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THE ROLE OF TEMPORAL UNCERTAINTY IN THE DEPLOYMENT OF ATTENTION TO EXTERNAL SIGNALS OR STIMULUS-INDEPENDENT THOUGHT AND FANTASY

by

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CHAPTER I

EXPERIMENT I - INTRODUCTION AND HISTORY

Task-Irrelevant Cognitive Activity

We have all had the experience of being engaged in some activity which requires close attention to the environment and yet found ourselves being distracted by intrusive thoughts, memories and fantasies. In situations of great stress or preoccupation with a personal problem, we may find it virtually impossible to focus our attention on the immediate milieu and find ourselves stumbling into objects or ignoring others who are speaking to us. Such dramatic "states of distraction" are relatively rare in most normal individuals but a milder form of these phenomena appears to be virtually omnipresent. It is only for very brief moments that we concentrate *all* our attention on the outside world for there is a steady stream of material from within which seems to demand and obtain a certain place in our awareness. This "stream" of material has been the subject of literary exploration in the "stream of consciousness" style of James Joyce and the basis of technique in clinical psychoanalysis. Only recently, however, has this tendency for man to monitor continuously the material from his own memory been the subject of psychological experimentation.

This paper will attempt to evaluate the body of research in this area and propose a model which accounts for the observed phenomena in terms of attentional scanning. The perspective is one in which spontaneous cognitive activity and fantasy are considered competitive with sensory stimuli for some central processor. The research itself is directed towards understanding the way in which the scanning mechanism associated with attentional processing can simultaneously operate on multiple inputs.

A series of studies by Antrobus and Singer (1964, 1966a, 1966b) over the last few years have studied how strong man's tendency is to process material from long-term memory, what conditions enhanced or suppressed his report of such material, and what consequences this activity had for perception and behavior. They found (1966a) that even in perceptual tasks characterized by a high rate of signal presentation and difficult short-term processing, reported fantasy and other task-irrelevant mentation persisted at a high level. While statistically significant reductions in reported task-irrelevant thought could be brought about through various task manipulations, these reductions were either short-lived or relatively minute. In one study (Antrobus and Singer, 1966a) signal rates of one per .6 sec. requiring a simple binary discrimination (high vs. low pitch tones) and a comparison with the previous signal produced only a small decrease in reported fantasy while the subject continued to perform at something above a 90% accuracy rate in his detections. Other studies demonstrated that conditions which aroused some area of interest or conflict for the subject were shown to increase significantly the rate of reported "task-irrelevant cognitive activity" (TICA) (Singer, Antrobus, and Greenberg, 1966b).

These studies also began to reveal some relationship between the rate of reported TICA and signal detection performance. When task difficulty was increased most S's would suppress TICA, to some degree, in favor of the task and maintain performance at a high level. In the situations which enhanced the production and/or report of TICA, there was a significant decrement in performance. While this reciprocal relationship made itself evident to a statistically significant extent, the actual changes in level of both report and detection variables were small. It appeared that the press of stimuli from long term memory was persistent and demanding and that the processing of this material bore some close relationship to sensory processing from external sources of signals.

Some Proposed Theoretical Models

The existence of some degree of reciprocity between the processing of material from these two sources of signals (memory and perception) suggested an operation or structure having limited capacity to handle simultaneously information from multiple sources.

Models to account for such phenomena have been developed in the past primarily to deal with the processing of material from external sensory sources but they seemed equally applicable to this area.

The model proposed in the Singer-Antrobus studies is one based on computer operation and information processing. The authors (Antrobus and Singer, 1966) propose a "cognitive operator" which has an upper limit to the rate at which it can process information from memory (internal) and sensory (external) sources. These sources occupy channel space in the operator and as the limit of this space is approached (capacity) "the operator will selectively favor one source over the other according to some priority system." By experimentally demanding priority for the external channel and then manipulating the stimulus rate of that channel, the authors observed systematic variation in the rate of operation on the other channel (stored events). These results were seen as compatible with the notion of a central operator having limited processing capacity. The manner in which such a mechanism might operate to produce such phenomena, however, was still an unanswered question. Several possible models were available which seemed applicable.

Broadbent (1958) has developed a model to account for multichannel operation between different sensory modalities. He postulates a filter which selects a channel based on several principles (e.g. novelty, intensity). He implies that only one channel is responded to at a time but that rapid shifts occur between channels.

Broadbent, in formulating his model, addressed himself to technique whereby a system having a limited capacity for processing information could select between several external sources of signals competing for limited space. Limited capacity is the basis for postulating a selecting mechanism - the "filter." The other important point that Broadbent makes is that such a filter must be centrally located. He supports this with evidence from inter and intra-sensory studies in which two channels are placed in competition for this limited response capacity. In these experiments [Poulton (1953), and Cherry (1953) and Broadbent (1952)] the channel selection is all based on verbal, symbolic or coded qualities of the stimulus array-factors which are clearly not available for purely sensory discrimination. The central locus of the filter is critical for arguing its applicability to a channel such as memory storage.

In considering the phenomenology and research on daydreaming, we are struck with the fact that in most instances <u>both</u> channels are seemingly processed continuously. The subject does both things at once, responding to a perceptual task yet monitoring ongoing fantasy.

However, the data also indicates evidence of limited capacity to do both things at once. This is in keeping with the purely sensory data cited by Broadbent (1958) throughout his book. For Broadbent, the basis for this limit is the system's inability "to handle more than a critical amount of information at a given time" (p.34).

A different basis for limited capacity to process information from several sources has been developed by Kristofferson (1965a, 1966a, 1966b, 1967). He sees the functioning of the switching mechanism as determining the limits of capacity, not on the basis of quantity of information handled, but on the basis of the rapidity and flexibility of the switching itself. The model, per se, is almost identical to Broadbent's but utilizes the analogy of a single pole, multi-position electrical switch.

> "Attention is thought of as a selective control of information flow in the central nervous system. This selective control or gating of information is accomplished within the central nervous system by a central neural mechanism. This mechanism has the logical properties of a many-poled highly-flexible switch which funnels messages into a single processing channel." (Kristofferson, 1965, p. 1)

Kristofferson's research is oriented to studying the actual values of switching time between channels (different senses in his case) and minimum durations for the time "the switch" can spend in one such channel. The actual time values (50-60 msec.) are less critical to the argument here than the concept of a switching delay and the finding that such delay is relevant when "a higher order of information (e.g. decoding vs. simple detection) must be processed (1965, p. 127)." This approach opens the way to a more detailed examination of the mechanism that allows for (as well as limits) the extent to which two channels can be simultaneously monitored.

The behavior and limitations of a switching mechanism in selective attention has been the focus of research on reaction time delays in situations where responses to multiple or consecutive stimuli are called for. This delay has been termed the "psychological refractory period" (PRP) and has been seen as due to various dimensions of the processing and response apparatus. Its relevance to the present problem is that there are many parallels between the concurrent monitoring of many channels and the rapid monitoring of several sequential events. Both situations demonstrate the characteristics and limitations of some central attentional switching mechanism.

Poulton (1950), Adams (1962) and others have argued that delays in RT to the second of two consecutive stimuli are due to particular preparation strategies developed to maximize efficiency in the face of uncertainty. While Davis (1965, 1967) and Bertelson (1967) have taken issue with this "expectancy theory" on the grounds that the refractory periods are longer than the time uncertainty involved, both authors have found evidence that when processing two signals sequentially "it is still useful to know when the second is coming" (Betelson, 1967, p. 56) and that, even without overt response to the first, there is still noticeable delay in RT to the second (Davis, 1959). Davis concludes that this effect is "due mainly to direction of attention to the first signal" (1967, p. 58) and implies that attention "sticks" to the first signal, that it takes some time to pry it loose and that until it is freed up it is unavailable for another job. (This can be seen as quite similar to Kristofferson's quantum approach.)

Moray (1967), in a review paper on models of limited attentional capacity, has introduced an important distinction between <u>carrying</u>

capacity and operating capacity. He offers for a model of a "human operator which envisages not a limited capacity channel in the sense of a transmission line, but a limited capacity central processor whose organization can be flexibly altered by internal self-programming" (p. 85). For Moray, a central processor is not a passive carrier of information but "receives, transforms and generates messages" and the extent to which it must perform such operations would determine its capacity. He argues that "the functions performed on the message themselves take up the capacity of the system" (p. 87). Posner (1966) has developed a similar notion that the "transformations" required between input and output are a critical factor in processing capacity. Such an approach is considerably different from a simple channel load-limit in that the type of operation and the organization (or disorganization) of signals is important to the outcome.

Self-Pacing and Uncertainty in the Development of Attention

If these findings are applicable to the simultaneous processing of material from perceptual and memory sources they suggest that the technique whereby a subject can apparently do both things at once is some sort of self-pacing of the switching itself. By self-pacing is meant some method whereby the switching of a central operator between several possible channels of input could be related, by the subject, to some characteristics of the situation in which he finds himself. Individuals may allot a certain portion of their attention to different aspects of a given environment, dependent on their own needs and interests; on the basis of externally imposed priorities; on the quality and quantity of external stimuli or on some mixture of these. Regardless of the basis for choice, however, the technique for accomplishing this self-pacing must, in part, be based on some ongoing assessment of the environment which would enable the individual to pace himself effectively. One dimension of such an assessment would necessarily involve the predictability of external events, for only with a degree of predictability could the individual project some pattern of self-pacing into the immediate future.

In many situations we operate by making brief anticipations of just how much attention we will have to devote to internal and external material. While driving a familiar route, for example, we merely sample the road conditions and can devote the bulk of our attention to thinking about the problems or situations we expect to encounter at our destination. If riding a subway to work and reading we will just glance up from time to time to see how far we are from our station. The attention devoted to each component of the environment will follow some temporal pattern appropriate to the situation. In terms of the model, we formulate brief programs which embody priorities of need, value or interest in allotting limited channel space to the universe of possible sources of information. The forms of these programs in terms of motivation and individual needs would necessarily be complex and will not be explored in detail here. These programs, however, must be based on some anticipations about the immediate future. By extrapolating the "here and now" state of affairs in our environment we can extend our functioning, on a provisional basis, into the next moment. The continuity of situations (i.e. the absence of change) helps consolidate these brief programs into plans or strategies (see Miller, Galanter, and Pribram, 1960) which we can utilize in a fairly automatic way and thereby increase the effectiveness of our functioning.

If these anticipatory programs for the deployment of limited response capacity are in fact being created from moment to moment, it would follow that discontinuities in the state of the environment would have a disruptive effect. An unfamiliar or irregular environment would impede our ability to formulate and run-off well established sequences by reducing predictability about the next moment. The effect of such decreases in predictability on self-pacing of response would necessitate new programs.

Moray (1966) has noted that applying Miller, Galanter, and Pribram's (1960) model to his concept of limited processing capacity would be one way of accounting for changes in limit. "Different Plans require different amounts of processor space, leaving different amounts to be used as transmission line, i.e., The Plan, its execution and storage and transmission, all compete for the available (central) capacity" (Miller, Galanter & Pribram, 1960, p. 88). In other words, the formulation of Plans as well as transmissions expend limited capacity.

Using George Miller's conception (1956), under conditions of uncertainty in signal input, we would not be able to organize our world into "chunks" but instead would have to deal with it "bit by bit." This would mean a considerable loss of capacity to process new information. If we maintain that signal predictability is important for developing the processing strategy component of Plans we can make the prediction that the introduction of irregularity in the rate of presentation of signals would make processing more difficult since switching could not be so easily synchronized with the expected occurrence of signals. The net effect of this would be a reduction in the efficiency of the system and would be reflected in a decrease in the capacity to process two channels at the same time.

Hypotheses

If we now apply this model to the Antrobus-Singer experiments in which data are obtained not only about external signal processing but the processing of material from memory (fantasy and task-irrelevant cognitive activity) we can make some specific predictions about the impact of uncertainty. When the priority for processing external signals is high and tones are presented at irregular rates, the frequency of reports of fantasy should be drastically reduced compared with conditions of regular signal presentation rates. If, however, the S does not reduce his priorities for processing his own "fantasy" material during conditions when the signal presentation rates are irregular his accuracy of detections should suffer.

METHOD - EXPERIMENT I

General Design

Subjects were required to respond to a simple auditory discrimination task which periodically changed from a series of regularly spaced tones (Reg.) to irregular tones (Irreg.). At the end of brief trials of tones, Ss were required to make retrospective scaled judgments of the quantity of intrusive task irrelevant cognitive activity (TICA) which occurred in that trial. Each S served as his own control and received five periods of each type of tone (Reg. and Irreg.). Tone regularity was the independent variable having two conditions and reported TICA was the dependent variable. Thus, the experimental design was a 20 x 2 x 5 Analysis of Variance - Subjects x Conditions x Replications.

Subjects

Twenty subjects were recruited from elementary psychology sections at City College on the basis of availability for testing at given hours. Ss ranged from seventeen to twenty-two years of age and were of both sexes. Each was paid two dollars an hour for his participation.

Procedure

a. Environment: Ss were seated comfortably in a light-proof and sound-proof test chamber for the duration of the experiment. Prior to entering, they were told that the experiment involved auditory discrimination and that the procedure would take about one hour. An intercom permitted subject and experimenter to communicate throughout the experiment. The subject wore headphones and had a microphone on the table before him. This table also included three telegraph keys on a movable wooden base which served as the response manipulandum for tones (one key) and TICA (a pair of keys).

b. Stimuli: Two pure tones were used differing only in frequency (High-1000 cps, Low-400 cps) and matched for loudness. They were presented for .125 milliseconds over a continuous white noise background. High and low tones were randomized, the probability of the occurrence of either being $p=.50$. In the Reg. condition, tones were evenly spaced at 1.0 second apart. In the Irreg. condition, the tones could occur at any one of four time intervals; .5 second, .8 second, 1.0 second, 1.7 seconds. The four inter-stimulus intervals were continuously randomized during the Irreg. condition and yield a mean ISI of 1.0 seconds. Thus, the over-all mean rate of tone presentation is equal in the Reg. and Irreg. conditions.

c. Pre-testing and Instructions: Once in the test cubicle, Ss were instructed to listen to a sample of the tones and, when they could discriminate the two different tones, to start pressing the telegraph key on the left every time they heard a low tone. They were informed that there was no order or pattern to the tones and that there would be about as many Highs as Lows. All Ss easily made the discrimination and were allowed to practice for five minutes during which they reached a criterion performance level of at least 95% accuracy.

Following this five minute period of uninterrupted tone monitoring, the signals were stopped, the experimenter entered the test cubicle, and the following instructions were given:

> "You may have noticed in the session you have just finished that sometimes you would find yourself concentrating fully on the tones and at other times find your mind wandering to things other than the task."

Most Ss readily acknowledge this and many spontaneously gave example of the type of outside thoughts they had had. The instructions then continued:

> "Now many subjects report this experience and it is one of the things we are interested in. Your main job, in this experiment, will still be to press the left key for every low tone but, from now on, these tones will come in brief trials - about twenty seconds long. At the end of each trial, the tones will stop and then I want you to think back and make a judgment about just how much outside thought, daydreams and memories, you had in that trial. In a moment I'll teach you a simple code for reporting how much outside thought you had, but for now I'd like to clarify what outside thought is. Anything you think of which does not have to do with the tones or your response to them is outside thought."

Typically, the subjects own outside thoughts from the warm-up period served as a good sample of TICA and usually required little augmentation to establish the concept. This would include thoughts of schoolwork, friends, dates, memories, plans, the purpose of the experiment, the equipment being used, hunger, fantasies and visual images. The concept was tested against a list of ten items, some of which would not be (by definition) outside thoughts - e.g., "the tones have a strange pattern or rhythm," or, "I just missed some tones." The instructions continued as follows:

> "At the end of each trial of tones, I want you to make a judgment of how much outside thought occurred in that trial, and to use presses on the other keys to report that judgment. The left hand key is for low amounts of outside thought (less than 50%), the right for high amounts (more than 50%). Two presses on the left key means very little outside thought - less than 25% of the trial; one press means between 25-50%; one press on the right key means 50-75%; two presses means over 75% or a great deal of outside thought."

The subject was shown a card with the scale placed before the appropriate keys:

KEYS	L		R	
	Low		High	
Presses	2	1	1	2
Quantity of outside thought	0-25%	25-50%	50-75%	75-100%

A few trials with the scale were then tried and the use of the ratings spot checked with the subjects intended reponse given verbally. Ss reported no difficulty with either the outside thought concept or scaling technique. Subsequently for ease of scoring this scale was considered as ranging from 1 to 4 with 1 representing the Low Fantasy limit (25% or less) and 4 the High Fantasy limit (75% or more).

Subjects were finally instructed:

> "From now on, your job will be to press for every low tone and, when the tones stop, to make a judgment of the quality of outside thought in that trial. There will be many trials and they will differ in length. Don't try to anticipate the end of a trial and don't worry about

> the rating till the tones stop. Then make your judgment. The next trial won't begin till after you make the judgments. Remember, the object of this experiment is to see how these phenomena operate naturally, so try to report accurately what happens.

d. Design: Five experimental periods, each consisting of a block of five Irreg. trials, was programmed for each S. Between these Irreg. blocks were between 15 and 25 Reg. trials which served as controls. This quantity varied so that the introduction of Irreg. tones would have no periodicity. A judgment of TICA was obtained for each trial yielding 25 Irreg. and 100 Reg. scores per S.

Schematically, these were programmed as follows for each S:

Period	1		2		3		4		5		
Condition	R	I	R	I	R	I	R	I	R	I	R
# Trials	25	5	20	5	15	5	20	5	15	5	5

Five trial durations were used to prevent anticipation of the end of the trial by S. These were 10, 15, 20, 25, 30 seconds and were randomized, the average trial duration being 20 seconds. The total session took about forty-five minutes, after instructions.

e. Apparatus: Audio oscillators were used to produce pure sine wave tones which were then timed and randomized by a digital logic program. These tones were presented to S over a constant white noise background fed through stereo headphones. Trial durations were preprogrammed on a punch-tape as were the inter-trial intervals, which were under the S's response control. The program functioned automatically within each trial, but a new trial could not begin until S had made his judgment of outside thought for the previous trial.

The responses were made on the triple telegraph keyboard, described above, and were recorded along with all stimuli on a five channel Esterline-Augus polygraph. This provided a complete record of all stimuli and responses in their exact time relationship, as well as the associated report (score 1-4) of outside thought.

RESULTS OF EXPERIMENT I

The main effect of time uncertainty upon fantasy is a marked suppression from the levels in the Regular condition. Table 1 shows this effect for the five experimental periods and total.

TABLE 1

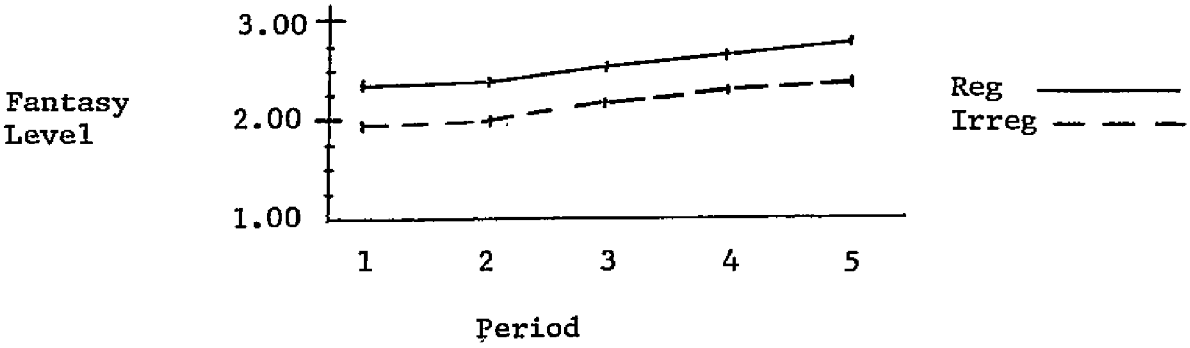
MEAN FANTASY LEVEL FOR TIME PERIODS IN REGULAR AND IRREGULAR TONE CONDITIONS (Fantasy scale 1.00-4.00, N = 20)

Period	1	2	3	4	5	$\overline{X}$
Regular	2.36	2.43	2.54	2.60	2.82	2.57
Irregular	1.94	2.00	2.15	2.34	2.35	2.19
% Diff. R-I/R	17.7	17.7	15.4	10.0	16.7	15.5

The same data represented graphically in Figure I show a clear upward trend in both conditions indicating that the level of fantasy appeared to rise over time in the experimental situation regardless of specific condition.

FIGURE 1

FANTASY LEVEL BY PERIOD AND CONDITION



Analysis of variance (Table 2) shows the main effect of Regular/Irregular tones upon fantasy levels to be significant at the $p < .005$; the effect of periods (the upward trend of fantasy) significant at the $p < .005$ and the interaction non-significant. This latter measure indicates that whatever was reponsible for the growth of fantasy over time did not differentially interact with the main experimental variable of Tone Condition. In addition, it indicates that suppression occurred to an approximately equal degree at different levels of fantasy.

TABLE 2

ANALYSIS OF VARIANCE: FANTASY LEVEL X PERIOD X CONDITION (N=20)

Source of Variance	SS	df	MS	F
Conditions (C)	7.73	1	7.73	12.88 **
Periods (P)	5.08	4	1.27	5.29 **
Subjects (S)	49.17	19		
P x C	.22	4	.06	.66 n.s.
S x P	18.32	76	.24	
S x C	11.41	19	.60	
P x C x S	6.49	76	.09	
Total	98.42	199		

** $p < .005$

While these data confirm the main hypothesis of suppression of fantasy by Irregular tones, they do not reflect the variation between subjects that occurred nor permit a test of the nature of individual differences in response to the two conditions. The overall suppression averaged 15.5% but this represents a range which runs from -80% (suppression) to +45% (increase) in fantasy within the Irregular periods (see Appendix of Ss individual results).

Based on the limited attentional capacity model and the greater processing required of Irregular tones, we predicted that those subjects who did not suppress fantasy in the Irregular condition would make more tone detection errors in that condition. A chi-square based on a median split of the extent of fantasy suppression in each S indicates that those subjects showing greatest suppression in the Irregular condition did in fact keep their tone errors down in the Irregular condition (Table 3). See Appendix A for individual data.

TABLE 3

X^2 OF FANTASY SUPPRESSION BY TONE PERFORMANCE (N=20)

	Tone Errors		
	$I \leq R$	$I > R$	N
High Suppression	8	2	10
Low Suppression	2	8	10

$X^2 = 5.00$ (corrected for continuity)

$p < .05$

A more complete view of this relationship can be obtained if we ignore the frequency of tone errors per se and merely look at the difference between those <u>trials</u> containing tone errors and those which are error-free. Again, the prediction is that fantasy suppression in the irregular trials will be associated with better tone performance. An analysis of those subjects who made tone errors in both conditions (2 did not) also enables us to see the reciprocal relation between tone performance and fantasy postulated in the model (Fig. 2). Two Ss, B1 and B6, made no errors in either condition and are therefore omitted from the following analysis.

FIGURE 2

FANTASY LEVEL BY CONDITION FOR
TRIALS WITH AND WITHOUT TONE ERRORS (N=18) [1]

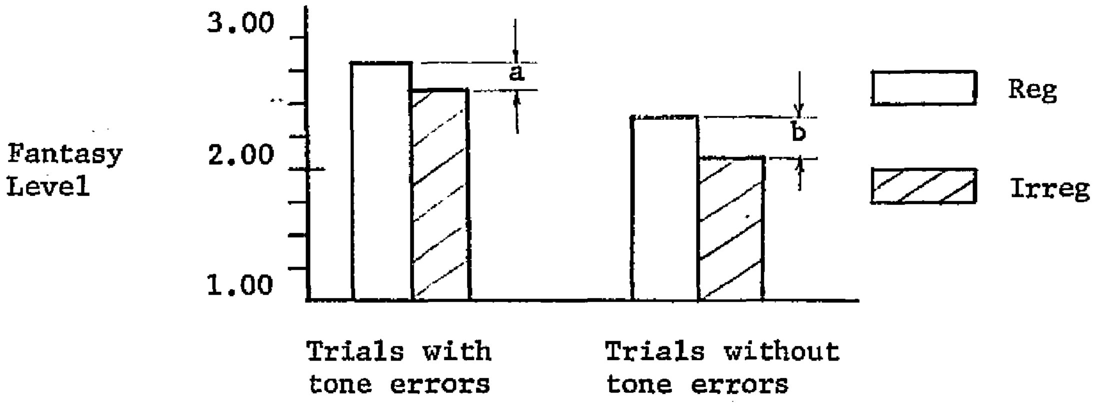


Figure II illustrates that fantasy levels are lower, regardless of condition, in trials which have no tone errors, and that the irregular condition is associated with greater fantasy suppression when tone detection perfórmance is maintained at a perfect error-free level (b > a). The Analysis of Variance in Table 4 tests this conclusion.

[1] " n " of trials :

	With Errors	Without Errors
Reg	290	2008
Irreg	102	500

TABLE 4

ANALYSIS OF VARIANCE: FANTASY LEVELS FOR TONE-ERROR AND NO TONE-ERROR TRIALS X CONDITION X SUBJECT (N=18)

Source of Variance	SS	df	MS	F
Tone errors (E)	5.16	1	5.16	20.24**
Conditions (C)	.94	1		
Subjects (S)	24.89	17		
C x E	.34	1	.34	5.61*
S x C	4.55	17		
S x E	4.33	17	.255	
S x C x E	1.03	17	.06	
Total	41.24	71		

**Tone error main effect: $p < .001$, 1 / 17 df
*Conditions / Error interaction: $p < .05$, 1 / 17 df

Low fantasy levels are associated with error-free tone performance in either condition. This finding supports the general limit concept and the reciprocity of attention to these two sources of information. However, it is the significant interaction of Reg/Irreg Conditions and Error Rate that is the real test of the hypothesis that uncertainty reduces functional processing capacity. This interaction suggests that the experimental introduction of uncertainty sharply reduces the capacity to operate <u>effectively</u> on both/sources of stimulation simultaneously.

Results Summary

Experiment I indicates that the predictability of one channel of information (external) is important to the maintenance of processing capacity at a level sufficient to simultaneously monitor another channel (LTM). The suggestion was made that the formulation of processing strategies or Plans enabled effective simultaneous processing and that such Plans were dependent on stimulus predictability for their structure. The introduction of temporal uncertainty necessitates the formulation of new Plans which are somewhat less effective due to inability to synchronize scanning with irregular input. Furthermore, there is a suggestion that the formulation of processing strategies themselves may draw on the same limited capacity available for actually transmitting and processing the target stimuli both internal and external. When a more complex pattern must be dealt with, necessitating a more elaborate or less efficient scanning strategy, there is a reduction of the ability to simultaneously process both tones and fantasy and some attentional choice must be made.

CHAPTER II

INTRODUCTION - EXPERIMENT II

In Experiment I, it was clear that attention was often withdrawn from processing LTM signals in order to maintain processing of the tones. So far we have held that priorities and available processing space merely shifted between these two possible targets. By minimizing the number and type of other external stimuli in the experimental environment (via the dark room and white noise), distracting events were theoretically restricted to cognitive activity, imagery, etc. - i.e., internally generated signals. However, it is rarely the case in real life environments that such a restriction is possible. In most tasks requiring focal attention to some external signal source there are other external signals competing for limited capacity, and it is of interest and theoretical significance to know what becomes of responsiveness to such signals. Furthermore, the presence of "incidental" or "irrelevant" stimuli has been shown to have important effects on an observor's capacity to process signals - especially in vigilance type tasks (McGrath, 1963). Instead of conceptualizing incidental stimuli as distracting or competing for limited capacity, some investigators have maintained that these extraneous events actually facilitate detection because they mitigate the effects of monotony and have the effect of <u>arousing</u> the observer. Hebb (1958) has asserted "the normal variety of sensory stimulation has the function of maintaining <u>arousal</u>: the alertness, responsiveness or 'vigilance' of the waking subject. When the stimulation is made drastically monotonous, mental function is significantly affected." With some qualifications this has held up experimentally in signal detection research with external incidental stimuli serving as the activator (McGrath, 1963).

In a good deal of this research stimulus novelty and unpredictability have been found to be the most effective arousing agents and this relates to some phenomena observed in Experiment I.

In Experiment I the introduction of temporal uncertainty in the tones had a noticeable effect upon most subjects. Ss reported that when the tones became irregular "it would be like someone shaking them awake; would snap them back to the task; would get them 'with it'". Besides this re-orienting effect, many subjects found the irregular tones "more interesting; more fun; and more challenging". Many spontaneously commented that they "were <u>easier</u> because your attention doesn't drift away so easily". Most subjects experienced dramatic changes in their alertness in the experimental trials and related these to changes in their ability to monitor the tones and to suppress attention to fantasy material.

These effects may be interpreted as reflecting a change in the arousal level of Ss apparently associated with the introduction of the Irregular tone condition.

As noted above arousal has been shown to have important effects on attentional functioning and its implication in Experiment I calls for additional research to clarify whether this factor was causally related to the findings or merely a correlated phenomenon. The second section of this paper is aimed at developing a theoretical model to specify the arousal phenomenon and relate it to and distinguish it from the scanning model proposed above.

Arousal and Uncertainty

Many theorists have argued that novelty and change are the basic parameters of environmental stimulation which affect activation level and arousal. Via the more complex variables of curiosity and exploratory drive, White (1959) and Berlyne (1960) have constructed theories in which novelty plays a major role. For White, novelty was to take an equal place with pain and pleasure as a motivator, while Berlyne saw it as the stimulus for curiosity and exploratory behavior. Hebb (1949) had earlier focused on the disruptive aspect of particular types of novelty in states of rage and fear in chimpanzees but the emotional arousal was clearly evident.

With the introduction of physiological data on the mid-brain structures involved in general arousal (Moruzzi and Magoun, 1949, Magoun 1954, Lindsley, 1951) there was a sharp increase in concern about the effects of the stimulating environment on arousal and the effects of arousal on responsiveness to that environment. The most primary relation of novelty to arousal was noted in the early work on EEG alpha rhythm (see Lindsley, 1951) in which it became clear that environmental change (i.e. novelty) led to important changes in the cortical state of the resting organism. These changes (described as arousal) were recognized as "organizing, mobilizing processes (Leeper, 1948) instead of "emotional disturbances" or disruptions (Hebb's view in the Organization of Behavior (1949), prior to Moruzzi and Magoun's work). Once the physiological findings on the reticular activating system were known, however, Hebb (1955) acknowledged the importance of cortical arousal for perception to occur at all. A natural extension of this line of reasoning was attempting to relate level of arousal to a continuum of perceptual reactivity. Thus arousal came to occupy an important place in research on perception and attention.

Lindsley (1957) and his co-workers began systematically to study correlations between arousal and environmental responsiveness and proposed that generalized arousal aids discrimination, facilitates response and decreases reaction time (Lindsley, 1956 ; Fuster 1961). Many of these findings may be easily interpreted as alternations in attentional level and/or deployment.

The work which most clearly integrates the relation of novelty to physiological response patterns and attention is that on the Orienting Response (OR). Sokolov (1960, 1963) has demonstrated that important changes in the reactions of sensory systems and the higher integrating centers occur when novelty is introduced. These changes may be seen as arousal insofar as asynchronous fast cortical activity typifies them but Sokolov's findings go beyond this and specify changes in sensory systems which can best be described as attentional responses. For Sokolov 'attention' is an automatic sequence of responses which in each instance evolves through two stages-the non-specific OR and a specific adaptive response. In the non-specific OR any novel stimulus elicits a general autonomic response in which the organisms receptivity to all external stimuli is instantly but briefly, enhanced by an overall lowering of sensory thresholds. (This is immediately followed by a more long-term state characterized by a physical directing of the sense organs to the novel source of stimulation and raised thresholds in the irrelevant sensory modalities.) The cortical arousal factor (alpha suppression and asynchronous-fast low voltage EEG) due to novelty is an integral part of the non-specific OR pattern. The significance for this paper is that the OR can also be described as a new pattern of attentional deployment.

Arousal and Attention

The research relating arousal to attention has for the most part concluded that higher arousal constricts the field of attention (Teece and Happ, 1964, McNamara and Fish, 1964) and that lower arousal brings about decrements in performance - especially in monotonous vigilance-type situations (Broadbent 1963, Eason, Bridsall and Jaffe, 1964). One of the more common forms of arousing Ss is the interruption of a long tedious signal detection session, but band music, Playboy pictures and verbalized free associations have all served to decrease the vigilance decrement (over time). These manipulations have all been based on the assumption that novel or interesting events increase arousal and that this improves attention to sensory signals. This increment in attention has been documented in general effects (e.g. lower Reaction Time) and specific effects on focal attention (narrowing of the attentional field to a restricted spatial area) but a common element is some improvement in responsiveness to the external environment. Tomkins (1962) theory of affect also proposes that moderate increases in novelty of stimulation arouse the positive affect of interest.

Implicit in much research about arousal and a good deal of clinical observation is the correlation between arousal and a bias of processing in favor of the external channel over long-term memory (LTM). States of low arousal are commonly associated with greater processing of internal/LTM material. Reverie states, day-dreaming and mindwandering all occur most frequently in monotonous and redundant environments. These environments as well as fatigue, seem to lead to marked inattention to the external environment and marked increases in LTM processing.

The following table is Lindsley's (1957) schematization of the relation of the arousal continuum to behavior and states of consciousness. Attentional patterns can be superimposed on this table and suggest that the attentional process undergoes important changes as activation level changes.

TABLE 5

PSYCHOLOGICAL STATES AND THEIR EEG,[1] CONSCIOUS AND BEHAVIORAL CORRELATES

Behavioral Continuum	Electro-encephalogram	State of Awareness	Behavioral Efficiency
1. Strong, Excited Emotion (Fear (Rage) (Anxiety)	Desynchronized; Low to moderate amplitude; fast, mixed frequencies	Restricted awareness; divided attention; diffuse, hazy; "Confusion"	Poor: (lack of control, freezing-up, disorganized
2. Alert Attentiveness	Partially synchronized; mainly fast, low-amplitude waves	Selective attention, but may vary or shift, "Concentration, anticipation, "set"	Good: (efficient selective, quick reactions) organized for serial responses
3. Relaxed Wakefulness	Synchronized Optimal alpha rhythm	Attention wanders - not forced. Favors free association	Good: (Routing reactions and creative thought)
4. Drowsiness	Reduced alpha occasional low-amplitude slow waves	Borderline, partial awareness. Imagery and reverie "Dreamlike states"	Poor: (uncoordinated, sporadic, lacking sequential timing)
5. Light sleep	Spindle bursts and slow waves (larger) Loss of Alphas	Markedly reduced consciousness (loss of consciousness) Dream state	Absent

Table 5 cont'd.

Behavioral Continuum	Electro-encephalogram	State of Awareness	Behavioral Efficiency
6. Deep Sleep	Large and very slow waves (synchrony but on slow time base). Random irregular pattern	Complete loss of awareness (no memory for stimulation or for dreams)	Absent

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[1] from Lindsley, D.B., Psychophysiology and Motivation. In Nebraska Symposium on Motivation, 1957

Higher levels of arousal correlate with "concentration and selective attention" while lower levels correlate with wandering attention and reverie. Implicit in this organization is the systematic shift away from the external with lower arousal levels and, in light of the reciprocal relation developed in Experiment I, re-focusing on internal/LTM material. This would correspond closely with the habituation phenomena observed by Sokolov and clearly indicates a relation between arousal and attention.

General vs. Specific Effects - If the material discussed above is viewed from the viewpoint of attentional changes, a certain contradiction emerges. The essence of the physiological approach to arousal is its general character. The reticular activating system (RAS) was first noted as non-specific sensory pathways (Moruzzi and Magoun, 1949) and the theory developed as "General Activation Theory" - "It is clear that it is the organism, not a single system, or a single aspect of response, which shows arousal or activation" Duffy, 1957, p. 266). Whatever effects were imputed to arousal were seen as general and non-selective. The research studies on changes in perceptual performance seem to bear this out since they show improvements in fundamental parameters such as response latency (Freeman, 1940; Lansing, et al, 1956) and detection (McGrath, 1963).

Implications of general arousal theory for processing LTM events- These findings are, however, restricted to classical sensory channels and the increments in responsiveness are all to external events. The contradiction arises if we consider responsiveness to other signal sources such as the internal/LTM channel. Here we find an inverse relation between reactivity to LTM and level of arousal. The higher probability of daydreaming during low-arousal states is the same order of relationship as the higher probability of detection of tones or lights in the high arousal state. Both express detection probabilities of signals or put another way, greater attention to a given channel. The only difference is the specific channel being considered (external or LTM). From this viewpoint (one of attentional deployment) we cannot speak of a general effect of arousal upon the detection of all signals. Rather the effect of arousal seems to be to bias the scanning mechanism in favor or external events in high arousal, and in favor of internal events in LTM during lower arousal. This can be seen in a study by Antrobus (1964) in which spontaneous varied speech was shown to improve vigilance performance over repetitive counting by Ss. The varied speech was seen as increasing arousal and thereby increasing externally directed attention. In this study the novelty came from within the subject (presumably LTM) and was experienced by him as less monotonous and more interesting. Yet the increase in performance and attention was to the external task. The source of the arousing stimulus was not relevant - its effect was general and biased the operator towards the external world.

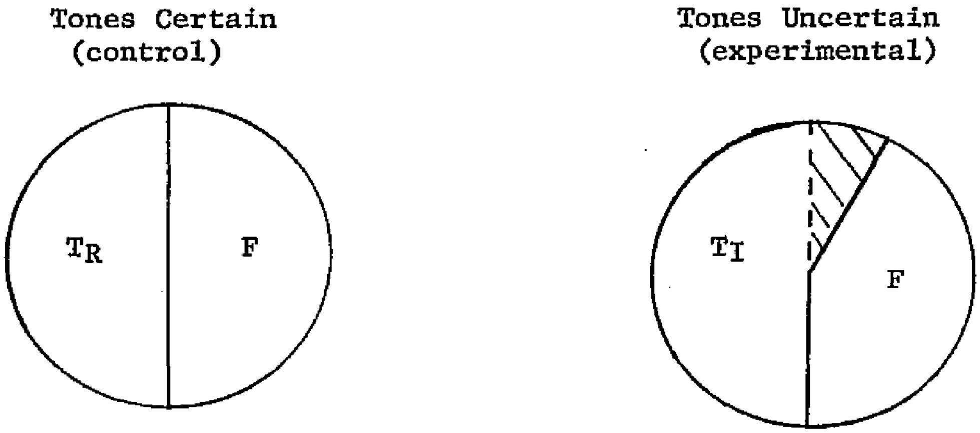
Going back to the "Plans" concept developed in Chapter I, we can say that fundamentally different deployment patterns (in terms of the quantity of attention available to a given channel) might apply as a function of different arousal levels and that the processing strategies used by the individual would reflect these patterns. As in the distribution of the national budget to domestic and foreign affairs, we must make do with what is allocated and strategy involves the best use of the limited quantity available. This would suggest that the introduction of stimulus uncertainty in Experiment I served to increase arousal and alter the deployment pattern in favor of less attention _available_ for processing LTM. The greater attention _available_ for less predictable external events permitted maintenance of performance level.

Implications of Alternative Models

The preceding model (the Arousal approach) can now be contrasted with the model of Chapter I - (the synchronous scanning approach). Figure 3 presents a schematization of these models in which the "pie"-diagram stands for the total attentional capacity and the segments stand for the possible ways of dividing that capacity under different conditions. The arousal approach is projected for an experimental situation in which attention to some other external sensory task is considered. This incidental task is specified as B in the schematic for Experiment II. It represents all non-focal sensory input which was minimized in Experiment I. In Experiment II changes in attention to this input will be studied directly as a dependent variable.

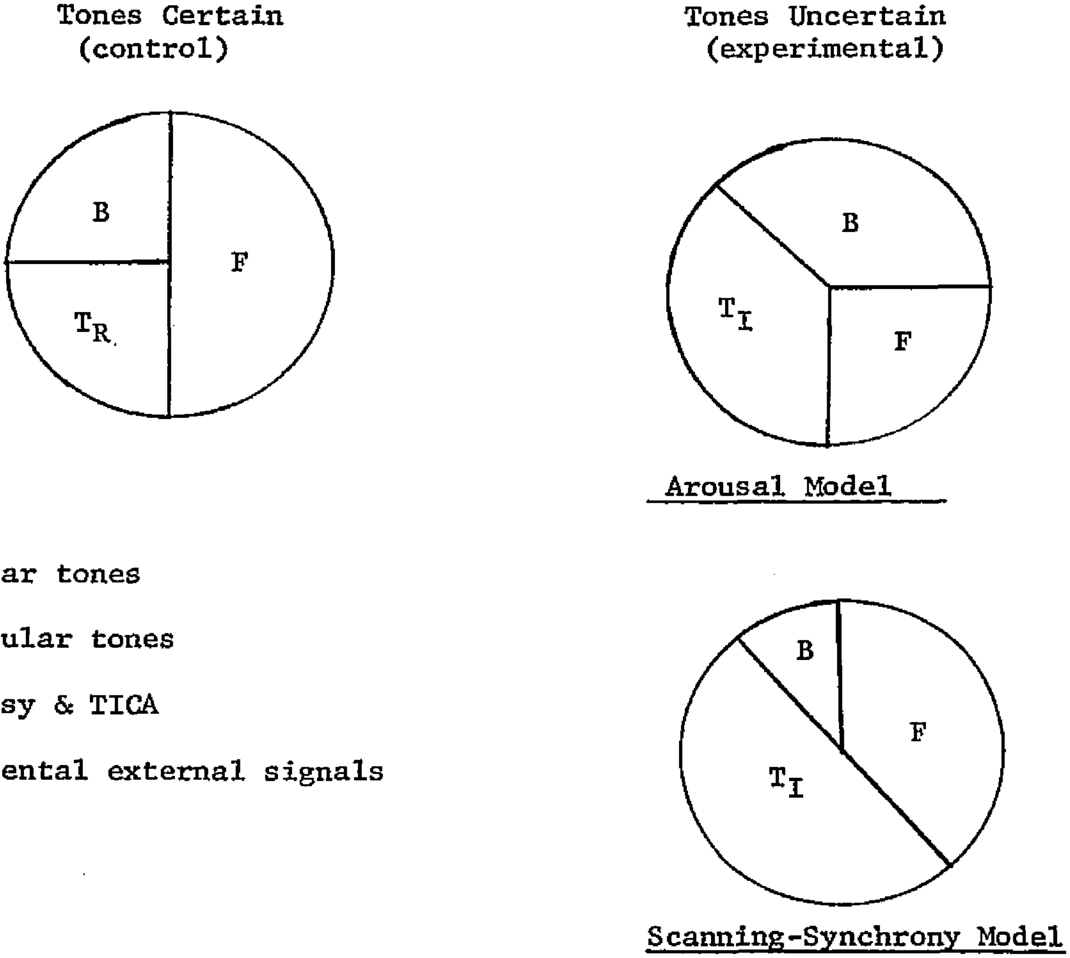
Experiment I-In Chapter I the idea was developed that stimulus predictability allowed some hypothetical scanning mechanism to synchronize with input and thus free-up limited capacity for other channels. Uncertainty in one source would disrupt this synchronizing process and reduce capacity available for other sources of signals if performance

Experiment I


Tones Certain (control)

Tones Uncertain (experimental)

Experiment II


Tones Certain (control)

Tones Uncertain (experimental)

Arousal Model

Scanning-Synchrony Model

T_R- Regular tones

T_I- Irregular tones

F - Fantasy & TICA

B - Incidental external signals

FIGURE 3

SCHEMATIC MODELS OF ATTENTION IN EXPERIMENTS I & II on that task is maintained. In the diagram for Experiment I the capacity needed to operate on Tones in the Irregular condition is greater than in the Regular condition. The shaded area represents the increment in attention to tones and, of course, the decrement in attention to fantasy. This shaded area may also be interpreted as an overall decrement in total functional processing capacity or a decrease in processing efficiency. This model, which had heretofore been utilized mainly for the analysis of multiple channel external events was applied to the internal/LTM channel and seemed to account for the findings.

Experiment II-In this section it has been suggested that general activation might have the effect of re-deploying limited attention through some built-in biasing of the central processor in relation to level of arousal. This relation would be one of increased deployment to the external environment under higher arousal. In the diagram for the Arousal Model of Experiment II there is a predicted increment in attention to all external signal sources (T_I & B) and a decrease to F. The introduction of stimulus uncertainty is seen as arousing and more attention is deployed to all the external signals. The limited quantity available leads, in turn, to withdrawal of some quantity of attention from internal/LTM and a drop in reported fantasy.

An extension of the Scanning Model of I however predicts a different outcome. The Irregular tones would draw on attention from all sources, internal and external. Thus the experimental condition would lead to decrements in the processing of both fantasy and other external signals (the angles of both B & F are smaller). In either case additional capacity is needed to process Irregular tones at the same level as in the Regular condition. In the Arousal model this increment is drawn from processing fantasy (F) and there is also an added increment to processing other sensory signals (B) due to the general re-deployment in favor of external channels. In the Scanning Model it is drawn from all available sources regardless of the internal/external location.

Now both these arguments seem reasonable and both apply to the reported data of Experiment I. They are by no means mutually exclusive and it should be clear that the operating characteristics of some scanning mechanism and a relationship between arousal and available attention are quite separate and independently valid questions. It is important, however, to understand their respective roles in attentional deployment as a function of temporal uncertainty of external events. In the "activation" approach the role of uncertainty is as an arouser or activator (i.e. it could just as well be intensity affect or need etc.). Given increased arousal certain re-deployment automatically follow which are of a general character. This implies that whatever changes occur in reactivity, they should equally apply to all external stimuli. The scanning model does not differentiate between internal and external channels insofar as the effect of uncertainty is concerned. It states merely that temporal uncertainty takes a greater quantity of attentional processing to yield a given level of performance. Choices in this case are attributed to the experimentally established priorities (e.g. instructions or pay-off) and individual differences.

The two models lead to different predictions for response to another external signal. The arousal model de-emphasizes limited attentional capacity by only observing the gains in external detection performance associated with varied stimulating conditions and ignoring the attendant decrements in the processing of internal/LTM signals. The general nature of the arousal - attention relation and its inner/outer differentiation suggests that increased arousal would improve attention to the external environment as a whole and thus to any part of it. Thus the arousal model predicts better processing of an additional external signal in the configuration of Experiment I.

The "scanning strategy" approach admits the possibility of biasing of the response priorities by arousal (as by instruction or pay-off) but holds that the effect of temporal uncertainty has to do with the operating characteristics and limitations of the device itself - not its subordination to other factors. It argues that total processing capacity is reduced by the introduction of temporal uncertainty since a greater portion of this capacity must be devoted to "observing" strategies, or Plans, and less is available for discriminations. Accordingly, this model predicts the same relationship as in Experiment I - decreased attention to task-irrelevant events due to decreased functional capacity available during the processing of temporally-uncertain input.

This should be reflected in lower reported fantasy and decreased processing of an incidental external task when uncertainty is introduced in the focal task. This result is postulated on the basis of a maintenance of performance level on the focal task (tones). If attention to other channels in the Irregular tone condition is not reduced, tone detection performance should suffer.

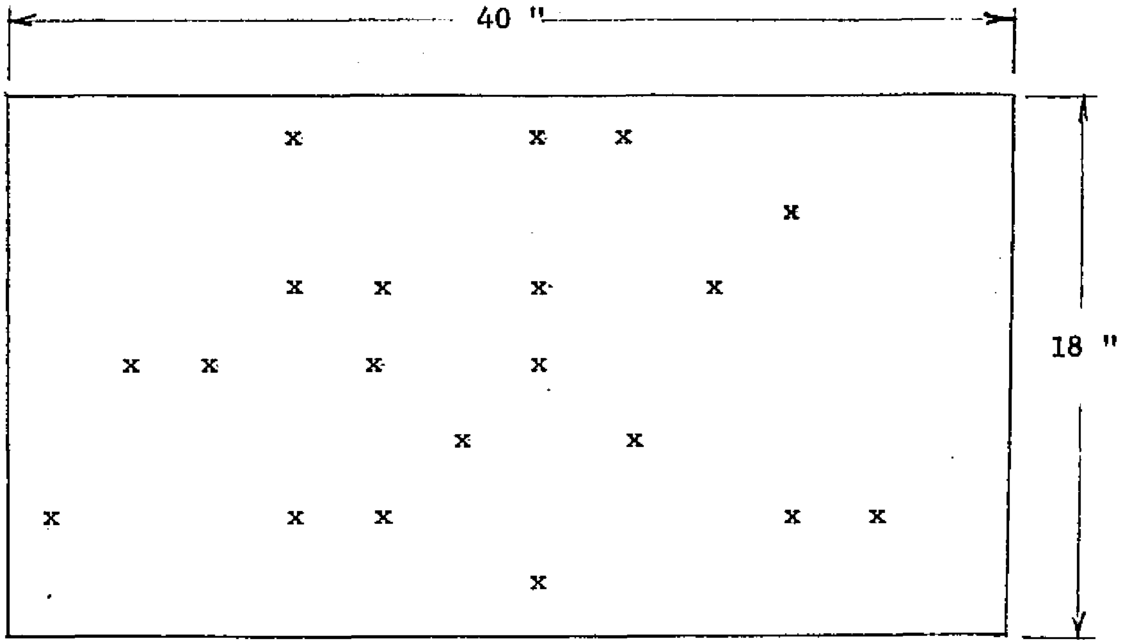
METHOD - EXPERIMENT II

General Design

As in experiment I, the subjects main task was the detection of the lower pitched of two pure tones presented randomly. The independent variable was the temporal certainty of these tones as characterized by the inter-stimulus interval (the ISI). In the regular (TC) condition the ISI was 1 second; In the irregular (TU) condition the tones were presented at randomized intervals ranging from .5 to 2.0 seconds and averaging 1 per second for a given trial. Tones were presented to the S through a head set over a white noise background.

The concurrent task was the detection of changes in small lights arrayed before the subject in a random pattern. This array constituted a visual field which the subject could scan as he was engaged in detecting the tones (See Diagram, Fig. 4). His task was to press a key associated with the lights as soon as he detected a change. The entire array was illuminated at all times, and the event the subject had to detect was the gradual rise of illumination (over the course of 5 seconds) of one of the lights. The total field covers a horizontal visual field of about 100^{o} and is 18 inches high. There are 20 lights of identical illumination and size. Ten of these are "active" and each was used once in each condition (TC/TU) as the signal. The rest served as dummies.

The subject was comfortably seated in a dark, quiet room for the duration of the experiment and there was an intercom between S and E's control room. Both the main detection performance (the tones) and the concurrent detection task (the lights) were continuously recorded on paper tape. For the tones, all signals and all responses were recorded so that both misses and false positives could be counted. For the lights,



Light Panel

Experimental array
(top view)

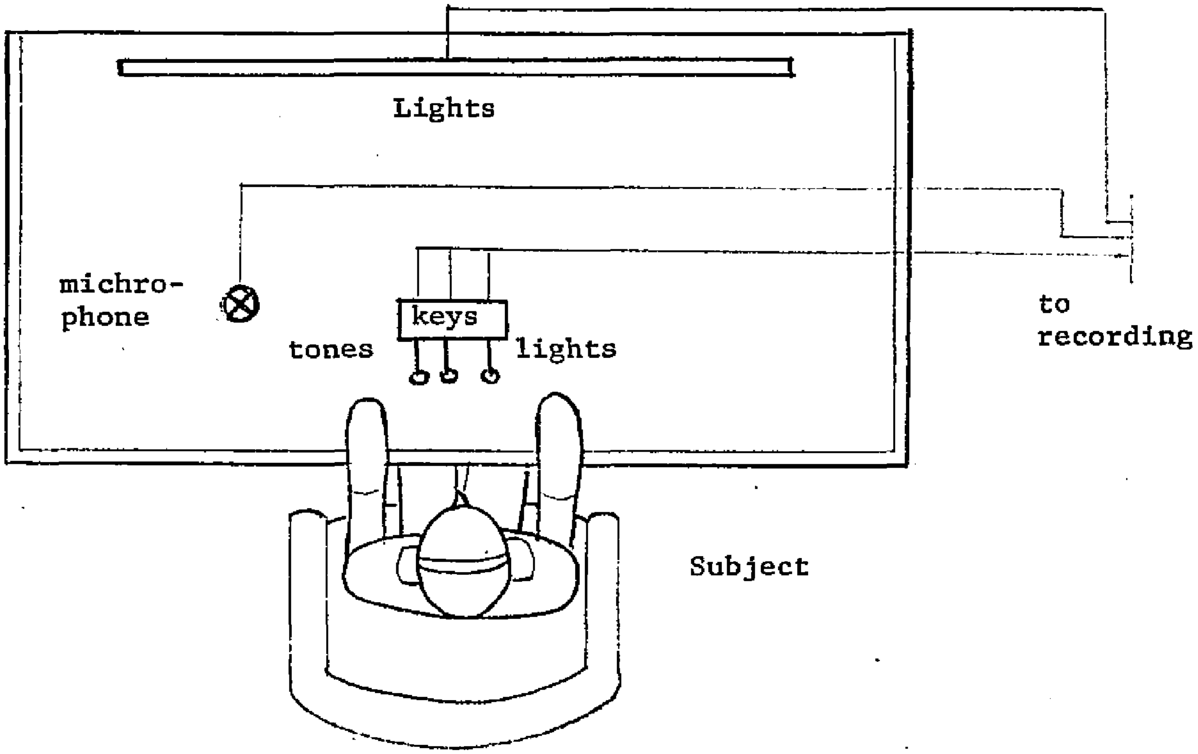


FIGURE 4

TEST CONFIGURATION OF EXPERIMENT II

each individual light was recorded so that detection and reaction times could be evaluated as a function of the position in the array.

Procedure

Each subject was familiarized with the main detection task. He was then familiarized with the visual detection task and allowed to practice rapid detection of each light. Finally, he was instructed to perform both task concurrently; To press for all low tones and to press whenever he noticed a light growing bright.

For convenience in the analysis of data, TC and TU periods were considered in terms of 1 minute trials. These were randomized with equal distribution of TU and TC trials. Any trial had a 50% probability of containing a visual signal. Thus, on the average, there was one visual signal every 2 minutes. The position of a visual signal in the trial was randomized and the subjects response turned the light back on again.

There were 20 trials each of TU and TC tones yielding a total experimental session of 40 minutes. Overall, there were 10 visual signals in each condition for each subject and each subject acted as his own control. Each "active" light was used once in each condition so that differential effects of position were controlled across TU and TC trials.

RESULTS OF EXPERIMENT II

The results of Experiment II may be best seen in a series of figures showing the changes in each variable by condition. The first deals with the expected suppression of fantasy in the Irregular condition.

TABLE 6
MEAN FANTASY LEVEL FOR 5 PERIODS IN
REGULAR AND IRREGULAR TONE CONDITIONS

Period	1	2	3	4	5	$\bar{X}$
Regular	1.82	2.06	2.37	2.38	2.60	2.185
Irregular	1.70	2.05	2.20	2.38	2.53	2.172
% Diff. R-I / R	7.7	.5	7.8	0	2.5	.6

$\bar{X}$ Difference not significant

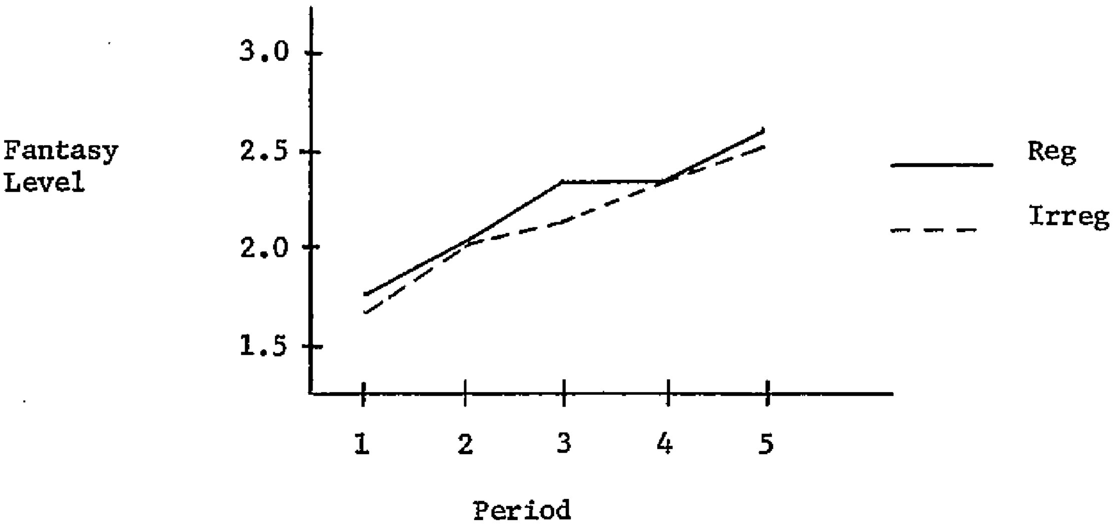


FIGURE 5
DATA OF TABLE 6

As in experiment I, there is a clear upward trend of fantasy over the periods regardless of condition but the differences in fantasy by condition are either small or non-existent and do not attain significance.

TABLE 7
LIGHT PERFORMANCE BY CONDITION
(FOR PAIRED LIGHTS ONLY)

	Regular	Irregular
Reaction Time	2.02 sec.	2.07 sec.
Misses	21	22
False Positives	3	3

Differences not significant

For the light detections, there is no significant difference in either the reaction time or detection variables for the group data. From these figures and those of Table 2.1, we may conclude that neither suppression of fantasy nor decreased processing of lights occurred in the Irregular tone condition. The limit model would, therefore, predict decreased processing of tones and decrements in tone performance. Table 8 presents this data.

TABLE 8
% OF TRIALS WITH TONE DETECTION ERRORS BY
CONDITIONS FOR EACH LEVEL OF FANTASY

	Fantasy Level				
Condition	1	2	3	4	$\bar{X}$
Regular	12.7	22.6	23.8	34.6	21.6
Irregular	17.4	28.7	33.3	42.3	28.2

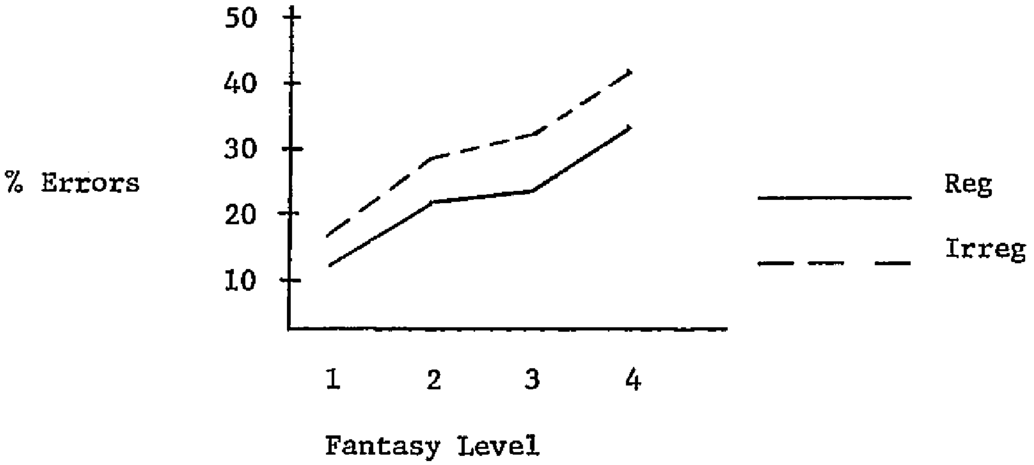


FIGURE 6
DATA OF TABLE 8

There is a marked deterioration of tone detection performance in the Irregular condition at each level of reported fantasy.

Comparing the levels of the three variables by condition, we can see that two factors (light performance and fantasy level) were maintained and one (tone performance) was lower in the Irregular condition (See Figure 7).

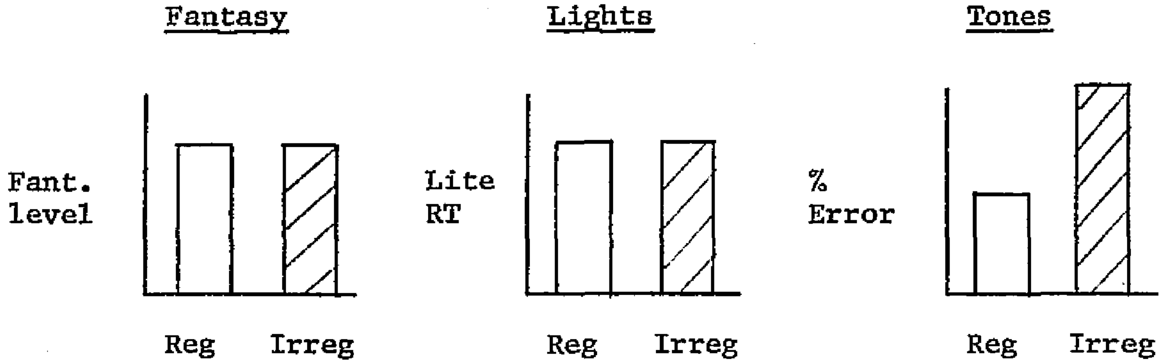


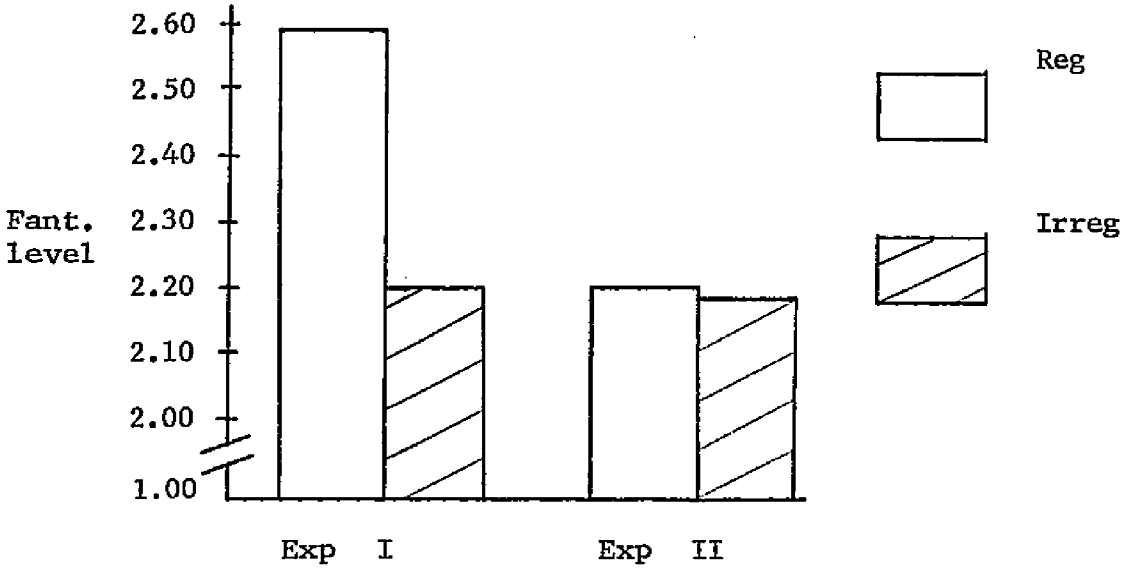
FIGURE 7
COMPARISON OF THREE PERFORMANCE
VARIABLES BETWEEN CONDITIONS
(SCHEMATIC)

This supports the contention that the Irregular tone condition requires greater processing for equal performance and that if attention is not withdrawn from other concurrent tasks or signals, tone performance will suffer. As in Experiment I, the total functional level of processing appears to be reduced by the introduction of uncertainty in one signal source. But there is no evidence that the occurrence of the Irregular tone condition led to fantasy suppression or to any direct alteration of light performance. Considered as an independent variable, temporal uncertainty in the tones seemed to have little influence upon deployment of attention to the other two variables within the configuration of this experiment.

Post Hoc Analysis

A comparison of the results of Experiments I and II, however, reveals some striking differences between these two sets of data and suggests that addition of the light detection task in II was responsible for these differences. If the light task *per se* is considered as an independent variable, Experiments I and II may be compared with respect to their common dependent variables of tone performance and fantasy level.

Fantasy level in Experiment II was reduced over-all to the same level as the Irregular condition in Experiment I.



Difference between Reg I & Reg II significant $p < .025$, ("t" for independent samples)

FIGURE 8
FANTASY LEVEL BY CONDITION FOR
EXPERIMENTS I AND II (N=40)

This means that the lights of Experiment II functioned to produce the same fantasy suppression effect in the Regular condition of II as the Irregular tones did in I. There is the possibility that this lower level of fantasy (2.18) is some sort of lower limit beyond which fantasy cannot be suppressed for the time periods involved in this experiment.

The tone performance of Experiment II shows the same pattern of decrement as I - lower error rate in the Regular condition. But the whole range of tone errors is shifted upward in II (i.e. regardless of tone condition, tone detection error rate is higher in Experiment II). Figure 9 illustrates this trend.

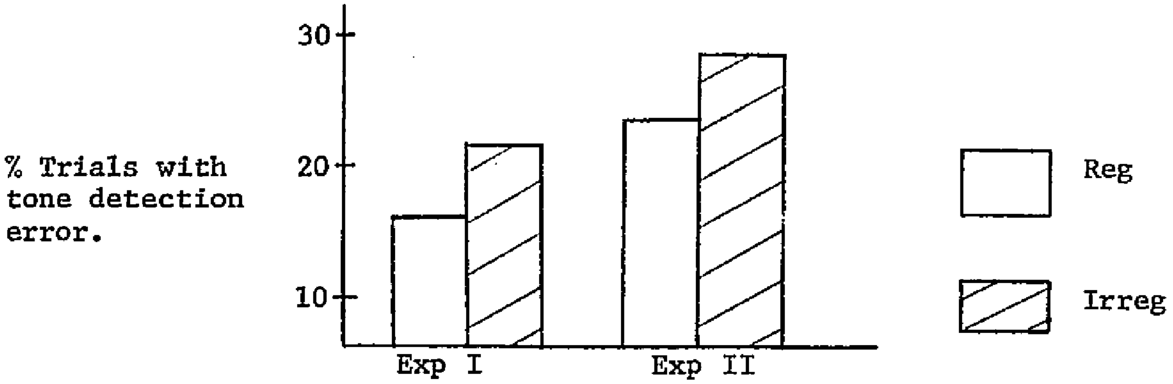


FIGURE 9
TONE DETECTION PERFORMANCE BY CONDITION
FOR EXPERIMENTS I AND II
(% trials with any error)

Further comparison reveals that at every level of fantasy there is a higher probability of tone error in Experiment II than in Experiment I. This pattern is over-laid on the tone performance decrement attributable to the Irregular tone condition in both I and II (Table 9).

TABLE 9
PROBABILITY* OF SINGLE TONE DETECTION ERROR
AT FOUR FANTASY LEVELS BY CONDITION FOR
EXPERIMENTS I AND II

	Regular				Irregular			
	1	2	3	4	1	2	3	4
Exp. I	.9	1.0	1.4	3.1	.6	1.4	2.2	5.0
Exp. II	2.1	3.7	4.2	5.4	3.6	5.5	6.4	7.4

* $\frac{\text{Tone detection errors}}{\text{Total \# of tones}}$ = P for each fantasy level.

Figure 10 shows the same data graphically.

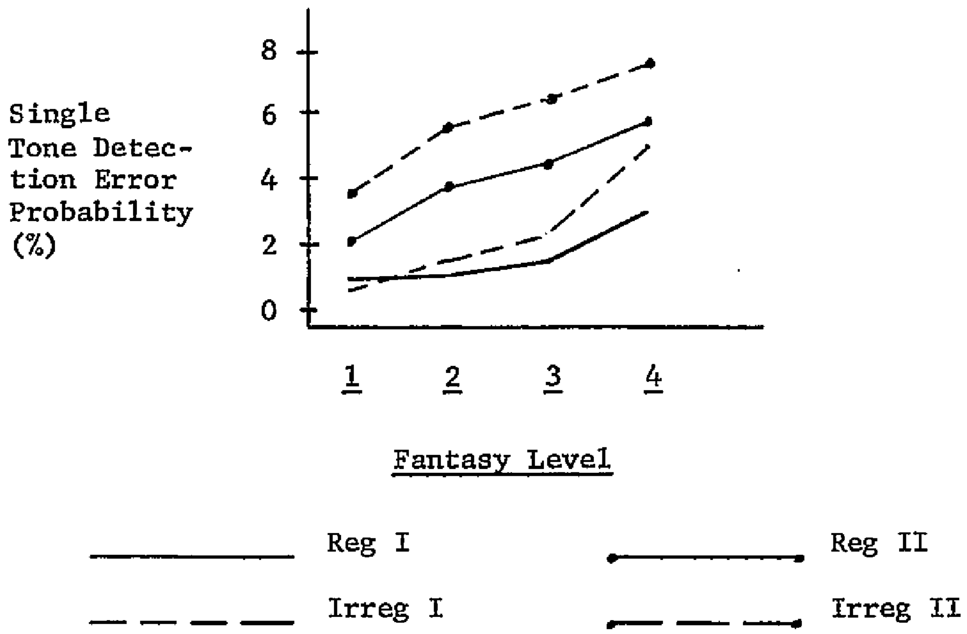


FIGURE 10
DATA OF TABLE 9

The upward displacement of tone-error probability in Experiment II regardless of fantasy level suggests a decrease in overall reserve capacity for that experiment. This tends to support the contention that some common processing capacity (attention) is being drawn upon by qualitatively different sources of information.

Results Summary

The results of Experiment II indicate that Ss established their own priorities for processing the three sources of input - tones, lights and fantasy. Most Ss maintained light detection performance at a high level regardless of the changes in the tones and seemingly "chose" to decrease processing of the other channels for the entire course of the experimental session. Accordingly the introduction of uncertainty in the tones was associated with marked decrements in tone performance.

Fantasy was suppressed equally in both tone conditions but only to a level still well above zero. The hypothesis of improved processing of lights due to some general arousal response to the Irregular tones was not adequately tested. That prediction was based on the expectation of equal tone performance and marked fantasy suppression in the Irregular condition which did not prove to be the case. However, the failure of Ss to completely suppress processing of LTM in the face of the inadequate external processing evidenced by poor tone performance tends to mitigate against the arousal model. The expectation of a major re-deployment of attention to <u>all</u> external channels is therefore not borne out.

Overall the findings of this experiment are consonant with the scanning model proposed for Experiment I - i.e., limited processing capacity which must be shared between the various inputs <u>regardless</u> of their origin in the internal or external environments. Given an equal assignment of processing capacity, uncertain events are less effectively processed than regular, predictable ones since synchronous scanning routines cannot be readily utilized. In Experiment II the adequate processing of the highly uncertain and infrequent visual detection task necessitated the commitment of considerable space to that task and thus its re-deployment away from the other two. The lower level of total functional processing in Experiment II also supports the view that processing and transmission should be differentiated insofar as they draw on the same limited capacity but yield different behavioral consequences. See Appendix (Tables B,C, & D) for analysis of individual differences in Experiment II.

CHAPTER III

CONCLUSIONS AND DISCUSSION

It is important to differentiate among the three areas with which this research deals if we are to draw meaningful conclusions from the data. As noted above they are 1) facts about the structure or system-attention, 2) the validity of using an attention approach for the evaluation of internal experience, 3) the effect of temporal uncertainty on the deployment of attention.

1) The Internal-External Distinction

It is in this realm that the data is most clear for it indicates the essential validity and reliability of regarding the internal world as a source of signals which should be treated in the same manner as external stimuli. The reliability of the subject-report techniques has been demonstrated before in the research of Singer and Antrobus and this study supports their findings with regard to the stability of the measure and adds a dimension of practicality by the fact that fantasy level is predictive of signal detection performance. We have argued before that attention to spontaneous cognitive activity played a major role in detection performance, especially vigilance tasks. The relation between tone performance, light detections and fantasy seems to indicate that overall attentional capacity remains constant but that the deployment between internal and external signals is quite variable. The reciprocity of attention to internal and external signal sources is the best description of this process and rests on the assumption that internal signals are full-fledged stimulus events having the same potential capability of "attracting" attention as external signals.

This line of reasoning is in contradistinction to the general activation or arousal approach to vigilance performance and decrement. A vigilance approach based on changes in arousal argues that "it is obvious that a man immured in a cubicle with a radar screen is likely to be in a low level of arousal, and particularly likely to trend downward in arousal as the stimulation he receives remains unchanged." (Broadbent, 1963, p. 184). Broadbent notes that arousal cannot account for many findings (e.g. Colquhoun, Colquhoun, and Baddely, 1963) but looks to the complex inverted U function as an explanation. But a general arousal approach to attention must always posit a general decrement in attention to all stimuli - not a differential effect where attention to some events is decreased while attention to others is increased. Yet this is exactly the finding of this study - while there is a performance decrement over time (e.g., the tones of Experiments I and II) which is presumably indicative of decreased attention to the signals, there is a corresponding reciprocal <u>increase</u> in attention to another signal source - the internal environment. If any conclusion can be drawn then, it is that lower arousal leads to a re-deployment of attention - less outward, more inward. The clear implication of this is that future research in attention must take into account the fact that a significant portion of limited processing capacity apparently is always being deployed to internal or LTM sources. The nature of the signals from these often inaccessable sources may prove to be critical to understanding individual differences in a variety of situations ranging from ability to attend to a lecture to the reliability of observers in radar and space-flight conditions.

2) Uncertainty

The findings of Experiment I indicated that temporal uncertainty in a tone detection task required greater attention for equal performance and generally succeeded in drawing that attention away from internal signals. While Experiment II continued to demonstrate that increased attention to Irregular events is needed to produce equivalent performance, the Irregular tones of Experiment II did not attract that attention and tone performance deteriorated markedly from the Regular periods. We noted also that the overall tone performance level of Experiment II was lower than in Experiment I and that fantasy levels were also lower overall. Thus the total amount of attention to tones and fantasy may be assumed to be lower in Experiment II. It is safe to conclude that this attentional deficit was the result of the light task and reflected the deployment of attention to that task.

In retrospect, it can be seen that the light task, in itself, provided a stimulus source having considerable uncertainty. Lights were infrequent and neither their position nor color was predictable. Comparatively, the Irregular tone task contained only one dimension of uncertainty - i.e., temporal. This probably accounts for the fact that fantasy was suppressed even in the Regular tone periods of Experiment II and that tone performance was worse in each tone condition of II than in Experiment I. Clearly, less attention was available for both tones and fantasy. This raises some interesting questions about the role of uncertainty in determining the deployment of attention. Given equal value and interest, the amount of attentional "draw" a task has might be a function of its level of predictability relative to the other possible stimulus sources. The stimulus array with the highest degree of uncertainty would attract the most attention and priorities of distribution would be determined by the hierarchy of predictability. In Attneave's (1959) terms, this would correspond to an information-redundancy scale for determining (or at least influencing) the distribution of attention.

These considerations center about the demonstration that uncertainty tends to draw more attention and has implications for the adaptive and executive function of an attention system. Adaptively, we may think in almost teleological terms about the need for more active processing of areas which, if left alone, yield less information. It is important that we differentiate between attentional considerations (e.g., curiosity, exploration, interest) and behavioral commitment. The latter, represented by a physical approach to uncertainty, would obviously be maladaptive and represent compulsion to act or almost mechanical tropism. Observation of animal behavior clearly indicates that there is a sharp and appropriate distinction between attentional and motoric response to uncertainty. The former is quite reflexively keyed to novelty and predictability (the orienting reflex, for example) while the latter bears the opposite relation (e.g., aversion to strangers on the part of pets, or fear-reactions to novelty in Hebb's monkeys). It should be noted that such behavioral aversion always is accompanied by extreme watchfulness.

These characteristic reaction patterns to uncertainty seem to play an important role in animal behavior with regard to the "hunter/hunted" relationship. Many animals behave erratically when attacked by predators - their movements become highly unpredictable taking the form of zig-zagging, looping, spinning or wild bouncing. Humphries and Driver (1967) have argued that such erratic behavioral displays act as "specific antipredator devices which function to confuse and disorient the predator and increase its reaction time." To the extent to which such behavior is unsystematic "it is resistant to defeat by learned modification of responses in the predator." Viewed from the attentional model of this paper, erratic behavior frustrates the possibility of elaborating strategies for processing that behavior and reduces the effectiveness of the predators limiting strategies. Furthermore, increased experience with erratic behavior does not help one organize a more effective plan except insofar as no time is wasted in trying to impose order on randomness. Thus in Experiment I there was no gain from repeated experience with Irregular tones. In order to maintain performance, fantasy had to be suppressed to the same extent in each of the five irregular periods.

The other aspect of uncertainty which needs discussion is the fact that uncertainty seems to need more attention to produce equally effective behavior. This has implications for the operation of the attentional mechanism itself - particularly its scanning components which control input. Neisser distinguishes between parallel and sequential processing in search tasks, the former involving simultaneous comparisons while the latter would "sweep" through possible choices accepting or rejecting each in turn. The model developed here is largely of the sequential sort in that we are defining uncertainty relative to a mis-match with the immediately preceding stimulus pattern (as in OR). It has been an assumption throughout this research that the effects of uncertainty are at least partially related to the nature of the attentional scanning mechanism. More specifically, the fact that uncertainty seems to require more attention suggests that what is limited in attention is the ability to process simultaneously several sources of information. A parallel processing model should not encounter any difficulty as long as the number of events remained equal. Only a sequential scanning device programmed to pause in the event of increased uncertainty would produce a deficit in the response to other signals since the very nature of a sequential process is that it can't be in two places at the same time. This raises the more important matter of some feedback connection between the information taken in and the scanning device which takes in that information. There must be some mechanisms for the stimulus influencing the processing program and rate of thescanning itself.

There is the possibility, however, that certain functions are conducted in parallel. The OR must be based on simultaneous comparison <u>between</u> the multiplicity of different modalities and stimulus dimensions. While <u>within</u> each modality or dimension scanning would be of a sequential type subject to the rules discussed above, there must be simultaneous scanning of all possible sources of information. It is possible that a response in the simultaneous processing of many possible sources triggers off sequential processing in that area to get more precise information on the signal source. The common experience of entering a familiar situation in which some aspect is different is a good example of this. Awareness that "<u>something</u> is amiss" precedes awareness of <u>what</u> that "something" is. Anyone who has had this experience knows that there can develop a need to find out what is different, which can be quite compelling and fix attention. This may lead to a redeployment of attention for the period of time elapsed between the notice that something has occurred and the discovery of what it is. We may examine the experimental tone task from this point of view.

In the Regular condition tones occur "on time" and there is no delay between the information that some tone is occurring and the information about which tone (High or Low) is occurring. Attentional deployment can be easily synchronized with the highly' predictable occurrence of these events and need begin scanning only a few milleseconds before the expected signal. Furthermore, this deployment need only be concerned with the question "<u>which</u> tone has occurred" (the <u>what</u> question), and not with the question "<u>has</u> some tone occurred" (the <u>if</u> question). In the Irregular condition, the picture is quite different. First, scanning cannot be synchronized with the predicted occurrence of events. The only possible "break" for attention is the shortest inter-stimulus interval (.5 seconds) - at all other times there is the possibility of an event. A great deal of attention (processing time) must be devoted to the <u>if</u> question. Second, it is questionable if the connection between <u>if</u> questions and <u>what</u> questions are as efficient as the synchronous <u>what</u> questions adequate for the Regular tones. In a sense, the system must shift gears from <u>if</u> to <u>what</u>, and this takes time. Finally, it is probable that some greater reserve would always be left to deal with future <u>if</u> questions within a context of uncertainty and thus leave less capacity for <u>what</u>.

Mandler (1964) has discussed this problem from the perspective of sensory psycho-physics. He presents a taxonomy of the "typical problems that the sensory systems of man are called upon to perform - 1) the detection problem - "is there anything there?", 2) the recognition problem - "what is it?", 3) the discrimination problem - "is this different from that?", 4) the scaling problem - "how much of X is there?" (p. 91-92). Our model of attention posits a super-ordinate processing system which, in effect, can deploy the time or energy devoted to each of these tasks. If the interpretation of the findings is correct, they suggest that time devoted to anyone of these "questions" reduces time available for the others. In the Irregular condition more processing must be devoted to the detection problem ("did a tone occur?") and less is available for the discrimination ("was it a High or Low tone?").

3) Structure

The previous discussion has inevitably gone into concepts about the structure of the attention system but it is worthwhile to reiterate and elaborate these for the purpose of more clearly formulating an idea of the system under consideration. The results support a model of limited attentional capacity and the reciprocity of attention to the component parts of the field. While arousal or stress may momentarily alter this capacity (as in the case of the Irregular tones of Experiment II) it is more likely that the debilitating effect of stress on information processing acts via changes in the scanning process by making voluntary localization more difficult. In high anxiety, for example, we know that many sources of signals are accentuated and minor events command disproportionately high attention. Once attention to internal events (which we should expand to include dreams and hallucinations) is considered there is really no clear evidence of changes in total attentional capacity - merely dramatic redeployment and/or disorganization. The reliable constancy relationships demonstrated in this study and the predictive power of this relationship argue strongly for a fixed capacity model.

The second matter for discussion is the scanning function of the system. This has been developed in an earlier section with regard to the type of scanning and the relation of this scanning method to environmental stimuli. The possibility of feedback loops between the environment and the scanning process has also been discussed and the data suggest that the type of scanning may depend in part on the type of stimulation. A rigid stereotyped pattern would not be as adaptive, especially in higher organisms, as a flexible system which could change its behavior to optimize performance in varying circumstances. The fact that there is a good deal of evidence for both parallel and sequential processing should deter any attempt to characterize the system at a more simplistic level. It should be made explicit at this point that the idea of "scanning" is not restricted to a perceptual model wherein the eye "scans" the horizon. Scanning is really an analogy for a complex selection process and the scanning mechanism and embodiment of the selector.

Thus the multi-dimensional "models" of Sokolov must be scanned and matched to the ongoing environmental phenomena. This matching includes conceptual and semantic variables as well as sensory ones (see the work of Luria in semantic conditioning and Sokolov's in OR to conceptual stimuli). We have no knowledge of the manner in which internal events and memories are encoded, stored and emitted by the brain and, therefore, can only grope towards models which seem to explain retrieval. Resonance may be as apt an analogy as scanning to account for recall of a specific fantasy. At this time, we simply do not know. But while there may be a unique process whereby intra-psychic events are processed and extended into the light of awareness (Freud would speak of needs determining the flow of thought), this research strongly suggests that the process of selection between internal and external events is subject to a common set of rules. This means one system super-ordinate to internal and external signal sources which somehow translates all signals into its own language and makes decisions based on this process. This language may be extremely limited and consist of a few scales: intensity, novelty and uncertainty, perhaps. Once a profile of the present stimulus situation was developed, the system would respond based on its program. This program could be permanent (as in the case of the pre-eminence of intense stimuli) or temporary (expectancy and set) but would be the basis of a decision about the future information processing behavior of the organism. It is the choice of which information to <u>further</u> process that is seen as the function of the system "attention", and brings us back to William James.

James (1890) saw "interest or usefulness" as the basis for selective attention and was loath to consider attention as an environmentally reactive system. His anti-empiricist position led him to emphasize endogenous factors such as reason, will, and purpose at the expense of external control. He put forth "interest - what I agree to attend to" as the prime determinant of attentional deployment but always insisted on the selective nature of attention and, quite explicitly, a limited capacity model - "it implies withdrawal from some things in order to deal effectively with others." (p. 403). This research has explored a parameter (uncertainty) which determines the "effectiveness" with which attention can deal with anything. It shows that uncertainty is an important stimulus variable which defines limitations on the rate of processing simultaneous inputs and suggests that this occurs because it is more difficult to develop effective processing strategies when information is uncertain. Concurrently, though, that which is most unpredictable often seems most interesting or important and thus easily gets the increments of attention needed. In short, we readily "agree to attend to" the unpredictable. It is doubtful if this arrangement is fortuitous for it elegantly sees to it that our limited attention is deployed where it is most useful. As is often the case in nature, a system responding in a rather mechanical fashion can articulate with a complex set of motivational factors and produce adaptive behavior. If this research makes any contribution to knowledge of the mechanism of attention it is because the initial concern was with adaptive function and with trying to understand phenomena which are experimentally so elusive, yet paradoxically so well known to each of us in his own experience.

CHAPTER IV

SUMMARY

Experiment I - Twenty college students performed an auditory signal detection task in a light and soundproof room under two conditions in which the temporal uncertainty of signals was the independent variable. In the Regular condition the interstimulus interval was a constant 1.00 seconds while in the Irregular condition four different time intervals averaging 1.00 second were used. The task itself was simple binary discrimination between two different tones varying in pitch (400 - 1000 cps) and presented in brief trials ranging from 10 to 30 seconds. At the end of each trial Ss were asked to give a rating of the extent of intrusive task-irrelevant thought and fantasy that occurred during that trial. It was proposed that the regular presentation of signals permits the synchronization of an attentional scanning mechanism with sensory input, enabling the S to simultaneously process material from long term memory and the external environment. The introduction of temporal uncertainty into the task should, therefore, reduce Ss ability to do both things at once and result in fantasy suppression or poorer tone detection performance.

Results indicated that most Ss decreased their processing of fantasy in the Irregular condition and maintained tone performance on a parity with the Regular condition. Those Ss who continued to process fantasy at a high level made significantly more tone detection errors in the Irregular condition.

Experiment II - It was proposed that the effects observed in the first experiment might be accounted for by changes in general level of arousal associated with the onset of the more novel and stimulating Irregular tone condition. In the arousal model this general activation might bias attention towards the external environment and thus bring about the redeployment observed in Experiment I. However, there should be increased processing of all external signals in the more aroused state. To test this hypothesis a group of 20 Ss were tested on the same procedure as Experiment I with the addition of a concurrent vigilance task in which S had to detect luminance changes in one of several small lights. The arousal model predicts that better performance on the visual detection task would be associated with Irregular tone periods. While no difference in light detection performance was found between the two conditions it was felt that the model was not adequately tested. Most Ss placed priority on the visual task and decreased their processing of both tones and fantasy. However fantasy was never completely suppressed even in the face of marked deterioration of tone performance. This finding does not support a simple internal/ external redeployment model based on arousal.

Theoretical Implications - The model of a mechanism for the simultaneous processing of internal and external events, based on the elaboration of scanning strategies and dependent on the predictability of input, is supported by the findings of both studies. Both studies also strongly support a limited processing capacity theory of attention but suggest that the production and execution of scanning strategies may draw on the same capacity as information processing *per se*. The complex and relatively inefficient strategies necessitated by unpredictable input seemingly reduce the total *functional* processing capacity of the observer. This finding supports those theorists who have argued that total attentional capacity is divided between active organizing factors and relatively passive processing or transmission factors. Finally the studies demonstrate that the ongoing internal world of thought, fantasy, imagery and memory must be considered a legitimate channel of information competing with external sensory signals for the limited capacity of a central attentional system.

APPENDIX: INDIVIDUAL DATA FOR EXPERIMENTS I & II

TABLE A; DATA OF EXPERIMENT I

FANTASY LEVELS AND MISSED TONES FOR REGULAR AND IRREGULAR CONDITIONS - INDIVIDUAL Ss AND TOTALS

	Fantasy		I-R	R-1	% Missed Tones		
Subject	Reg	Irreg	Δ	% Δ	Reg	Irreg	Δ
30	2.48	1.68	-.80	-54	4.0	1.0	-3.0
31	2.33	2.04	-.29	-22	.7	1.5	.8
33	2.27	2.84	+.57	+45	7.6	13.5	5.9
34	2.83	2.28	-.65	-35	.2	0	-.2
35	2.78	2.12	-.66	-37	.1	.5	.4
36	2.74	2.60	-.14	- 8	2.3	2.5	-.2
37	1.48	1.40	-.08	-17	.1	.5	-.4
38	2.28	1.80	-.52	-41	.3	0	-.3
39	2.68	2.25	-.43	-26	.2	0	-.2
40	2.15	2.12	-.03	-3	.7	2.0	1.3
B1	2.81	2.08	-.73	-40	0	0	0
B2	2.01	1.92	-.09	-9	8.3	10.4	2.1
B3	3.58	3.48	-.10	-4	.8	1.6	.8
B4	1.87	1.48	-.39	-45	1.6	1.2	-.4
B5	3.09	3.20	+.11	+5	.7	2.4	1.7
B6	2.99	1.88	-.11	-6	0	0	0
B7	2.84	2.12	-.62	-34	2.2	.4	-1.8
B8	1.50	1.47	-.03	-6	2.4	1.2	-1.2
B9	3.76	2.00	-1.76	-64	.8	.4	-.4
B10	3.00	3.12	+.12	-6	.7	.4	-.3
Means	2.57	2.19	-.38	-19.8			

$S_R=.59$ $S_I=.57$

TABLE B: DATA OF EXPERIMENT II

Subject	Light RT (sec)			Tone Errors (%)			TICA & Fantasy		
	Reg	Irreg	Diff	Reg	Irreg	Diff	Reg	Irreg	Diff
1	1.63	2.09	+.46	.6	5.6	+5.0	2.17	2.24	+.07
2	1.04	1.55	+.51	1.5	1.2	-.3	2.04	1.88	-.16
3	1.73	1.66	-.07	0	0	0	3.13	2.56	-.57
5	2.37	1.95	-.42	2.7	4.0	+1.3	2.24	2.24	0
6	1.92	1.86	-.06	2.4	2.8	+ .4	2.15	2.40	+.25
7	1.65	2.40	+.75	.7	2.4	+1.7	2.30	2.36	+.06
8	2.25	1.92	-.33	1.5	3.6	+2.1	1.16	1.12	-.04
9	2.76	2.52	-.24	3.6	9.2	+5.6	2.25	2.44	+.19
10	2.07	2.37	+.30	2.0	2.8	+ .8	1.85	1.64	-.21
11	2.88	2.20	-.68	20.2	33.2	+13.0	1.93	1.84	-.09
12	2.71	3.04	+.33	3.5	7.2	+3.7	1.93	1.96	+.03
13	1.98	2.15	+.17	3.2	2.0	-1.2	2.28	2.32	+.04
14	2.19	2.10	-.09	6.3	6.0	-.3	1.95	2.00	+.05
15	2.66	2.40	-.26	2.8	2.8	0	1.68	1.60	-.08
16	1.69	1.16	-.52	.4	.4	0	1.90	1.40	-.50
17	1.94	2.19	+.25	1.8	0	-1.8	2.33	2.40	+.07
18	2.58	2.87	+.29	7.0	9.2	+2.2	3.30	3.44	+.14
19	2.19	2.36	+.17	3.6	6.8	+3.2	2.43	2.84	+.41
20	1.75	1.63	-.12	1.0	1.2	+.2	1.71	1.96	+.25
21	1.00	1.35	+.35	8.1	9.6	+1.5	2.97	2.80	-.17

Direction of change (Diff.) for each variable is taken relative to baseline in Regular condition.

Although there is a wide range of individual differences, examination of the data in Table B shows that most Ss who substantially reduced their reaction times to the lights in the Irregular condition did so at the expense of tone performance. For Ss 5, 8, and 11 Light RT's are substantially reduced, fantasy approximately equal in the Irregular condition, and tone detection errors higher. Ss 3 & 16, who held tone detection performance at a high level in both conditions, markedly suppressed fantasy levels in the Irregular condition.

Analysis of the light detection misses indicates the missed lights were associated with different patterns of attentional choice in the two conditions (Reg. & Irreg.). Table C shows that in the Regular condition missed lights are associated with High levels of fantasy while in the Irregular condition fantasy level does not differentiate those trials in which lights were missed from those in which they were detected.

TABLE C

MEAN FANTASY LEVELS FOR TRIALS
WITH LIGHT DETECTION ERRORS

Condition	n	Trials with missed light	Total population
Regular	24	2.75	2.18
Irregular	25	2.08	2.17

If tone performance is taken into account it becomes clear that missed light trials are also poor tone performance trials. Table D indicates that in both Regular and Irregular conditions the probability of a trial which contained a light detection error also containing a tone detection error is about double the population mean.

TABLE D

% TRIALS WITH TONE DETECTION ERROR FOR
TRIALS WITH LIGHT DETECTION ERRORS

Condition	n	Trials with missed light	Total population
Regular	24	50%	21.6%
Irregular	25	50%	28.2%

Recalling that in the Regular condition fantasy was also exceptionally high in missed light trials we may conclude that attention was withdrawn from tones and light processing and deployed to increased processing of LTM and fantasy. However, for a similar sample of missed light trials in the Irregular condition, we find both tones and fantasy being processed less as well as lights. Thus, in these Irregular trials all three indices of attentional processing are lower than in a comparable sample of Regular trials. This analysis further supports the conclusion reached in Experiment I - that the effectiveness of simultaneous multi-channel processing is dependent on the predictability of the information in those channels.

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