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Relative discriminability of configuration and brightness differences in a monitoring task

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RELATIVE DISCRIMINABILITY OF CONFIGURATION AND BRIGHTNESS DIFFERENCES IN A MONITORING TASK

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ABSTRACT

RELATIVE DISCRIMINABILITY OF CONFIGURATION
AND BRIGHTNESS DIFFERENCES IN A MONITORING TASK
(June 1977)
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Various models have been hypothesized in an attempt to explain the information processing of two or more simultaneously encountered stimuli. These range from a serial model, in which the rudimentary physical characteristics of only one stimulus can be analyzed at a time, to a parallel model in which the only interference occurs at the response stage. A third type of model seperates stimulus variables into two classes, one of which requires serial processing, while the other has no apparent capacity limitations.

The purpose of the present set of experiments was to detect any qualitative differences in processing demands between two stimulus variables, each of which was assumed to belong to a different class.

A monitoring paradigm was used in which Ss had to detect either a change in line configuration or a change in brightness. The targets could appear in either or both of two separated fields of letters, thus allowing control over devision of attention. Percent correct and error rate were used to measure Ss' monitoring ability as a function of type of target, number of targets, simultaneity of targets, homogeneity of targets, and distance between targets.

Clear, qualitative differences were found in processing demands between the task of detecting a target differing in line configuration from the noise elements, and the task of

detecting a target differing in brightness from the noise elements.

The results clearly support a model in which some stimulus variables can be processed in parallel with no apparent attentional control by the Ss, while others require serial processing and apparently use capacity.

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Recently, psychologists have devoted a considerable amount of research to addressing the issue of "division of attention among concurrent streams of mental activity." (Kahneman, 1973).

It is true that the human organism is sometimes capable of performing several activities in parallel, such as holding a conversation while driving. In this case, it would seem that attention is divided between the two activities. It has been established, however, that often responses to two simultaneously presented stimuli are made in succession, or serially, rather than in parallel. At other times, only one response occurs indicating that one stimulus has been perceived, while the other has not been processed to the point where a response is elicited. Any model of sensory information processing, therefore, must incorporate a bottleneck, a point at which only one stimulus is processed at a time. The three major models do account for this bottleneck, but they disagree as to where in the system parallel processing ends and serial processing begins.

If material is not attended to, is it simply rejected without any analysis at all, or does some analysis take place before rejection occurs? A common experience is the "cocktail party phenomenon" in which a non-attended conversation suddenly becomes significant enough to attract your attention (Cherry, 1953). This observation leads to the conclusion that non-attended material is processed to at least some degree. The three models differ then in answering the question of how much processing has occurred.

The three models are in general agreement as to the order of analysis through the system. A stimulus enters the system through the receptor organ, and then it undergoes an encoding process in which its rudimentary physical characteristics are analyzed. The stimulus then makes contact with memory, where a naming process occurs. It then passes on to a point where mental operations such as rehearsal, logic and higher-order semantics come into play. At this point a decision is made and a response is elicited.

If, however, there are more than one stimulus entering the system concurrently, and only one response is elicited, the models disagree as to how far the non-attended stimuli have been processed.

The first model is a single-channel limited-capacity model. According to this model, there is only one source of information monitored at any one point in time. Since there are many possible sources of sensory information, it is assumed that attention must be rapidly switched among them.

According to this model, stimulus analysis takes capacity, therefore the bottleneck occurs at or before the stimulus stage. Minimal analysis of the nonattended material, based on physical characteristics takes place, but no memory contact is made. Only one stimulus can be perceived at a time.

Broadbent (1958) summarized a large area of the research in attention and information processing and proposed his "filter theory" in an attempt to provide a unified explanation of selective attention. Specifically, several messages simultaneously reaching the senses are initially processed in parallel. However, as the stimuli converge on the perceptual analysis stage (which has limited capacity) the load of information must be reduced. This reduction is taken care of by selective filters which block irrelevant messages. As a result, the number of signals that can be stored in LTM or used in influencing behavior in any short time period is limited. All elements initially registered are available for a specific amount of time, after which none are available.

Broadbent's filter theory, originally proposed as a result of his auditory experiments, has been supported by data obtained by Franzen, Markowitz and Sinets (1970) in experiments on near-threshold vibrotactile information, and by Estes and Taylor (1966) in experiments on visual processing.

In Estes and Taylor, two symbols (consonant letters) were designated as critical elements and the rest as noise elements. Each trial consisted of a 50 msec. display of a number of discrete

letters on a tachistoscope. One of the critical elements was present in each display and it was up to the subject to indicate which one was present. The results indicated that efficiency among Ss was variable and the proportion of correct detections decreased significantly as display size was increased.

To explain these results, Estes and Taylor concluded that there is some point in the processing where each element in the tachistoscopic display is reacted to individually. That is, although the elements are registered simultaneously on the retina, there must exist a channel which permits passage of only one element at a time-a channel similar to Broadbent's filter.

Specifically, they make the following assumptions in suggesting this model. First, when a display, consisting of discrete elements is presented for a short time, a subset of the elements is registered in the receptor apparatus. Secondly, there is an inverse, exponential relationship between the time since exposure, and the traces of the display in the nervous system. Therefore, knowing the time since exposure, it is possible to calculate the probability that the traces have passed below the threshold level, and will not influence behavior. Thirdly, the subject scans the display elements one at a time, classifying each one as a noise or as signal. If the subject has scanned a signal element before the stimulus traces fall below threshold, s/he will make a correct report; if s/he has not had time to scan a signal element, the subject will report a random guess.

Estes and Taylor, although unable to develop another model to fit their data, warn that this serial processing model, where processing is on an all-or-none basis, should not be taken to be more than a provisional and incomplete model.

Franzen, markowitz and Swets (1970) conducted two experiments, the results of which they feel support this single-channel model. The procedure in both experiments was similar. The index finger and the middle finger were placed on discs which could be made to

vibrate. Either one or two discs were made to vibrate with equal probability, and the subject had to make a forced choice as to where the vibration occurred. The dependent variable was the proportion of correct responses.

In Condition 1, the subject knew exactly which finger or fingers would be stimulated; the signal was constant throughout a block of 100 trials. The results were consistent with a model in which the subjects could attend only to inputs in a single channel at any one point in time.

The second condition consisted of a procedure the authors called "signal specified statistically"; that is, it was randomly determined whether one or two fingers would be stimulated, with the probability of the three kinds of stimulation being equal. The results of this condition showed that the probability of a correct response when both fingers were stimulated was greater than for either finger alone. Since these results were not consistent with a single-channel model, (the authors explain the discrepancy as a result of learning) a second experiment was conducted in which the two conditions were counter-balanced.

For Experiment 2, which used new subjects, six groups of 150 trials were presented each day. There was one block for the index finger alone, one for the middle finger alone, one for both fingers, and three blocks in which the signal was specified statistically. These six blocks were presented in a random order.

The results again showed evidence of spatial summation. However, the authors explain this away by claiming that this difference between two-finger and one-finger sensitivity reflects a decrement in the performance of the signal finger. The authors also conclude that their results can support the model if it is applied to weak signals only.

Treisman (1969) points out a few examples of results that are not explanable by Broadbent's filter theory. First, subjects are only able to follow one passage of prose if two are presented simultaneously, one to each ear. However, a single passage presented

at twice the normal rate of speed is able to be understood by the subjects. Secondly, when two auditory messages are presented dichotically, the subjects are able to repeat back one, with very little interference from the other. However, if printed words are presented which are the names of specific colors, but are themselves different colors, there is much interference (Treisman, 1969).

Furthermore, in dichotomous listening experiments, Treisman (1960) found that meaningful words in the nonattended message can elicit responses, thereby overcoming the block imposed by the shadowing task. Also, when the context of the message was switched from the attended ear to the unattended ear, intrusions sometimes occurred. These results suggest that the bottleneck could not possibly be an all-or-none filter as claimed by Broadbent.

Furthermore, evidence for this model relies heavily on an observed direct relationship between amount of information transmitted and reaction time. Seibel (1963) and Mowbray and Rhoades (1959) were able to show, however, that with enough practice, RT did not vary with the number of alternative stimuli.

Does the amount of time used to process a stimulus really reflect the attentional demands that the stimulus places on the system? If processing demands can be characterized in terms of both time and capacity, then the answer is no. Perhaps a specific task requires time, but may not use capacity.

The serious objections which have been raised to this model (too all-inclusive, misinterpretation of specific phenomenon) and the relatively clear-cut examples presented by Treisman which contradict this model suggests that it is not a feasible explanation of the flow of information through the system. Even Estes and Taylor, who could not fit their experimental results into any other model, concede that this all-or-none model is indeed limited and should only be used as a stopping off point in devising new models of sensory processing.

In the second model, a parallel, unlimited-capacity, non-attentional model, there are assumptions of only minor limitations of capacity and no attention during perceptual processing. It assumes no spatial limitations at the perceptual level. All stimulus items are processed simultaneously by independent, parallel channels, therefore, the perceptual efficiency for any given stimulus does not vary as a function of the number of items being processed. Any attentional effects are attributed to characteristics of short-term storage which follow the perceptual processing.

Stimulus analysis and memory contact occur automatically and in parallel. There are no capacity limitations or selection until the mental operations stage is reached. Therefore, two concurrent stimuli will make contact with memory and their meaning will be extracted simultaneously and without interference regardless of which one is attended to.

This model was originally proposed by Deutsch and Deutsch (1963) based on data from auditory experiments. Eriksen and Spencer (1969), Gardner (1973), Shriffin and Gardner (1972), Corteen and Wood (1972), Posner and Boies (1971), Donderi and Zelnicker (1969), and Egeth, Jonides and Wall (1972) have claimed support for this model as a result of data obtained in experiments on visual processing and general sensory processing.

In Deutsch and Deutsch (1963), where this parallel, unlimited-capacity model is proposed, they start with the observation that complex discrimination mechanisms are necessary in order to select wanted from unwanted messages. They proposed such a mechanism which assumes the existence of a shifting reference standard, which takes up the level of the most important arriving signal.

How is information processed when it is being simultaneously emitted by two different sources? How are different streams of information kept distinct by the nervous system? Proposed answers are that messages can be kept distinct because they are processed

by different channels (such as different neural pathways), or that items are selected for attention because they have some features in common (such as their frequency spectra). Both of these solutions require a relatively simple mechanism for these discriminations.

Secondly, after the messages have been kept seperate, why is only one dealt with at a time? Broadbent's proposed filtering mechanism would select a message on the basis of the characteristics that the filter has been biased toward. As a result, a whole complex message could be rejected and therefore ignored because it possessed some specific single quality.

Further experimentation, however, seems to indicate that the selection task is really much more complex. For example, it was found that the amount of interference is a function of the similarity of the message. Other evidence indicating that Broadbent's filter would need to be capable of highly complex discriminations was obtained from experiments concerning the selection of novel stimuli, and effects of habituation.

On the basis of the above, Deutsch and Deutsch postulate an additional complex discrimination system, below or at the level of the filter. As a result of this evidence, they are led to the conclusion that these perceptual and discriminatory mechanisms are able to group and segregate information, whether attention comes into play or not.

This leads one to ask how might the most important of a group of signals be selected. The most economical system would be the following: suppose there are signals, varying in some dimension, which corresponds to their importance to the organism. Now further assume that as each signal arrives it will push some "level" up to its own level of importance. Thus, at any particular time, the most important signal will be the determiner of the level. If a signal of lesser importance arrives, it will not come up to this level, and will therefore have no effect on behavior. Conversely, if the signal of greatest importance leaves, the level will sink to a level

reflecting the importance of the next highest signal. Only the most important signal coming in will be acted upon, and furthermore, more important signals will be able to break in and displace previously important signals. Here we have a mechanism that will display the type of behavior associated with attention.

Shriffin and Gardner (1972) have added evidence which they feel supports the model proposed by Deutsch and Deutsch. Their paper concerns itself with three experiments testing whether visual processing operates under attentional control, and with temporal-spatial capacity limitations.

They propose to answer the following questions: "Can the amount and rate of information processed from a briefly presented image at a given location in the visual field be varied by the subject voluntarily?... Is the information processed from a given location of a briefly presented display affected by the simultaneous processing of information from other locations in the display?"

In the experiments, a four-letter display was presented briefly and the subjects had to identify which of two key letters (F or T) was present. In the simultaneous condition, the letters were presented concurrently for 50 msec., preceded by a masking field for .4 seconds, and followed by a masking field until a response was made. The conditions of the sequential conditions changed between experiments. In all sequential conditions, the subjects were given the onset order of the four letters.

If a model postulating attentional control and limited capacity were at work, then the result should show an advantage for the sequential condition - since in the simultaneous condition processing capacity must be shared among the four letters. This was not the case, however. In all three experiments, the simultaneous and sequential conditions did not differ significantly. As a result of these experiments, Shriffin and Gardner concluded that information is processed, at least to the level of letter recognition, without capacity limitations and without attentional control.

Lappin and Ellis (1970) point out, however, that the performance limits found in this type of experiment "primarily reflect the limitations of immediate memory; that is, the limited quantity of information that can be retained in short-term memory after recognition, and not the characteristics of the recognition process itself." They set the performance limits at five items. The conclusions of Shriffin and Gardner, therefore, are expected considering that their display of four items did not tax the limits. Perhaps the recognition of the four letters did not occur simultaneously, but in a serial manner rapidly enough to effect performance.

Another interpretation is possible. Perhaps the noise elements are rejected not because of what they are, but because of what they aren't. The target element must itself be processed to at least the identification stage. The noise elements, however, need not be identified except as non-targets.

Eriksen and Spencer (1969) also claim support for a non-attentional model. The display in their experiments consisted of a circular array with ten letters, presented one at a time, in a random sequence, in random positions in the array. The critical variable was the time between successive letters (ISI). It was hypothesized that when the ISI was very short, any limitations on processing capacity would come into play, and processing capacity would have to be shared among the ten letters. Conversely, when the ISI was long, no processing limitations should be encountered because every letter could be processed separately. However, this was not the case. Detection performance was identical for an ISI of 5 msec. as for an ISI of 3,000 msec. The results were taken to imply an unlimited-capacity system.

In an experiment by Donderi and Zelnicker (1969) and replicated and confirmed by Egeth, Jonides and Wall (1972), Ss were presented with tachistoscopic displays of geometric forms. In half of the trials all the forms were identical, the rest used a display with one disparate form. The task was to indicate which type of array

occurred. As the number of discrete forms in the array was increased, the RT remained the same for both types of displays.

Both of these examples provide data which the authors feel support a model in which each element in the stimulus display is processed by a separate, independent channel. However, the data can be explained in terms of a limited capacity model. Suppose that all stimulus items are analyzed at a perceptual level simultaneously, but noise items are recognized earlier in the system than target items. Capacity could then be switched from the noise elements to the critical elements. There would be no interference, then between noise and target items at the stage of mental operations, since only target items would have been processed this far. Thus, it would be expected that performance would not be affected by a reduction in ISI or an increase in the number of noise elements.

Corteen and Wood (1972) conducted a dichotic listening experiment, the results of which they interpret in terms of the Deutsch and Deutsch model. A message (the attended material) which the Ss were to shadow was presented in one ear. Material was presented to the unattended ear, and embedded in this material were city names which were previously shock-associated, non-shock associated city names, and control words. Their first result showed that shock-associated city names produced a significant number of autonomic responses, even though they occurred in the non-attended channel and Ss were not aware of them. Secondly, non-shock associated city names produced significantly more autonomic responses then control words. These city names, although not shock-associated, were of the same class as the shock-associated words. This finding suggests that the parallel processing of the attended and the non-attended material made contact with memory and furthermore, reached the level of mental operations. Some analysis of its semantic had occurred; the material was assigned a word class and that class was assigned some significance. Presumably,

all of this analysis occurred without the material reaching a level of conscious awareness.

The first finding is not in conflict with a limited-capacity model. The shock-associated city names were obviously previously heard by the Ss. Therefore, the responses to them could have been based solely on acoustical properties. This implies that the attended and the non-attended messages could have been processed only in parallel as far as a perceptual analysis stage, and the unattended message was attenuated prior to its recognition or contact with memory.

The second finding, however, suggests that analysis sophisticated enough to put the word in a category and to assign significance to that category occurred in the unattended channel, without awareness on the part of the Ss. There was no apparent shifting of attention from the attended to the unattended message.

There are a number of alternative interpretations of this result, however. The conclusion that the words producing autonomic responses did not reach awareness is based on two observations. First, S's shadowing of the attended message was not impaired when a non-attended word produced a response. Since Lewis (1970) found slower shadowing reaction time when the word in the non-attended ear was the same as the word in the attended ear, Corteen and Wood assumed that no impairment in shadowing indicated no awareness of the unattended message. This is not an absolutely necessary conclusion, and furthermore, Corteen and Wood did not measure latency as did Lewis, but rather omissions and errors. Secondly, Corteen and Wood questioned the Ss about their awareness of the unattended message after the experiment was complete. This lack of memory so long after the actual presentation perhaps would not have occurred had they been able to question the Ss immediately after the presentation of the response-producing non-attended word.

Suppose, however, that their conclusions about non-awareness are accurate. They are claiming parallel processing and no interference for two stimuli presented simultaneously.

Although Corteen and Wood equated volume and rate of presentation of the two messages, the messages differed in at least one important way. The attended message was read by a female, while the unattended message was read by a male. Treisman (1964c) found that if two simultaneously presented messages differ in voice quality, they can be more easily separated than two messages read in the same voice, and attention can be shifted from one message or channel to the other. There was certainly a difference in voice quality between Corteen and Wood's messages, possibly allowing them to be easily separated by the Ss.

Posner and Boies (1971), in an attempt to detail the processing requirements of a letter-matching task, gave Ss a secondary task of responding to a burst of white noise. A presentation consisted of a warning signal, followed by one letter, then a second letter. The S's task was to press a button if the letters had the same name, and to press the same button with a different finger if the letters had different names. In one experiment, within each pair of letters, one was uppercase and one was lowercase, assuring that a decision as to their sameness could only be made after the letters were actually named. In the second experiment, on half of the trials, the letters differed in case, but the other half used letters that were physically identical.

The Ss were told that the letter-matching was the primary task, and they were given feedback for each trial as to their accuracy and RT. There was also a secondary task. On half of the trials in each experiment fifty decibels of white noise was presented to the S's left ear. The Ss were instructed to concentrate on the letter-matching task, but if they heard the white noise they were to press the button with a finger of the other hand.

Posner and Boies claimed three interesting results based on a consideration of RT to a probe as a function of the eight possible probe positions. First, RT to a probe occurring before

the warning signal was longer than for a probe occurring between the warning signal and the presentation of the fist letter. This indicates that a S who was already prepared for the primary task would have a faster probe reaction time, even though it was made clear that the warning was for the letter-matching task. It seems reasonable, however, that it would be difficult for a S in a state of readiness to inhibit a resonse to the auditory stimulus to maintain preparedness for the visual task.

Their second finding was that a short probe RT could be obtained for at least 300-500 msec. after a one second presentation of the first letter. However, when the exposure time of the first letter was .5 seconds, RT to the probe increased immediately after presentation. This data, combined with encoding functions obtained from other experiments (Posner and Boies, 1971) led them to tentatively conclude that the first letter was encoded before the probe could cause interference. Therefore, the two signals were processed in parallel, at least until the letter was encoded.

Thirdly, RT to a probe was longest when it just followed the presentation of the second letter. This suggests that the attention demands for the visual task are greatest at the response stage. At this point mental operations have already come into play, and it can be assumed that not only does encoding not require capacity, but a contact has been made between the visual stimuli and long-term memory without any attentional demands.

Posner and Boies have claimed to delineate the processing requirements of the letter-matching task by use of the probe. A possible alternative explanation, which they offer themselves, is that Ss were shifting their attention between the primary and the secondary task. In this case, processing of the two stimuli (visual and auditory) would be actually occurring serially rather than in parallel. In order to test for this, they conducted another experiment identical to the condition where the letters differed in case, except that the exposure time of the

first letter was shortened. Even when the first letter was presented for only 50 msec. there were few errors in the matching task. Posner and Boies concluded from this that the Ss were not switching their attention. Furthermore, the obtained functions of probe RT by probe position were similar to those previously obtained. From this they concluded that the probe RT is indeed sensitive to the processing demands of the visual task.

One major criticism of Posner and Boies' conclusions concerns their methodology. The two stimuli were in different modalities; the letter-matching task was visual while the probe was auditory. Is the probe RT by probe position function really indicative of interference between the two stimuli? Perhaps the two tasks were qualitatively different in that the processing of the white noise can occur without attention and the processing requirements are only due to the primary task. If the processing of white noise takes no capacity, then it can occur in parallel with the processing of any other task.

This assumption that stimuli differ in their attentional demands leads to the third type of model of sensory information processing. The Broadbent model and a model such as that proposed by Deutsch and Deutsch can be seen as the two possible extremes. The first assumes complete serial processing after the rudimentary physical analysis, while the latter claims parallel processing at least until the stage of memory contact.

There seems to be no reasonable evidence that an unattended message is rejected before its contents are analyzed, and Broadbent's theory seems rightly to be abandoned. Furthermore, the major evidence for the Deutsch and Deutsch position can be interpreted in other terms besides purely parallel processing.

The third type of model has many variations but all can be seen as a compromise between the two extremes. Instead of a single channel, there could be a multi-channel, limited-capacity system. In this case processing capacity would still be limited,

bur information could be serially processed from many channels simultaneously. The amount of information processed for a particular channel would be determined by the attentional control of the S.

Anne Treisman (1969) reviewed experiments on selective attention and distinguished four types of attentional strategies: "The first restricts the number of inputs analyzed; the second restricts the dimensions analyzed; the third the items for which the S looks or listens; and the fourth selects which results of perceptual analysis will control behavior and be stored in memory." She proceeded to explore the role of these mechanisms in various experimental tasks and assessed their relative importance and efficiency. She concluded that if there are a number of separate analyzers, providing mutually exclusive descriptions for a stimulus and consequently independent judgments about different dimensions of a stimulus, the parallel processing of such simple stimuli as color, size, brightness and shape are easily explained. However, the hypothetical system is not sufficient when attemptin to explain complex or multidimensional patterns such as faces or spoken words.

This dichotomy between "simple" stimuli and "complex" stimuli is reflected in a model proposed by Neisser (1966) which accounts for both spatial localization and visual discrimination. Neisser proposes a "preattentive" system, analyzing spatial relationships, and a "focal attentive" system, analyzing information about the identity of physical objects in space.

Neisser characterizes the focal attentive system as a serially operating system which produces an identification of a stimulus based on both a detailed analysis and memory. The processes of focal attention cannot operate on the entire visual array simultaneously, but only after preliminary operations have already segregated the figural units involved. The preattentive system, which responds selectively and in a parallel manner, to stimulus

variables which are more global, performs these preliminary operations.

This dichotomy between global stimuli and focal stimuli is not arbitrary. Recent neurophysical, behavioral and information processing investigations has yielded evidence supporting a model of two independent but well-coordinated visual systems, each of which is sensitive to different aspects of visual information. A consideration of the biological significance of such a model is compelling. An organism must be able to function within its environment, and sensory information provides the means for it to do so. It is not only necessary for an organism to be able to identify physical objects in that environment, but it must have a sense of the spatial position of those objects in relation to itself. The visual system, therefore, must be able to analyze content and spatial relations between the organism and its environment.

Ingle (1967) suggested that visual processes which enable fish to orient to a moving object are clearly distinguishable from processes which enable the fish to evaluate the identity of the object. One is a shape-analyzing process, while the other is an orientation process.

Held (1968) experimented with kittens in order to investigate the relationship between the feature analyzing system and the orienting system. In visual deprivation experiments, he gathered evidence suggesting that there is one system for form analysis and a separate system for visually-guided motor behavior. When there was binocular deprivation of pattern stimulation, visually-guided motor behavior was grossly affected, while the processes for form analysis were unaffected.

Held characterizes the feature analyzing system as being capable of extracting properties that remain invariant over a wide range of sizes, orientations, distortions, illuminations and hues, while this is not true of the orienting system.

Sceneider (1967) reported dissociation of spatial localization (visually-guided orientation) and visual discrimination by means of brain lesions in the golden hampster. After ablation of the superior colliculus, the hampsters were still capable of pattern discrimination, but were completely unable to orient to the positions of the visual stimuli. The opposite effect was produced by ablation of the visual cortex; that is, the hampsters were able to visually localize an object in space, but failed to discriminate visual patterns.

The hypothesis that there are anatomically distinct brain mechanisms controlling vision of space and vision of object identity led Trevarthen (1968) to conduct studies with primates. His work led him to suggest two processes. The first he termed "ambient", or extensive, that is, determining space around the body. The intensive or "focal" system would control the examination of details in small areas of space.

Neisser (1964) investigated the cognitive operations involved in looking for specific target digits, letters or words in a list, by timing the scanning process. Plotting position in the list against the time needed to find the target yields a linear function. The slope of such a graph indicates the increase in search time necessary for each additional item in the list which is scanned.

After practice, the Ss were able to scan the lists at about ten lines per second, whether they were looking for one specific target or a target from a set of four possible targets. These data indicate that visual search can involve a number of processes carried out simultaneously. This seemingly surprising result can be explained quite readily if one considers that scanning involves a relatively low level of cognitive analysis.

It is necessary for the subject to extract enough information from the non-targets to at least make a judgment that they lack

properties that characterize the target. In this sense, the content of the non-target element is "seen", but not well enough for the S to choose a non-target from a pair of non-targets in the list. Furthermore, the Ss' subjective reports indicated that they did not identify the non-targets to determine if they were targets. The non-targets were processed only to some intermediate stage.

The processing that precedes the actual identification of the target need only detect physical features of the non-target (eg. curved lines, particular angles) to determine if these features are those characteristic of the target. Identification need not take place in order for a non-target to be rejected. Nothing takes place at the level of letter naming until the actual target is found.

This leds Neisser to hypothesize that there is an hierarchy of information processing operations. Perceptual analysis seems to have many levels, carried out by many separate mechanisms. The elementary mechanisms assimilate and predigest the information (pre-attentive level), and then pass this information on to more complex mechanisms (focal attentive level). This suggests that inspection may be terminated after feature formation and before identification, and that some of the processes occurring at an early stage are most likely parallel rather than serial.

In a later experiment, Neisser again had Ss search through word lists; however, the targets were sometimes defined in terms of their meaning.

When targets are defined by their meaning rather than their figural properties, stimulus examination alone is not sufficient to discriminate between the target and the non-targets. Processes involving stored information are also necessary. Neisser termed this process "memory examination". In order to insure

that memory examination was used, it was necessary to use target sets containing enough elements so that it was impossible to establish the figural properties beforehand.

The major hypothesis to be tested; that is, that for targets such as single words and letters (which presumably can be distinguished by stimulus examination alone), the scanning rate would be faster than for target classes defined by their meaning, was decisively confirmed. In these experiments, then, Neisser was able to operationally define two discrete levels of cognitive complexity.

Beck (1972) maintained that similarity grouping depends on specific stimulus properties picked up prior to focal attention; that is, that grouping involves the simultaneous discrimination of stimulus differences prior to a narrowing of attention. It is possible, therefore, that grouping is an operation involved in preattentive processing and occurs most strongly for those variables that guide fixation and to which the preattentive system is highly sensitive.

Work by Hubel and Weisel (1962) suggests that the analysis of the configuration of a stimulus requires information about the slopes of the lines making up that stimulus. Therefore, the analysis of the slopes of lines is made relatively early in the system.

Beck's work indicates that slope is indeed a global variable, while line arrangement is a stimulus variable that requires finer discriminations and thus focal attention. These findings led Beck and Ambler (1972) to do a number of experiments investigating the relative discriminability of figures differing in line slope and figures differing in line arrangement.

In the first of these experiments, the basic experimental manipulation was the interval between the offset the stimulus array and the onset of a post-stimulus mask. According to the hypothesis, the sooner the mask follows the stimulus display, the less the subject is able to attend to individual letters;

that is, the shorter the masking delays, the more discriminability would be based on distributed attention. To insure that the subjects' attention was distributed across the entire field, they were given no information as to where to expect the stimuli.

If a difference in line slope is more easily discriminated than a difference in line arrangement when attention is distributed, the discrimination between a T and a tilted T (representing a difference in line slope) should be significantly better than the discrimination between a T and an L (representin a difference in line arrangement) when shorter intervals are used between the stimulus and the mask.

The mean errors for an L increased more than the mean errors for a tilted T when shorter delays were used, indicating that the discriminability of a tilted T improved relative to the discriminability of an L.

The second experiment in Beck and Ambler (1972) was designed as a control for the interpretation of the results of the first experiment. The basic experimental manipulation was the duration of the stimulus exposure. Reducing the exposure duration may be expected to reduce the adequacy of a stimulus, but at the exposure times used (25-55 msec.) does not seem to change the time available for the inspection of the fading visual trace (Sperling, 1960; Mackworth, 1963). Beck and Ambler hypothesized, therefore, that as the exposure duration is reduced the discriminability of the tilted T's and the L's should both decrease, since the visual trace is less clear, but the discriminability of the tilted T should not improve relative to that of the L.

The results were as expected, suggesting that there is a fundamental difference between the effects of reducing the stimulus exposure and reducing the masking delay. Reducing the exposure time produces a qualitatively poorer visual trace which impairs the discriminability of tilted T's as much as L's.

However, it seems that reducing the delay of the masking field not only decreases the quality of the visual trace, but also affects the processes of analysis; that is, determines whether there is enough time for focal attention to come into play.

Beck and Ambler presented a third experiment in the same paper. Whereas in the first experiment six letters were presented around an imaginary circle, in this experiment only one letter was presented in any one of the same six positions. The Ss' task was to decide whether the stimulus element was a T or a tilted T (in one condition) or a T or an L (in the other condition). In this case, the difference in brightness between the figure and the background directed the Ss where to attend.

Since the attention in this situation is focused rather than distributed, a model such as Neisser's would predict that the relative discriminability of the L and the tilted T would not vary as a function of masking delay. The results obtained by Beck and Ambler support this hypothesis.

Beck and Ambler (1973) reported two experiments designed to further compare the peripheral discriminability of targets differing in their line slope and in their line arrangement. The stimulus consisted of an array of eight letters arranged around the circumference of an imaginery circle. The array could consist of eight T's, or it could have an L or a tilted T as a disparate element. The Ss' task was to indicate whether a disparate letter appeared or not. Both the exposure duration and the masking delay were 50 msec.

Dot indicators were presented 150 msec. before the onset of the display, and the subject was told to attend to the positions where the dot indicators appeared, as these were the possible target positions. The distribution of attention was controlled by varying the number of dot indicators.

There were five conditions. In Condition 1, there was only one dot indicator, enabling the Ss to focus their attention. In Condition 2, there were two adjacent indicators, and in Condition 3, there were two indicators separated by the diameter of the circle. Condition 4 required the maximum distribution of attention with eight indicators. Condition 5 also had eight indicators, but the masking delay was extended to 320 msec.

The results of this experiment were consistent with Beck and Ambler (1972), and a two-stage model of visual processing. The results showed that: 1) Increasing the number of indicators adversely affected the discriminability of an L but not a tilted T. 2) There was no inherent discriminability difference between L's and tilted T's. 3) The discriminability of an L varied with the number of locations that needed to be simultaneously processed, and not their spatial proximity.

The second experiment reported in Beck and Ambler (1973) was concerned with relative reaction times in discriminating L's from T's and tilted T's from T's. The stimulus display consisted of two imaginery circles, the inner one having six positions, and the outer one eight positions. Again, the background consisted of upright T's and the target was either an L or a tilted T. The results show that for all conditions, the mean reaction time was less for tilted T's than for L's.

The principle finding of this group of experiments was that, in peripheral vision, with distributed attention, a tilted T is more easily discernible than an L. When attention was focused, however, the discriminability of these two targets was about the same.

These results suggest that line slant is a stimulus variable to which the visual system is highly sensitive; a stimulus variable which may be processed pre-attentively, in

parallel. Line configuration, on the other hand, appears to be a property which is processed serially, and only after focal attention has come into play.

In a set of experiments designed to investigate perceptual dependence, Baron (1973) found evidence for successive processing stages. In one such experiment, subjects were asked to indicate the position of a letter in a visual array, and to make a judgment about the sound of the letter (eg. does it rhyme with E?). It was found that these two factors were dependent. When the position discrimination was incorrect, the judgments about the sounds of the letters were at chance level. When the position of the letter was correctly indicated, however, the subjects performed significantly above chance on the sound discrimination.

According to a two-stage model, this result is expected. The sound of the letter when pronounced is a higher order property of the stimulus than is location. The information about the sound of the letter requires focal attentive processes, and does not become available to the subject prior to information about location. It seems necessary to postulate two systems or at least two levels in the visual system. Furthermore, the empirical evidence points to two separate, independently operating, but well-coordinated systems.

The evidence characterizes the first system (pre-attentive, locus, orientation) as wholistic, sensitive to lower order stimulus variables, possibly functioning in parallel and controlled by the colliculus. The second system (focal-attentive, content), possibly controlled by the cortex, is a hierarchical feature analytic system, particularly sensitive to details, and operating serially.

The present set of experiments employs a paradigm designed to further differentiate between the processing demands of focal and pre-attentive stimuli.

A change in brightness is a variable which is more global than focal, more "ambient" than "intensive" (Schneider, 1967), providing orientation as opposed to shape analysis (Held, 1968). On the other hand, evidence suggests that a change in line configuration is a variable which would require focal attention (Hubel and Weisel, 1962; Beck and Ambler, 1972, 1973). These two variables, therefore, were chosen as representative of the two distinct classes postulated.

The per cent correct and error rate of Ss attempting to detect a target letter in a field of background elements was assumed to be a measure of the processing demands of a change in line configuration. Pre-attentive demands were tested by having the Ss detect a letter which differed in brightness from the background letters.

A guarantee of divided attention was designed into the paradigm by presenting two fields of letters which had to be monitored simultaneously. The letters in a specific field were presented one after another, but all in the same location on the screen. Division of attention, in a spatial sense was controlled by varying the distance between the two fields of letters. The effect of a temporal division of attention was tested for by having the targets sometimes appear in both fields simultaneously.

Experiment 1

Experiment 1 was designed to test for any differences in processing demands for focal versus pre-attentive stimuli, under conditions of divided attention, both spatial and temporal. Specifically, if the Ss' ability to detect a change in line configuration in a single field is equated through experimental manipulation to the detectability of a change in brightness in a single field, what effect on error rate and per cent correct detection will the addition of a second target have? Furthermore, is there an effect due to the type of target in that second field relative to the original target type?

Any differences in demands for the two target types resulting from a temporal division of attention were tested for by having targets sometimes appear in both fields simultaneously.

Method

Subjects

Twelve undergraduates enrolled in Psychology courses at the University of Massachusettes served as subjects. They were volunteers who recieved some credit for their experimental participation.

Apparatus

The stimuli were presented on a HP 1300 Oscilloscope operated by a HB2114B computer which selected the stimulus display and recorded hits and false alarms. The Ss' responses were made on two keys separated by 9.5" mounted on a 12" by 14" keyboard.

Presentation of Stimuli

The stimuli were simultaneously presented pairs of letters chosen from a letter set including T,F,E,H,I and L. The letters, in both fields were presented one after another at a rate of 225 msec. Alternating with the letters was the character "$" which served as a mask.

The two fields of letters were 2.5" apart, this separation subtending a visual angle of $2^{\circ}5.64'$. The letters, as they appeared on the screen, subtended a visual angle of 14' horizontally, and 21.3' vertically. The order of presentation of the letters was randomly determined within the restrictions of the design. A white dot was displayed halfway between the two fields of letters, on which the Ss were instructed to fixate.

Each block of trials consisted of 324 presentations of the pairs of letters. There were five types of trials as follows: (FA) focal target alone, in which both fields were presented but the S had to respond to an "F" occuring in one field, while ignoring the other field; (BA) bright alone, in which the S was instructed to respond to a bright letter in one field while ignoring the other field; (M) mixed, in which the S was instructed to respond to an "F" in one field and a bright letter in the other; (FF) double focal, in which the Ss were responsible for detecting an "F" in either field; and (BB) double bright, in which the S responded to a bright letter in either field. Each of these conditions were counterbalanced between the left and the right fields.

Procedure

Each S was tested individually on eight test blocks. Each S was run in exactly the same conditions, with order of presentation counterbalanced across Ss.

The S was seated at a table five feet from the oscilloscope screen. The response keyboard was on the table directly in front of the S. The lights in the room were on full.

The targets were indicated on the screen before each block of trials, and the S began the block at will by pressing a key. The Ss were instructed to respond to targets in the left field by pressing the left key with her/his left index finger, and similarly for the right field.

Within a trial block, there were nine targets presented in each field, with three of the targets occurring simultaneously and six of the targets occurring successively. There was no feedback to the Ss during the experiment. They were not told how many targets would occur nor how many would be presented simultaneously. Ss were asked to respond as quickly as possible, while neither anticipating the response nor making too many errors.

The Ss were asked to respond to several stimulus pairs while the E was in the testing room. Ss were then exposed to a practice block. The E then checked the hit and false alarm rate to insure that the Ss understood the directions.

After practice, a block of (FA) trials was presented. The per cent correct was then calculated to determine whether more practice was necessary, with 75% as the cut-off point. When the S was performing up to this criterion, a (BA) trial was presented. The brightness of the target letter was varied by the E until the S was performing equally well on (BA) as on (FA). After the brightness value for a particular S was determined, the testing session was begun.

Each S was tested under all possible conditions FA,BA,FF,BB and M; with all possible targets presented in both the right field and the left field. For example, in Condition M, there was one block with the S responding to target "F" on the left and a bright letter on the right, and one block with the

targets reversed. At the conclusion of the testing sesion, the Ss were given a brief idea of the purpose of the experiment and were asked for any comments.

Results

Analysis of variance was used to examine the effects of the four critical variables: (N) number, either single or double fields; (T) target type, either an "F" or a brightness change; (S) simultaneity, either simultaneous or successive targets; and (H) homogeneity, either same targets or different targets.

Three separate analyses were conducted; one comparing the single conditions to the double-same conditions; one comparing the single conditions to the double-mixed conditions; and one comparing the double-same conditions to the double-mixed conditions.

The first analysis of variance indicated that the NT interaction was significant ($F(1,11)=43.1$, $p<.001$). The per cent correct* for each of these factors are presented in Table 1.

Results of a t-test indicated that the per cent correct for the bright targets did not change as a result of the addition of the second bright target ($t(11)=.97$, $p>.05$). There was a significant decrease, however, for the focal targets as a result of adding the second target ($t(11)=4.97$, $p<.001$).

The second analysis of variance indicated that the NT interaction was not significant ($F(1,11)=1.9$, $p>.05$). However, the results of a t-test indicated that detection of a bright target in a single channel was significantly better than the detection of a bright target when the Ss were also looking for an "F" in the other channel ($t(11)=2.27$, $p<.025$). The addition

* An Arcsin transformation was also performed on all scores. The analysis of variance for the transformed scores yielded the same results as the untransformed scores.

Table 1

Percent Correct as a Function of Number, Target Type, Homogeneity and Simultaneity for Experiment 1

	Focal Targets		Bright Targets	
	Simultaneous	Successive	Simultaneous	Successive
Single	.92	.91	.90	.93
Double-Same	.63	.68	.92	.98
Double-Mixed	.68	.88	.83	.91

Figure 1

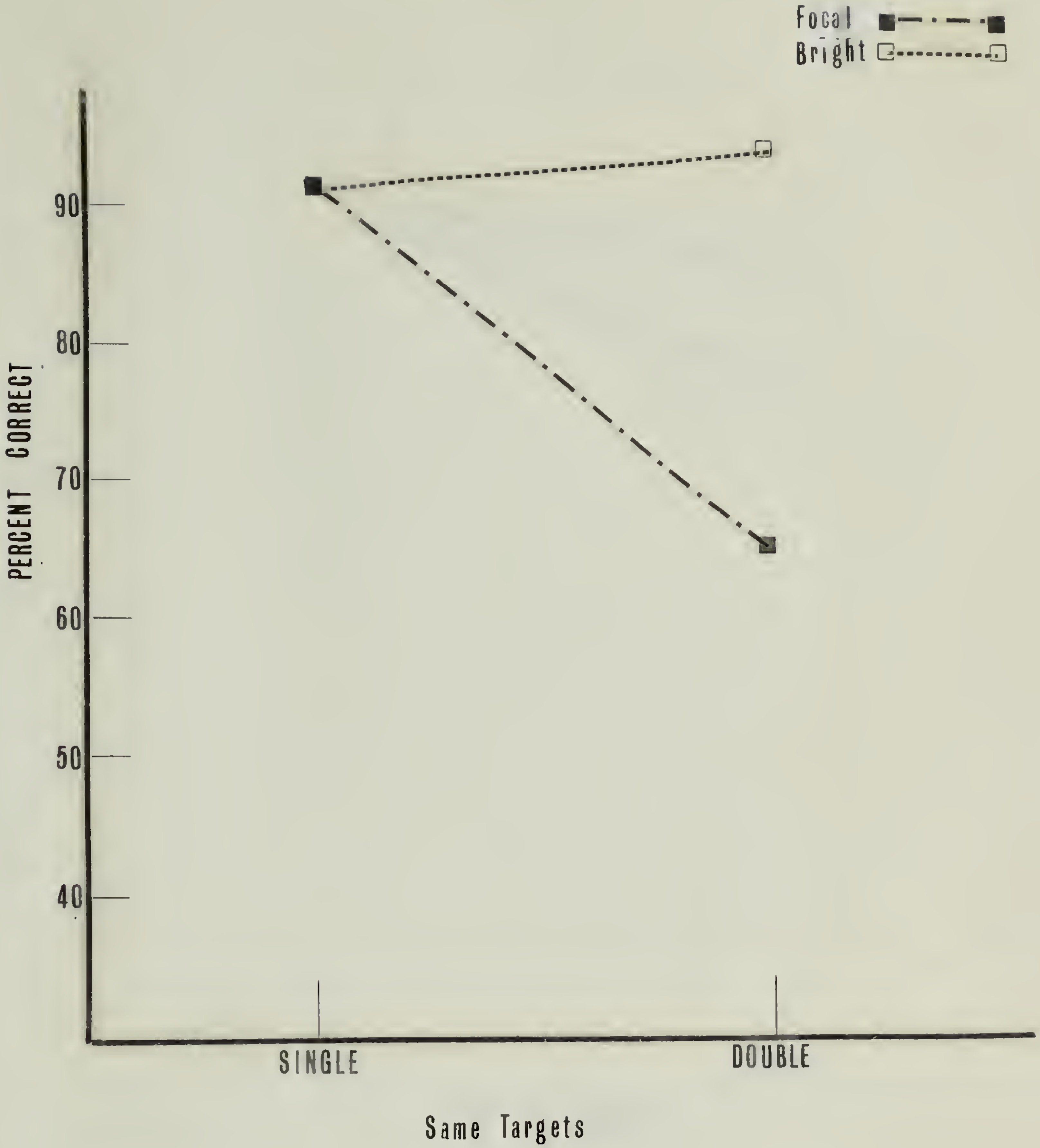

Focal
Bright
PERCENT CORRECT
90
80
70
60
50
40
SINGLE
DOUBLE
Same Targets

Figure 2

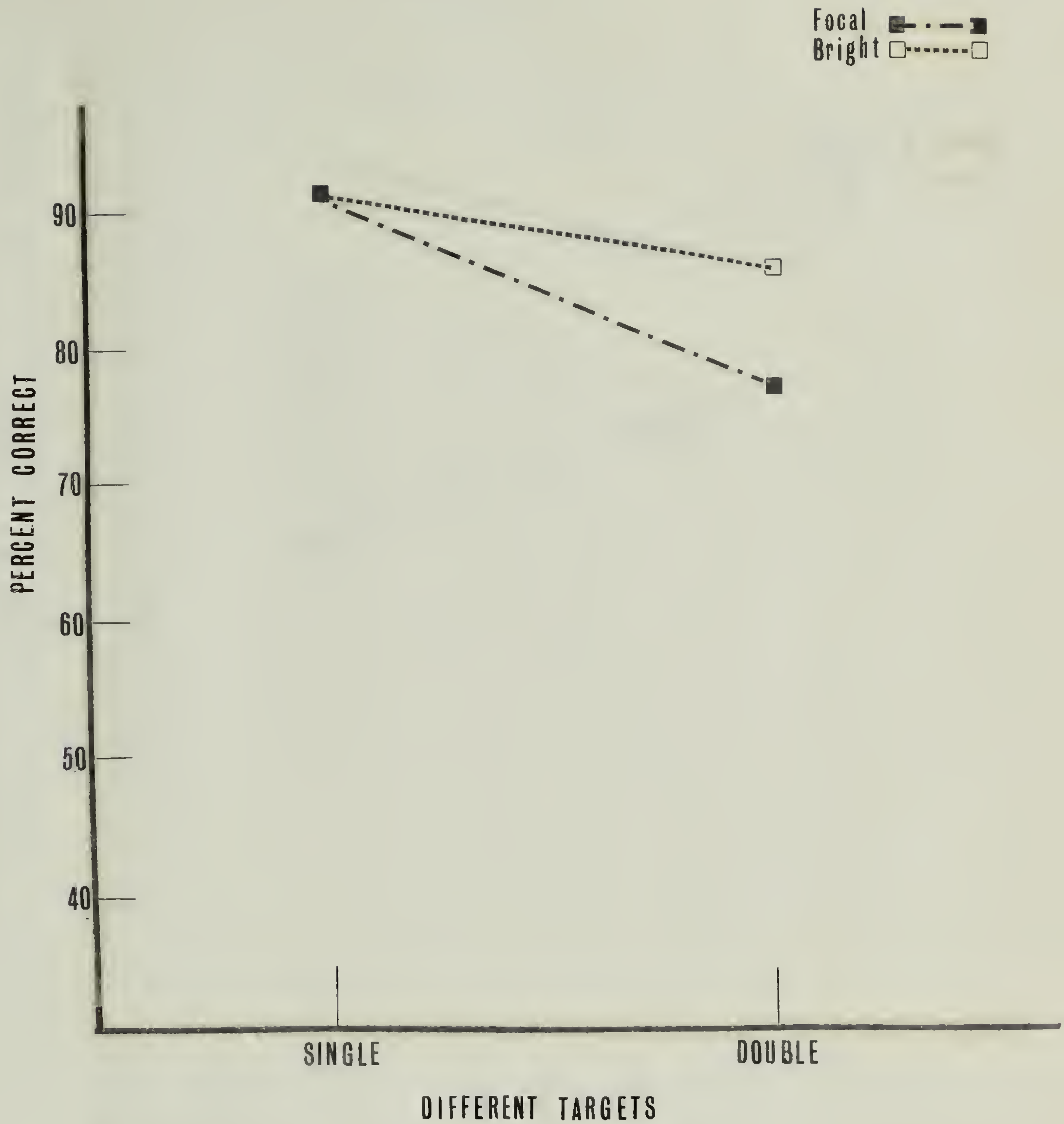
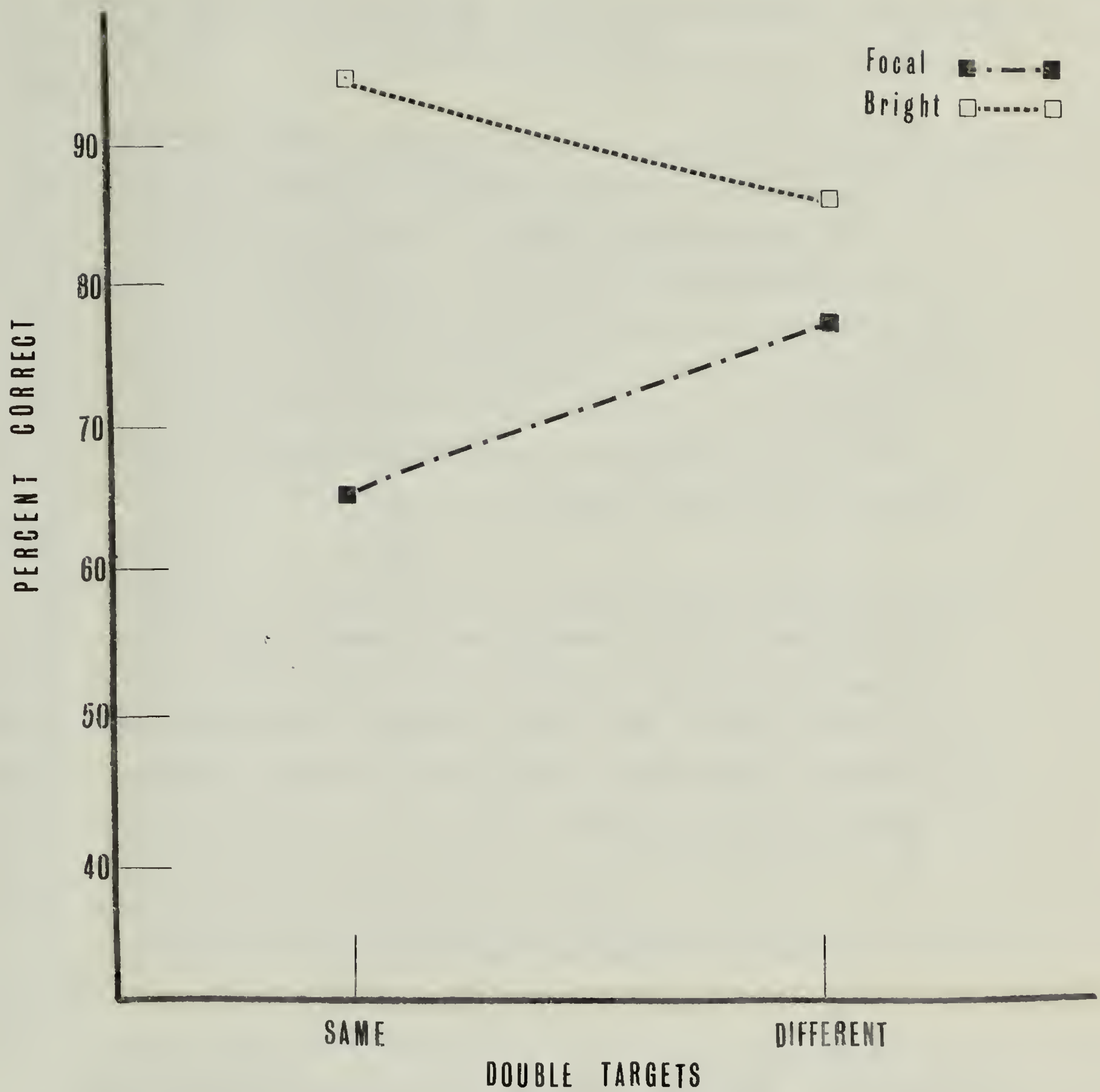

Focal
Bright
PERCENT CORRECT
90
80
70
60
50
40
SINGLE
DOUBLE
DIFFERENT TARGETS

Figure 3


Focal
Bright
90
80
70
60
50
40
PERCENT CORRECT
SAME
DIFFERENT
DOUBLE TARGETS

of a bright target in the second channel also decreased detection performance for an "F" relative to the (FA) condition ($t(11)=2.70$, $p<.025$).

An analysis of the double conditions, collapsed across levels of simultaneity, indicated that the HT interaction was significant ($F(1,11)=20.2$, $p<.001$). A t-test comparing the (FF) condition to the double-mixed condition showed significant facilitation in detecting "F"'s caused by the substitution of a bright target for an "F" in the second channel ($t(11)=2.49$, $p<.025$). A comparison of the (BB) condition to the double-mixed condition showed significant interference as a result of looking for an "F" instead of a bright target in the second channel ($t(11)=4.28$, $p<.005$).

The decrease in detection of a bright target when looking for an "F" in the other channel, as compared to the (BB) condition was significant for simultaneous targets ($t(11)=3.05$, $p<.01$), but not for successive targets. ($t(11)=1.02$, $p>.05$). The improvement in detection of an "F" when there was a bright target in the other channel relative to the (FF) condition was significant for the successive targets ($t(11)=2.77$, $p<.01$), but not for the simultaneous targets ($t(11)=1.32$, $p>.05$).

A comparison of the detection performance between an "F" and a bright target showed that there was no difference ($t(11)=.53$, $p>.05$) for the double-mixed conditions.

The number of false alarms was also recorded. Only sixteen false alarms occurred throughout the entire experiment. The false alarms were distributed across the conditions, and had no discernible affect on the data.

Discussion

The data indicate clear, qualitative differences between the task of detecting a change in brightness and in detecting a change in line configuration when attention is divided.

Ss ability to detect a target in a single field was the same irregardless of target type (due to experimental manipulation). However, with the addition of the second field, an effect was demonstrated. Furthermore, this effect was different relative to the type of targets being monitored.

Ss' performance declined for focal targets from the single to the double condition, while the addition of a second bright target had no effect on performance. This suggests a sharing of processing capacity for focal targets alone. A comparison of the single condition to the double-mixed conditions yielded no difference between the detection of a focal and a bright target. This also suggests that the detection of a bright target required little processing capacity or attentional control on the part of the Ss.

A comparison of the double-mixed conditions to the double-same conditions yielded consistent results. For focal targets, performance was significantly facilitated by the substitution of a bright target for a focal target in the second field. However, for bright targets, interference resulted from the substitution of a focal target for a bright target in the second field.

This suggests that the processing of the bright targets occurred in a simultaneous manner, with minimal attentional demands on the Ss. Even a temporal division of attention had no effect on the detection of the bright targets, with Ss performing equally well for two simultaneously occurring bright targets as for one bright target.

In the simultaneous conditions, a focal target in either field had an interfering effect relative to the double bright condition, with the double-focal condition yielding the poorest detection performance of all. This suggests greater attentional demands for focal targets relative to bright targets. The data further suggest that two focal targets cannot be processed simultaneously, but require a rapid switching of attention, a serial process.

The question of eyements must also be considered. The Ss were instructed to fixate on the point midway between the two fields of letters. Although similar results were obtained with the use of an eye-movement monitor in a pilot study, it is possible that the Ss were rapidly shifting their attention from one field to the other. If this were the case it could explain the decrement in performance resulting from the addition of a second, especially simultaneously-presented, focal target. If Ss were attending to one field, any targets occurring in the other field would be missed, if it is necessary to employ focal vision to pick up a change in line configuration.

Using the same argument, the non-interference resulting from the addition of a second bright target implies that the change in brightness could be picked up even if occurring in peripheral vision.

EXPERIMENT 2

Experiment 2 involves the same stimuli and procedure as Experiment 1 with the exception of the distance between the two fields of letters. In Experiment 1 the fields had a center-to-center separation of 2.5", while in Experiment 2, the fields were adjacent to each other. This experiment was designed to test the effect of keeping spatial division of attention to a minimum.

Method

Subjects

Twelve Ss were drawn from the same population as in Experiment 1.

Apparatus

The apparatus was the same as in Experiment 1.

Procedure

The procedure was the same as in Experiment 1.

Results

Analysis of variance was used to examine the effects of the four critical variables; (N) number, (T) target type, (S) simultaneity and (H) homogeneity.

As in Experiment 1, three separate analyses were conducted: one comparing the single conditions to the double-same conditions, one comparing the single conditions to the double-mixed conditions, and one comparing the double-same conditions to the double-mixed conditions.

The first analysis of variance indicated that there was no significant interaction between number and target type ($F(1,11)= 1$, $p > .10$). The percent correct for each of these factors is presented in Table 2.

Table 2

Percent Correct as a Function of Number, Target Type, Homogeneity and Simultaneity for Experiment 1

	Focal Targets		Bright Targets	
	Simultaneous	Successive	Simultaneous	Successive
Single	.76	.76	.76	.78
Double-Same	.47	.56	.65	.72
Double-Mixed	.61	.71	.64	.67

Results of a t-test indicated a significant decrease in percent correct for the bright targets as a result of the addition of a second bright target (t(11)=2.74, p<.05). There was a significant decrease also for the focal targets as a result of adding the second target (t(11)=5.40, p<.01).

The second analysis of variance yielded a non-significant NT interaction (F(1,11)=3.50, p>.05). However, a t-test indicated that detection of a bright target in a single field was significantly better than the detection of a bright target when the Ss were also looking for an "F" in the other channel (t(11)=1.60, p<.05).

An analysis of the double conditions, collapsed across the levels of simultaneity indicated that there was no interaction between homogeneity and target type (F(1,11)=3, p>.05). A t-test comparing the double-same conditions to the double-mixed conditions showed no difference in detection of an "F" caused by the substitution of a bright target for an "F" in the second channel (t(11)=1.78, p>.05).

A comparison of the double-bright condition to the double-mixed conditions showed no interference as a result of looking for an "F" instead of a bright target in the second channel (t(11)=0.60, p .25).

There was no difference in detection of a bright target when looking for an "F" in the other channel, as compared to the double-bright condition for either simultaneous targets (t(11)=0.46, p>.25) or for successive targets (t(11)=1.45, p>.05).

There was no difference in detection of an "F" when there was a bright target in the second channel, relative to the double-focal condition for simultaneous targets (t(11)=1.23, p>.05). A difference did result, however, for successive targets (t(11)=2.10, p<.05).

Figure 4

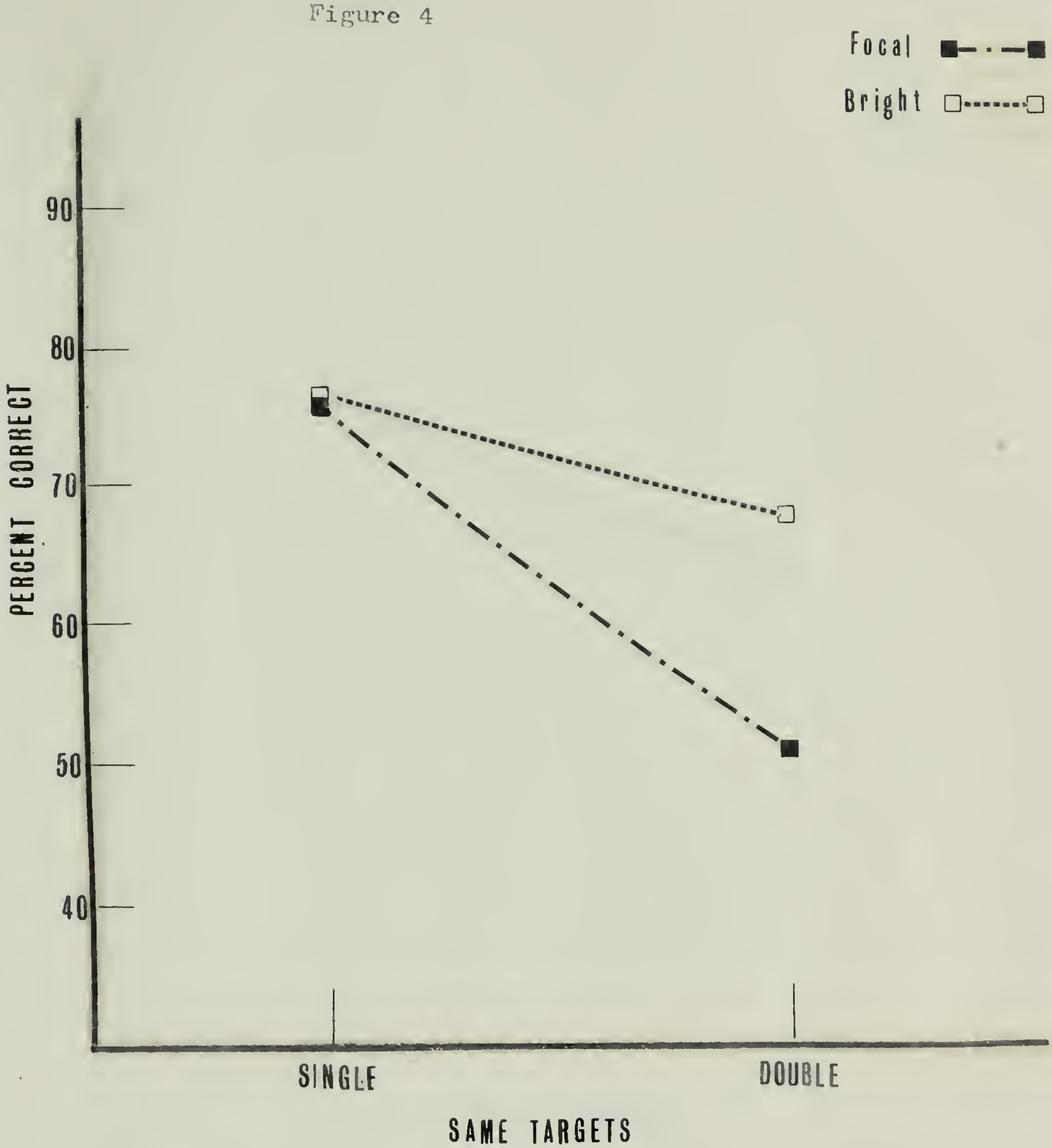

Focal
Bright
90
80
70
60
50
40
PERCENT CORRECT
SINGLE
DOUBLE
SAME TARGETS

Figure 5

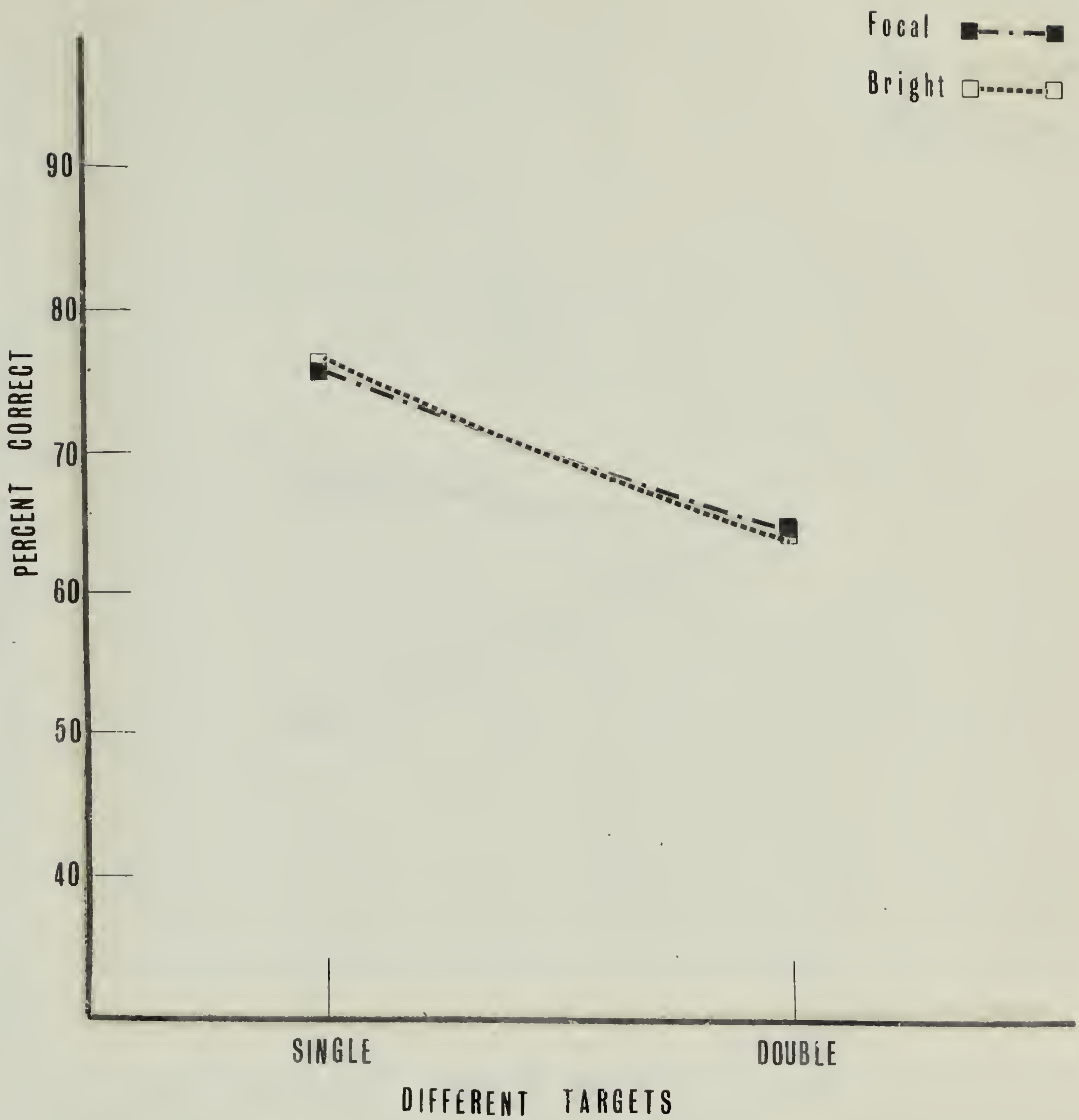
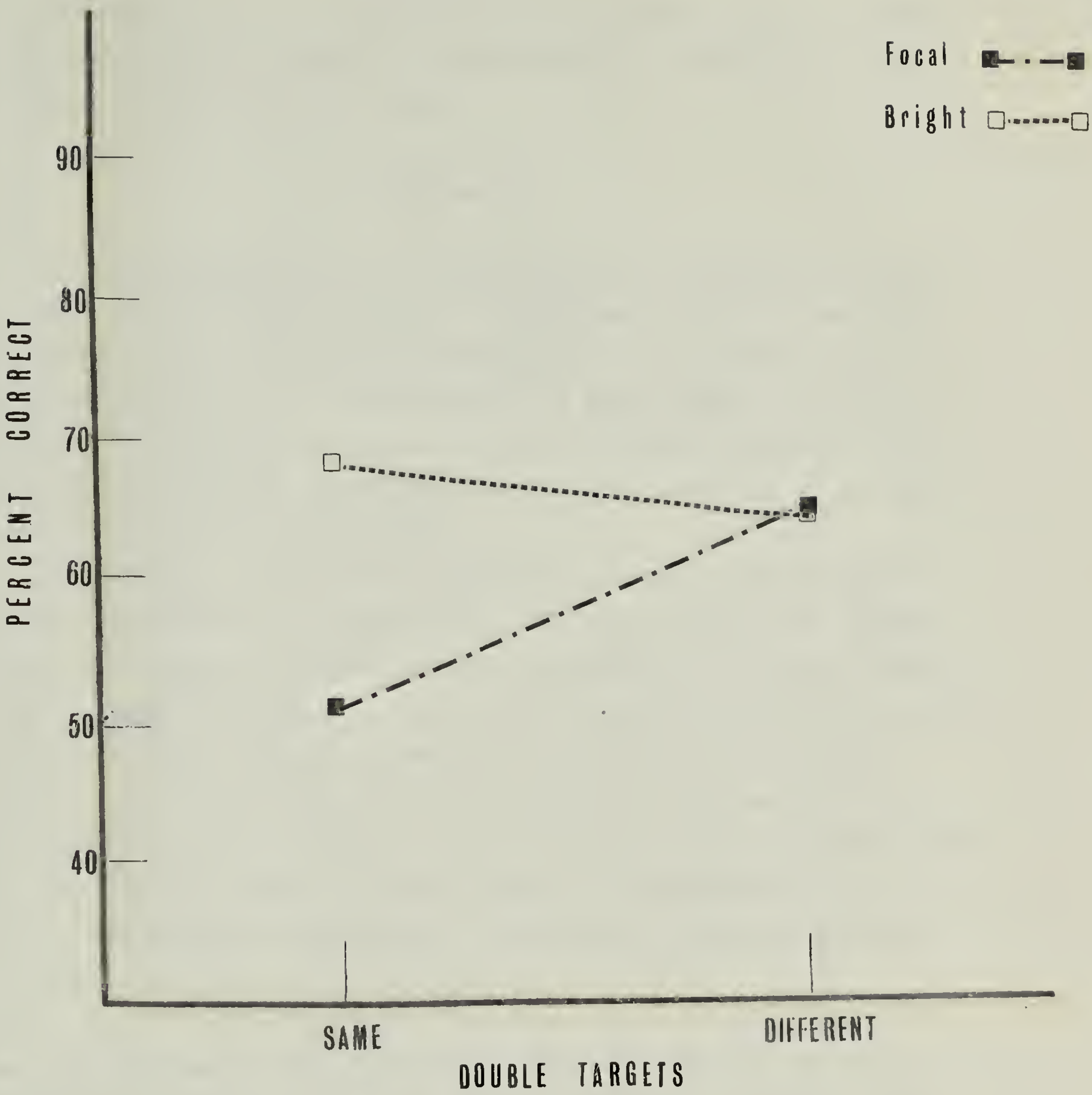

Focal
Bright
90
80
70
60
50
40
PERCENT CORRECT
SINGLE
DOUBLE
DIFFERENT TARGETS

Figure 6


Focal
Bright
90
80
70
60
50
40
PERCENT CORRECT
SAME
DIFFERENT
DOUBLE TARGETS

A comparison of the detection performance between an "F" and a bright target showed no difference for the double-mixed conditions ($t(11)=0.02$, p .25).

Discussion

The data suggest that the qualitative differences between the task of detecting a change in brightness and the task of detecting a change in line configuration are dependent upon a division of attention. The results of Experiment 1, in which the two fields were separated by 2.5", are very different from those of the present experiment in which the fields of letters appeared adjacent to each other.

Ss' ability to detect a target in a single field was the same irregardless of target type. The addition of the second field with the same target caused interference for each target type. As in Experiment 1, there was a larger decrease in performance for focal targets; however, this difference was not significant. This suggests that the decrease is due only to the necessity of dividing attention between the two fields, with the two types of targets having similar processing needs.

A comparison of the single conditions to the double-mixed conditions yielded similar results. The addition of the second bright target caused a decrease in detection performance for both "F" and bright targets. This decrease was on the order of ten percent for both types of targets. Again, this suggests that focal and bright targets have similar processing demands in this paradigm.

A comparison of the double-mixed conditions to the double-same conditions yielded results very dissimilar from those in Experiment 1. Whereas in Experiment 1, the HT interaction was significant, this was not the case in the present experiment.

Ss' detection ability was the same for all double conditions, irregardles of homogeneity or target type.

The differences in the processing demands of the focal and the bright targets which resulted in Experiment 1 have been eliminated along with the separation between the fields of letters.

Also eliminated was the possible effect of eye movement which may have occurred in Experiment 1. In the present case, Ss had no reason to shift their eyes from one field to the other, since the fields were adjacent. Therefore, the presentation of a target in an attended field would have no effect on the probability of Ss missing a target in the other field.

General Discussion

One major finding of Experiment 1 is that the task of detecting a change in line configuration is qualitatively different from the task of detecting a change in brightness, when attention is divided between two separated fields of stimuli. It appears that detecting a change in line configuration is a serial process with two simultaneously occurring stimuli causing interference with each other. On the other hand, the Ss' ability to detect a change in brightness was the same irregardless of the number of bright targets. The addition of a second bright target had apparently no effect on the targets' detectibility. Furthermore, the Ss' ability to detect a change in line configuration was the same for a single focal target as for a focal target with a bright target in the other channel. The addition of the bright target apparently had no effect.

These findings provide evidence that the two types of stimuli used in this paradigm have entirely different processing demands. Detecting the two "F"'s could not occur simultaneously implying that a serial process is going on. The detection of a bright target, however, seems to occur in parallel with other tasks, without apparent attentional control on the part of the Ss.

These apparent qualitative differences in the processing demands of the two stimuli did not hold true for Experiment 2 in which the two fields of letters were adjacent and could be both attended to focally simultaneously. In this case, the addition of a second target caused a decrease in detection

performance, but this decrease was the same irregardless of the type of target added.

Reagrding the data in terms of the three types of information processing models outlined, it is clear that it provides evidence for a model that is neither always serial nor always parallel. Broadbent's model would predict that the addition of the second target would always have an interfering effect on detection performance. This was clearly not the case, considering the Ss' performance for bright targets. On the other hand, a model such as that proposed by Deutsch and Deutsch would predict that the addition of the second target would have no effect on performance. The interference effect found, especially for two simultaneously presented focal targets, suggests that the focal targets could not be processed in parallel. The data suggest a model in which processing occurs in serial or in parallel, depending on the type of stimulus variables being processed. Furthermore, it appears that line configuration is a stimulus variable requiring focal attention and serial processing, while brightness is a stimulus variable which can be processed in parallel, without necessitating application of focal attention.

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