15	1743.46	116.23		
Expectancy	1	44210.84	44210.84	127.22	0.00
Error	15	5212.55	347.50		
TE	1	894.84	894.84	6.03	0.02
Error	15	2225.21	148.34		
NE	1	11.26	11.26	0.05	0.82
Error	15	3350.38	223.35		
TNE	1	111.78	111.78	0.86	0.36
Error	15	1949.36	129.95		
LE	1	14656.28	14656.28	21.87	0.00
Error	15	10051.19	670.07		

Analysis of Variance Summary Table

Experiment 2 (cont)

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F-Ratio	Tail Probability
TLE	1	2355.50	2355.50	5.30	0.03
Error	15	6664.97	444.33		
NLE	1	53.65	53.65	0.05	0.82
Error	15	16663.57	1110.90		
TNLE	1	175.37	175.37	0.25	0.62
Error	15	10516.01	701.06		
Size	2	95829.07	47914.53	70.91	0.00
Error	30	20271.01	675.70		
TS	2	4234.34	2117.17	4.41	0.02
Error	30	14396.65	479.88		
NS	2	2559.37	1279.68	3.19	0.05
Error	30	12027.45	400.91		
TNS	2	1530.76	765.38	1.11	0.34
Error	30	20694.48	689.81		
LS	2	33559.38	16779.69	40.94	0.00
Error	30	12295.36	409.84		
TLS	2	1015.63	507.81	2.80	0.07
Error	30	5437.86	181.26		
NLS	2	521.37	260.68	1.23	0.30
Error	30	6349.62	211.65		
TNLS	2	595.38	297.69	1.46	0.24
Error	30	6112.86	203.76		
ES	2	17118.19	8559.09	34.67	0.00
Error	30	7405.46	246.84		
TES	2	367.79	183.89	0.90	0.41
Error	30	6109.95	203.66		

Analysis of Variance Summary Table

Experiment 2 (cont)

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F-Ratio	Tail Probability
NES	2	234.65	117.32	0.99	0.38
Error	30	3560.76	118.69		
TNES	2	554.82	277.41	2.29	0.11
Error	30	3635.84	121.19		
LES	2	7795.13	3897.56	11.61	0.00
Error	30	10071.69	335.72		
TLES	2	222.16	111.08	0.21	0.81
Error	30	15779.91	525.99		
NLES	2	3616.07	1808.03	2.85	0.07
Error	30	19058.01	635.26		
TNLES	2	624.07	312.03	0.39	0.67
Error	30	23760.09	792.00		