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ABSTRACT

A two-process model of infant visual attention is constructed based on research using the modified Berlyne technique with three- to five-month olds. The length of time an infant fixated a pattern was examined along with what caused him to turn to the pattern at all. The study was based both on a re-examination of previous research and on new experiments. Two distinct sets of processes were found in infant attention: Attention-Getting and Attention-Holding. It was found that in the four-month-old infant, habituation is primarily a function of the Attention-Holding process, and occurs more in males than females, although both sexes initially show preferences for, or look longer at, the more complex patterns. Performance on some trials indicates a tie-in between Attention-Getting and Attention-Holding, with the information obtained from prior fixations of the stimuli somehow determining the speed of subsequent head and eye orientation. The model is followed from occurrence of an Environmental Event, to operation of the Peripheral Perceiver, to information processing and splitting up by the Perceptual Processor, to Memory. Detailed flow charts are included. (LH)

# A Two Process Model of Infant Visual Attention[1]

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I would like to construct a model for you, a model of infant attention. It would be better to construct it rather than simply to describe it for at least two reasons. First, it should be easier to follow; it provides a convenient way of organizing a large body of research on infant attention. Second, and more importantly, it should also provide some idea of how the model gradually evolved. This model is not formal by any means. It is not yet at the stage where we can estimate parameters or make quantitative predictions. Instead it is an example of the typical flow chart, schematic, arrow and box type of model so common in psychology today. However, as I hope to show in this paper, most of the boxes and arrows have empirical support. The model has also been a valuable heuristic, it has guided our research on infant attention and has suggested new hypotheses we might not have otherwise discovered.

Before the model is discussed, however, it might be valuable to review the literature on infant attention, very briefly and superficially, for those of you who might not be too familiar with the rapid growth of this area over the last few years. Actually, observers of infants have been interested in attention for many years. The interest goes back at least as far as Darwin (1877) where he describes in his infant biography the kinds of stimuli his little son looked at and at what age the boy first started visually tracking a candle or other moving objects. Subsequently, other studies began to appear, some (e.g. Beasley, 1933; Ling, 1942) refinements of Darwin's study of visual tracking ability; others (e.g. Staples, 1932;





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Valentine, 1914) examinations of infant visual preferences. In one of the latter ones an experimenter held balls of yarn of different colors in front of his infant to see which ones the infant would look at longest. The basic assumption was that if the infant looked longer at one than at the other, it would mean he could tell them apart or discriminate between them.

Several other investigations have appeared in the literature over the years, but the field remained relatively dormant until 1958. At that time two experiments were published, one by Berlyne (1958) and one by Fantz (1958). Both turned out to be very influential and have provided the impetus for the current boom in infant attention research. Their main value was methodological; they demonstrated the relative ease of testing young infants in a reasonably objective way.

The Berlyne experiment involved showing two different visual patterns to the infant simultaneously. The patterns were placed on a board by one experimenter, and then another experimenter, looking through a peephole between the two stimuli, recorded which pattern the infant first fixated. The Fantz procedure was more technologically advanced. Instead of simply observing gross head and eye movements as Berlyne had done, Fantz' observers were able to estimate which pattern the infant was attending to most from the corneal reflection of the stimulus in the infant's eye. The two procedures had much in common. Both tended to use a paired-comparison technique where two patterns were presented simultaneously and the infant had to choose between them. Both had observers recording infant attention. And both of these techniques, with various modifications, have been used repeatedly up to the present day.

At least two modifications since 1958 might be of some importance. One is that now investigators not only present stimuli simultaneously but successively as well. In some experiments, as we shall see, it is useful to present repeatedly just one stimulus and then change that stimulus in some specified way. The other modification is that experimental techniques are getting a bit fancier electronically. The observer is being removed from that little peephole and is being replaced by a television or movie camera. An observer is still required in the system somewhere, however. If he is not watching the infant directly, he is watching a TV screen or going through a film strip frame by frame, and trying to decide whether or not the infant is looking at the stimulus.

Each of the procedures has some advantages and disadvantages. One obvious advantage of the Fantz technique is its precision: one can tell not only whether the infant is looking right or left or in the approximate area of the stimulus, but by carefully checking corneal reflections, can tell what portion of the stimulus he is actually fixating. Some very interesting research by Salapatek and Kessen (1966), for example, involves actually tracking the eye movements of an infant as he scans a certain pattern.

One disadvantage of tha Fantz technique is that because the observer can sometimes see the actual pattern in the infant's eye, there is more chance for experimenter bias. This is usua'' .ot a problem with the Berlyne procedure. A second advantage of the Berlyne method is that it is possible to measure not only how long the infant looks at the pattern, but also how rapidly he turns his head and eyes toward the source of visual stimulation. Recording of corneal reflections requires that the infant's head remain relatively immobile, so some type of pillow or other restraint is used to prevent gross head movements. Such restraints are not needed in the Berlyne procedure. Both techniques have been shown to be highly reliable, and inter-observer reliability measured several different ways almost always is very high with a minimum of observer practice. Which technique one uses really depends upon what one wants to measure, and both are quite good.

Most research on infant attention can be classified into one of two groups, depending upon the type of stimuli presented. One group of studies has examined what may crudely be called stimulus complexity. In this group can be included all the studies where some physical property of the stimuli is varied. The other group involves varying some temporal characteristic and examines the effect of the novelty or familiarity of the stimulus.

Early investigations of physical characteristics seemed to select patterns almost at random. Pictures of panda bears were compared to baby bottles and bulls-eyes to checkerboards. Later, for theoretical reasons, it became important to present stimuli along some type of physical continuum, and studies began to use patterns of flashing lights which varied in randomness or apparent movement, or randomly determined shapes varying in number of turns or the most common of all, checkerboard patterns varying in the number and size of the squares. Probably the classic study was conducted by Brennan, Ames, and Moore (1966). Infants at 3, 8, and 14 weeks were shown either 2 x 2, 8 x 8, or 24 x 24 checkerboard patterns. They found that the pattern infants looked at longest changed over age. The youngest infants looked most at the simplest pattern, intermediate aged infants looked most at the intermediate pattern, and the oldest infants looked longest at the most complex pattern.

The reasons for this developmental change are unclear. One class of explanations involves changes in cognitive processing and assimilation. Basically, it has been argued that as an infant gets older, his ability to assimilate or process visual information increases. Theorists as diverse as Piaget or Dember and Earle (1957) propose that if a stimulus is presented which is just beyond the infant's ability to process it, the stimulus will be maximally attractive. However, if the stimulus deviates too much in either direction from this optimal level it will be less attractive; if it is too complicated or unusual, the infant will be unable to assimilate it at all; whereas if it is too simple or dull so that he has no difficulty processing it, then he will be less interested. In either case he will look less at such stimuli. The general prediction coming out of this theoretical framework is that infants' visual preferences should fit an inverted U function and as the infant becomes older, this whole curve should move toward preferences for more and more complex stimuli. The Brennan, Ames, and Moore data seem to follow this prediction.

An alternative interpretation which has not been entirely eliminated yet is that preferences for complexity are tied to visual acuity, which increases during the first months of life. Using this interpretation one might argue that from his earliest days, the infant will always be most interested in the most complex pattern that he can see clearly. When he is very young and he sees a 24 x 24 checkerboard, it may be a fuzzy, blurry kind of image. A less complex pattern may be preferred simply because it provides a more clearly defined pattern with a large amount of edge. More research should be done to determine which of these alternatives is the most reasonable. In any case, for the purpose of this paper, it is important to remember the basic empirical finding that by 3 or 4 months of age, infants will look longer at more complex checkerboards, at least up to the level of a 24 x 24 pattern.

Research on the temporal characteristics of visual patterns typically involves repeated presentations of one pattern followed by a test in which that familiar pattern and a novel pattern are presented. If, as is often the case, the infant decreases his fixation time to the repeated pattern, he is said to be habituating his response. Most definitions of habituation also require the infant to respond more to the novel than the familiar stimulus in the test.

The obvious reason for this requirement is that if an infant is placed in an infant seat and looks less and less over time, he could be looking less for any number of reasons. We've had occasions where after the experiment was over and we checked the infant's diaper, it became clear why he didn't look on the later trials. State changes can also be a problem when working with infants. The younger ones tend to fall asleep on you, and the older ones sometimes begin to cry. Some won't tolerate the infant seat for more than a few minutes. All of these conditions, which we call general fatigue, will also produce a decrease in fixation time, but the infant would not show the difference in the test between the novel and familiar stimuli. Other types of more specific fatigue should also be mentioned. Effector fatigue may occur as an infant tries to follow a moving light or scan a pattern. Again, unless one wishes to make the unlikely assumption that for every different pattern, a different set of eye muscles is being used, greater fixation time to the novel than familiar pattern should negate the importance of that type of fatigue. Finally, one could argue that decreased fixation time to the same stimulus over trials is due to sensory adaptation. Perhaps the set of receptors stimulated by the pattern adapt as the infant fixates. Since different stimuli are likely to stimulate different receptors, greater looking at the novel stimulus would not rule out this explanation. A more adequate test would be to wait a period of time after the infant has habituated and then present the familiar stimulus once more. If sensory adaptation has taken place fixation time should increase.

Several studies (Fagan, 1970; Gelber, 1972; Pancratz and Cohen, 1970) have tested for these various types of adaptation or fatigue, and the general conclusion is that none of these peripheral mechanisms can account for the infant's decreased attention to the pattern over trials. We can be reasonably confident that his looking less and less at the same pattern has something to do with that pattern becoming familiar. The model to be described later will provide a possible explanation for this habituation.

As an example of a typical habituation experiment I would like to describe a study done in our laboratory by Margaret Wetherford (Wetherford and Cohen, 1971). She examined habituation and recovery to novel stimuli in infants at four different ages, 6, 8, 10, and 12 weeks. The patterns she used were simple geometric shapes of different colors. Seventeen trials were presented, and each was 15 seconds long. On 14 of them the same stimulus was shown. On trials 2, 9, and 16, novel stimuli were presented so that fixation to them could be compared to fixation to the familiar stimulus. Wetherford used the Fantz corneal reflection technique and presented stimuli successively. Performance was clearly a function of age. Six- and eight-week-old infants did not habituate. Their fixation time to the familiar pattern on the later trials was just as great as it had been on the early trials. The ten- and twelve-week-olds, on the other hand, showed a regular decrease in looking to the familiar pattern over trials. Age also seemed to influence preference for novelty; by the end of the testing session the older infants were looking longer at the novel pattern, while the younger ones were looking longer at the familiar pattern.

Although this study and several others have been unable to find habituation to visual stimuli in infants less than two months of age, a few have reported habituation in newborns (e.g. Friedman, Carpenter, and Nagy, 1970; Friedman, Nagy and Carpenter, 1970). The reason for this discrepancy is still unclear. In any case, just as we reached the general conclusion that by three months of age infants prefer the most complex pattern, we can reach a similar conclusion about novelty. The evidence is consistent that by two to three months of age infants will habituate their attention to a repeatedly presented pattern, and their response will recover to a novel pattern.

Explanations of habituation and recovery have typically invoked the concept of infant memory. If the infant responds less on trial N+1 than he did on trial N, and if some type of fatigue is not responsible, there must be some carry-over from what he saw on trial N to what he is seeing on trial N+1. Something about what he saw on trial N must be stored for later use. Not only must there be some storage or memory, but the infant also must compare what he has remembered with what he is currently watching. To the extent that the comparison indicates that he is watching something new, he's going to continue looking. To the extent that it indicates he's watching something old and familiar, he is going to stop looking.

This is basically Sokolov's (1963) neuronal model and is presented schematically in Figure 1. Start at the far left. Assume some Environ-

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Insert Figure 1 about here

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mental Event or stimulus (S) occurs. By following the horizontal arrow we see that the infant will attend to that stimulus. Once he attends he will store, in some unspecified memory, something about that stimulus. On the next trial an environmental stimulus again occurs, the infant attends to it, and then (as the next horizontal line indicates) he compares what was stored in Memory with what he's currently attending. If, on the basis of that comparison, the stimuli are different, the system loops back and the infant keeps on attending. If, however, the comparison indicates the stimuli are the same, the infant stops looking, and the system goes back to S and starts all over again.

As we shall see, there are several problems with the model as it now stands. Nevertheless it can serve as a good starting point for the elaboration of our current model. In the remainder of this paper I would like to show you how we've had to modify and extend Sokolov's model in order to make it cover more adequately some recent infant attention literature.

All the research I will be discussing used the modified Berlyne technique discussed earlier. All used infants from three to five months of age. Practical considerations account for both of these decisions. The Berlyne procedure was chosen, first, because it was available when we began this series of studies; second, because we wanted to minimize experimenter bias; and third and most importantly, because we wanted to examine not only how long an infant fixated a pattern, but what got him to turn to the pattern as well. Therefore, we had to use a procedure which allowed the infant to move his head freely back and forth.

We decided on three to five month olds because compared to other infants they are a joy to test. If infants are less than three months, they may fall asleep in the middle of the experiment. They won't have good head control, and their visual accommodation will be poor. If they are over five months, a whole new set of problems may arise. They may panic at the sight of strangers. They often won't tolerate the infant seat but will be continually trying to sit up; and for some sadistic reason they almost invariably will prefer looking at their hands or feet to anything you may project on the screen in front of them.

Our first clue that explanations of infant attention had to be modified came when we began to reexamine the most frequently used dependent variable, total fixation time. In a typical experiment stimuli are presented for several trials, each of a fixed duration. Under this procedure it is possible to have two infants with identical total fixation times whose patterns of responding are quite different. For example, on any given trial one infant may fixate just once for ten seconds, while the second may turn to look ten times with each fixation one second. Both would have total fixation times of ten seconds for that trial, yet very different processes might be involved. The interpretations of infant attention mentioned so far have involved cognitive-sounding terms such as assimilation and comparison between what is old and what is new. These interpretations seem to imply some sort of active information processing on the part of the infant, and in order for them to operate the infant must be attending to the stimulus pattern. But what gets the infant to turn to the pattern in the first place? Other processes might be responsible for his orientation to something presented in the periphery.

In order to test this assumption that two distinct sets of processes are at work in infant attention, we reexamined data from several experiments we had run some time ago, and instead of looking only at total fixation time, broke it down into two component measures. One was the number of times an infant oriented on a trial, and the second was the average duration of a fixation on that trial. The number of times an infant looked was our indication of what may be called the Attention-Getting process, and the average length of a look an indication of the Attention-Holding process. Suggesting two processes would not be very helpful, however, unless stimulus parameters affect the two response measures differently. In other words, if we found that the two measures were highly correlated, there would be no point in considering them reflections of different attentional processes.

In one experiment, conducted at the University of Minnesota several years ago (Summarized in Cohen, 1969), three- to five-month-old infants were simultaneously shown two matrices of blinking lights. Only one light blinked on and off in each matrix, but it could either remain stationary or move randomly among 3, 9, or 27 positions. A paired comparison procedure was used so that on one trial an infant might see the stationary light on the left and the 27 position light on the right, while on the next trial it might be the 9 position light on the left and the 3 position light on the right. Each trial lasted 15 seconds.

The total fixation time data came out as one might expect: the only significant result was the not too startling finding that an infant will attend longer to a light if it changes position than if it does not. No differences were found between responding to the 3, 9, and 27 position lights.

These matrix stimuli differed in the probability they would change position from moment to moment. The stationary one, of course, never moved. The 3-position light moved two thirds of the time and stayed in the same position one third of the time. Similarly, the 9-position light moved 8/9 of the time and the 27-position light, 26/27 of the time. If percentage of movement influences orienting toward a stimulus in the periphery, we should see the effect in the number of fixations measure. That is exactly what happened. The greater the number of position changes (or the greater the probability of apparent movement), the greater the number of fixations. Apparently, the more the light moved the more an infant would turn toward it.

The average length of a look measure produced very different results. Once they had turned, infants looked significantly longer at the stationary, 3 and 9 position stimuli than they did at the 27 position one. Our interpretation at the time was that lights with many position changes provided more complexity or information than our infants could handle, and thus they actually attended to them less. Whether this interpretation is accurate or whether infants looked less at the 27 position light simply because they could not follow its almost constant movement is unknown. Whatever the reasons, the number of fixation and average length of a fixation data were quite different and support our contention that two different psychological processes are operating.

The second reanalyzed experiment examined habituation (Pancratz and Cohen, 1970) in four-month-old infants. In this study the same simple geometric pattern (e.g. a red circle) was shown repeatedly for ten trials, each trial lasting 15 seconds. It was followed in the test phase with a novel stimulus to check for fatigue. Figure 2 shows total fixation times

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Insert Figure 2 about here

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for both males and females during the habituation phase of the study. As you can see, the males habituated, but the females did not. This pattern of sex differences, while difficult to explain, keeps cropping up in our work, so it evidently is reliable.

The important point to be considered next is whether this habituation of total fixation time is reflected in number of fixations, average duration of a fixation, or both measures. If habituation requires the storing of past inputs, and a comparison of what is stored with what is currently being perceived, then such cognitive processing should influence the duration of each fixation. Figure 3 presents changes in the number of

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Insert Figure 3 here

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fixations over trials in the habituation phase of the experiment. As you can see there was no evidence either of habituation or of sex differences.

On the other hand a different picture is presented by the average fixation time data. As Figure 4 shows, the males decreased their length of each look over trials, while the females did not. Evidently the habituation

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Insert Figure 4 about here

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which occurred in infants' total fixation times resulted mainly from habituation of the duration of each look rather than from a decrease in number of looks. Again we have support for a two process model of infant attention, with habituation primarily a function of the Attention-Holding process.

In the next study we decided to manipulate something we thought might differentially affect Attention-Getting and Attention-Holding. (Summarized in Cohen, 1969). As many before us had done, we presented checkerboard patterns varying in number of checks; however, we also varied the overall size of the checkerboard. The patterns were either 2 x 2 or 8 x 8 checkerboards and they were either 1.6 in. or 8 in. on a side. Each infant was given 16 trials, four with each type of pattern. Infants were again four months old.

In the vast majority of checkerboard studies, size is held constant and number of checks is varied. Infant fixation times to these patterns are usually interpreted in terms of ability to process edges, angles, or complexity. If this were the case, then, Attention-Holding should be affected more by number of checks than by size. Grosser differences such as the size of the pattern (and perhaps brightness which was correlated with size in this study) probably should exert more influence on the infant's turning to something in the periphery, i.e., the Attention-

Getting process.

The results came out just that way. A four-way mixed analysis of variance with Age and Sex as between factors and Size and Number of Checks as within factors was computed for average fixation duration. The only significant result, the only factor even to approach significance, was the number of checks. As we had predicted, the average duration of a fixation was reliably longer to 8 x 8 patterns than to 2 x 2 ones.

A similar analysis was computed for number of fixations. No significant differences were obtained. However, the predicted difference, that the greater the size the greater the number of fixations, fell between the .10 and .05 levels of significance. On the other hand the Number of Checks variable did not even a ,oach significance.

So again we have evidence that two different processes are involved; that one process apparently is more cognitive, the other more reflexive. One involves more active information processing and the other is more an automatic orienting to an abrupt change in the periphery.

Now that I have convinced you of the merits of these studies, let me explain some of their problems. In fact the same problems exist in most research on infant attention that uses fixed trials. The typical procedure is for the experimenter to set arbitrarily both the length of the trial and the intertrial interval. Slides or other stimuli then are turned on and off at a fixed rate, independent of the infant's behavior. The first problem arises in that a pattern may appear when some infants already are looking in that direction and others are not. If the infant happens to be looking he is likely to have a longer fixation time on that trial. If he happens to be looking in some other direction he may fixate that pattern much less, because it will take him some time to turn to it.

Differences between the two infants would not necessarily result from their varying interest in the pattern but from their initial head and eye orientation. A few investigators (e.g. Freidman, Nagy, and Carpenter, 1970) have solved the problem in a very reasonable way. They do not count a trial as starting until the infant starts looking at the stimuli.

That, however, does not eliminate a second common problem. What should be done when a trial ends while the infant is still fixating? If the slide had remained on longer, he most probably would hove looked longer. Yet, invariably, investigators assume his fixation ended with the termination of the slide. This problem is of particular importance when investigators are attempting to assess stimulus preferences. If the trial length is somewhat short and if the infants tend to look most of the time, differences in fixation time to the stimuli could be masked, whereas they might have been quite apparent if infants had been allowed to fixate as long as they wished.

Additional problems exist when the infant's behavior on a trial is separated into number of fixations and average fixation duration. For one thing, the two measures may not be independent. If an infant looks once for 12 seconds during a 15 second trial, how many other times can he look? If the infant looks for only one second, then he has considerably more opportunity to turn and look again. In other words what I am saying is that in the studies mentioned above there is a negative correlation between number of fixations and average duration of a fixation. The correlation is not high, it is about -.3, but the measures are not totally independent.

Another tricky problem occurs when the infant does not look at all on a trial. It can be counted as zero number of looks, but what about the average duration. It is not completely fair to discount the trial entirely; yet it is not fair either to assume his actual fixation time to the pattern was zero.

In an attempt to eliminate these difficulties, we have developed a new procedure for testing infant attention. Two blinking lights have been added to the display board in front of the infant, one on the left and one on the right. Now each trial starts with a blinking light. As soon as the infant looks at the light, we turn it off and turn on a slide on the opposite side. In this way we have control over where the infant is looking when the pattern appears. Our measure of Attention-Getting is no longer the number of turns, but the latency of turning from the light to the pattern. After the infant has turned, we let him fixate as long as he wants. It is only when he turns away that the slide goes off and the light blinks on and off again to start the next trial. Our measure of Attention-Holding is now the duration of that one fixation to the pattern. This procedure is much more under the control of the infants, and as a side benefit, they seem to enjoy it more and we lose many fewer subjects.

The next experiment I'd like to mention used this new procedure (Cohen, 1972). Otherwise, it was essentially a replication and extension of the last checkerboard study. The patterns were red and white instead of black and white. Each stimulus was either a 2 x 2, 12 x 12, or 24 x 24 checkerboard and was either 2 1/4, 4 1/2, or 9 in. on a side. There was a total of 18 trials with the nine different stimuli each presented twice, once on the left and once on the right.

The results were essentially the same as in the earlier study. Only Number of Checks, and not Size, reached significance for the duration of a fixation. Results on the latency measure were somewhat more complicated, partly because the 2 1/4 in. 24 x 24 checkerboard had checks so small that they were beyond the infants peripheral acuity. Primarily for this reason, both the main effects of Size and Checks, and the Size x Checks interaction were significant. More important than statistical significance, however, is the relative importance of the two parameters. In the latency measure Size accounted for 2.4 times the variance of Checks, and in the duration measure Checks accounted for 2.0 times the variance of Size. So, again we find the same pattern of results. Size seems to be more influential in infants' turning toward the pattern, checks in how long they look once they have turned.

It is obvious that the model of infant attention presented earlier needs to be modified to accommodate the results mentioned so far. The revised model is presented in Figure 5. Infant attention is now separated

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Insert Figure 5 about here

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into two processes, Attention-Getting and Attention-Holding. Reading from the far left, an Environmental Event or stimulus occurs in the periphery. The next step is a Peripheral Perceiver which is sensitive to gross kinds of changes, such as movement, brightness, size, etc. If the level of these parameters is sufficiently high, an Orienting Response will be made. The orienting response simply means the infant turns his head to the source of stimulation. If the level is low, he will not orient. Once he does turn his head he will start fixating and the Attention-

Holding process will begin operating. This process is simply the same as the Sokolov model presented earlier, showing that the information in the stimulus will get stored somehow and that it will be compared with what he is currently fixating. If the comparison indicates the two inputs are different, he will continue fixating; if they are the same, he will stop.

The separation of infant attention into two processes is a step in the right direction. However, we have reached the point where we have more questions than answers. For example, is it the case that the infant will always turn his head if the stimulus is bright enough or if it moves? What sort of information does the infant store in memory and how long can he store it? And what about those weird sex differences in habituation. Do they mean that females have no memory? I know from personal experience that that cannot be the case. Much more information is needed before these questions can be answered satisfactorily. We have made a start, however, and I'd like to describe some of this research to you.

One step was to try to replicate the sex differences found in the earlier habituation experiment. We also wanted to see what kinds of information an infant stores when he is habituating to a simple pattern. This experiment (Cohen, Gelber, and Lazar, 1971) preceded our conversion to the new procedure, so each subject received a total of 20 trials, with each trial lasting 15 seconds. Half the infants were male, half female. The experiment was divided into two phases, habituation and recovery. During the 16 habituation trials four-month-old infants were repeatedly . shown one simple geometric pattern (e.g. a red circle). Then in the recovery phase they were given eight more trials – two trials with the habituation stimulus, two with a familiar form but novel color (e.g. a green circle), two with a familiar color but novel form (e.g. a red triangle), and two with both a novel form and novel color (e.g. a green triangle). The basic question was under what conditions will infant fixation times increase or recover. If recovery occurs when the color alone changes then the infants must have attended to and stored something about the color. If they recover when only the form changes, they were storing something about the form; and if they recover when either changes, they must have stored some aspect of both.

Figure 6 gives the results. We again get male-female differences.

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Insert Figure 6 about here

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Again we find males habituating and females not habituating. In considering the recovery phase of the experiment you can see that if either the color or form changes, responding increases; and when both are changed it increases even more. The two are additive. Main effects for Color and Form were significant, and there was no interaction. So it can be concluded from this study that infants are capable of attending to and remembering both color and form.

A question still remains, however. Did we obtain these results because some infants were attending only to form, while others were attending only to color? Or were most infants attending to both? An examination of the performance of individual infants revealed that most were in fact attending to and storing both color and form.

Given that infants do remember both, an interesting theoretical question arises. How do they do it? Is it the case that four-month-old infants store a red circle as a compound? Are the form and color somehow tied together? Or do they split it up into its components and store the form and color in separate locations? One could speculate that infants are built with separate perceptual or neurological mechanisms for storing simple dimensional information such as colors and forms, and it is only later as infants develop cognitively that they are capable of integrating them into compounds. On the other hand, one could argue from a Gestalt point of view that the first thing they store is an undifferentiated representation of the actual pattern they see and only later can they separate it into components.

To show you how we tested these two hypotheses consider the design of the next experiment presented in the Figure 7. This study employed the new procedure with the blinking light on the left and the patterns

Insert Figure 7 about here

successively presented on the right. During the 16 trials of the Habituation Phase infants were exposed to two patterns. (e.g. a red circle and green triangle). The patterns alternated from trial to trial. Then in the Test for recovery, subjects were randomly split into one of three groups. The first group (the top row in the figure) received the same patterns they had been shown in Habituation. This could be considered a control group. One would not expect them to display any recovery. The third group (bottom row) received two totally different stimuli, and one would expect a great deal of recovery from them. The interesting group, theoretically, was the second one (middle row). They received the same four components (e.g. red, green, circle, and triangle) which they had seen during Habituation, but arranged into different compounds. If infants stored components, this middle group should respond like the top one and show little or no recovery since they were being given the same components they had seen earlier. However, if infants store the information in compound form, the middle group would be seeing new compounds and should recover as much as the bottom group. Now for the results: the mean duration of a look for the top group was 1.9 seconds, for the middle group it was 2.2 seconds, and for the bottom group 4.1 seconds. Statistically, the top two groups did not differ from one another, but the bottom group looked significantly more than either of them. So, our tentative conclusion was that by four months of age infants are able to attend to and store the information in terms of individual components. We are currently running another study to double-check this finding, and preliminary results so far indicate the same conclusion.

The final experiment I would like to describe combined everything. We used the new procedure, we showed the infants checkerboard patterns with differing numbers of checks, and we studied habituation. At some point you have to put it all together and see what happens. The infants were four months old, and half were male, half female. A total of twenty trials was presented in all. On the first two trials a red circle was shown, on the next 16 trials the same checkerboard pattern was presented repeatedly, and the red circle again appeared on the last two trials. During the checkerboard trials infants received either a 2 x 2, an 8 x 8, or a 24 x 24 pattern. For one-half of them all patterns were always on the left, for the other half always on the right.

Fixation duration data during the checkerboard trials are presented in Figure 8. A log transformation was computed due to the large variability

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Insert Figure 8 about here

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of the scores. As you can see, once again, the males habituated and primarily to the two most complex patterns. They fixated longer initially to the 8 x 8 and 24 x 24 checkerboards, but by the last block of trials were looking as little at them as they were at the 2 x 2 pattern. But look at the females; for the third time we didn't get any habituation. It is not that they didn't pay attention to the stimuli. They looked much more to the 24 x 24 than the 8 x 8, and more to the 8 x 8 than the 2 x 2. So they were doing something, but it certainly was not the same thing the males were doing.

We also looked at performance to the red circles. We wanted to see whether infants responded differently on the final red circle trials, after they had been exposed to the checkerboards, than they did on the initial red circle trials. Figure 9 provides the data. One interesting point is

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Insert Figure 9 about here

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that we obtained significant differences in the latency of head turning measure but not in the fixation duration one. Males generally increased their speed of head turning from the beginning of the experiment to the end. The females' behavior, however, depended upon the type of pattern they had been exposed to during the checkerboard trials. If they had seen a relatively uninteresting 2 x 2 pattern, their head turning slowed down. If they had seen an 8 x 8, it remained about the same; and if they had seen a 24 x 24, it increased. These changes in latency also tended to occur during the checkerboard trials, but were only of borderline significance.

A summary of the results, then, is that in the four-month-old infant habituation is primarily a function of the Attention-Holding process, and occurs more in males than females, although both sexes initially show preferences for, or look longer at the more complex patterns. Performance on the red circle trials indicates a tie-in between Attention-Getting and Attention-Holding, with the information obtained from prior fixations of the stimuli somehow determining the speed of subsequent head and eye orientation. This seems more true of females since they either speed up or slow down their turning depending upon the type of pattern seen. Male orienting, on the other hand, apparently is less influenced by the specific stimulus, since they generally speed up no matter what the pattern.

Now how can these additional facts be incorporated into our model? Here is one attempt, shown in Figure 10. It is our current version until

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Insert Figure 10 about here

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we complete another experiment and need to change it further. Let's follow it through. An Environmental Event occurs. The Peripheral Perceiver goes into operation. If the stimulus has a good deal of movement, brightness, etc. the infant probably will orient to it. (Forget about the O.R. Inhibitor-Facilitator box for now. We will get back to it in a moment.) If the stimulus is not moving or bright enough the arrow labelled "low" is followed and he will not orient. Given that he orients he will also fixate, and given that he fixates two things will happen. First he will process the information contained in the stimulus. Based upon the results of the compound-component experiment, that information is split up by the Perceptual Processor into color, form, and probably other dimensions as well. That information is then stored in memory to be compared later with what is currently coming in, the same as in the old model. If it's different he will continue to fixate; if it is the same, he won't.

But, something else must be happening as well. Remember the experiment with the red circles. Since all subjects were seeing the same thing on the last two trials, the only way the females could have responded differently to those final red circles was if they had somehow stored some information about the checkerboard patterns they had seen earlier. What I'm suggesting is that they stored something either about how long they had looked in the past, or about how interesting or reinforcing those patterns had been. This is represented by the vertical arrow going from the Fixation on Pattern box to the Memory. That information feeds into the O.R. Inhibitor-Facilitator of the Attention-Getting Process, so that the next time they are about to orient they will turn more rapidly if it was something interesting and more slowly if it was uninteresting. This is essentially an operant conditioning mechanism, and we have recently completed two studies (DeLoache, Wetherford, and Cohen,,1972) which indicate that conditioning is, in fact, involved.

One additional point needs clarification. Females may not have habituated, but they did look longer at some stimuli than at others. Somehow this fact must be represented in the Attention-Holding process.

What I would like to suggest, and at this point it borders on pure speculation, is that infants make use of two memory systems. One memory, contained within the Perceptual Processor, is short-term, lasting just a few seconds. While an infant, male or female, fixates a pattern, a representation of that pattern, probably not broken down into components, is building up in the Perceptual Processor. That representation is also compared with what the infant is currently attending, and when there is a match between the two, the infant will stop fixating. The more complicated the pattern, the longer it will take for the representation to become accurate and hence, the longer the infant will continue looking . Once the infant looks away, however, that short-term representation will be replaced by a new one. Therefore, the next time he fixates the old pattern, the representation will have to build up once again from scratch. This might explain why females start out looking longer at complex patterns and continue to do so even after many trials.

With males the process is somewhat more complicated. Stimulus information not only gets stored in short-term memory but gets broken into components and stored in long-term memory as well. Unlike short-term memory, information in long-term memory remains even when the infant looks away. It is the permanence of this information which accounts for habituation. Over trials the representation in long-term memory comes to match the current input more and more closely and causes the Comparator to decide the inputs are the same even before the short-term memory has had time to build up. In the first few trials one would expect males to fixate longer on complex patterns since their attention is being controlled primarily by the Perceptual Processor. However, as the experiment continues, one would expect the long-term memory to take over more and more, and the fixation times to these complex stimuli to decrease.

I am not suggesting that females have no long-term memory. What I am saying is that at least at four months of age males and females store different kinds of information in long-term memory. While males are storing specific information about the physical nature of the stimulus, (i.e., its color and form), females are storing information about the consequences of turning to look (i.e., whether or not they will find something interesting to look at). While the males are attending and habituating, the females are attending and learning. They are being reinforced for turning their head, and the strength of the reinforcement determines how fast they turn.

One may reasonably ask whether this model applies only to four-month-old infants or whether it is applicable to other ages as well. At this point I do not know. I believe our extensive research at this one age level has been justified, however, for without it we would never have been able to arrive at the model. The model does suggest some interesting developmental questions which are amenable to experimentation. For one thing one might ask to what extent the Attention-Holding process gradually becomes more important as infants become older. Most researchers have had difficulty obtaining habituation to visual stimuli with infants under two months (Jeffrey and Cohen, 1971), although some (Friedman, Nagy, and Carpenter, 1970) have recently found it in newborns.

A second set of questions of some interest involves attending to compounds versus components. Do younger infants also respond to components? At what age does compounding first appear? What other stimulus dimensions should be included, and how might the number of them change with age?

Perhaps the most intriguing questions relate to what gets stored in long-term memory. It may be that as an infant gets older the amount of information he can store in long-term memory at any one time increases. At four months he appears to be able to store something either about the physical characteristics of the stimulus or how interesting, motivating or reinforcing the stimulus was, but not both. Which is he capable of remembering first, or do they both develop simultaneously in some parallel manner? Research on infant learning suggests that even newborns can be operantly conditioned (e.g. Siqueland, 1968). However, it usually takes several days to accomplish it, and in our experiments conditioning occurred in one ten minute session. Perhaps as John Watson (1969) suggests the rapid storage and utilization of information necessary for conditioning in one or two sessions does not occur until the infant is two- to three-months of age.

Newborns also seem to be able to process information about the physical characteristics of stimuli and show definite preferences for certain patterns over others (e.g. Hershenson, 1964; Hershenson, Munsinger, and Kessen, 1965). But, here also, preferences for novel patterns begin to be seen most clearly in his third month (Weizmann, Cohen, and Pratt, 1971; Wetherford and Cohen, 1971).

Apparently, then sometime before four months of age infants are capable of storing information either about the physical properties of visual stimuli or about the contingency between their response and the reinforcement. Why four-month-old males should store one thing and four-month-old females another is still a mystery. We obviously need to study this phenomena with both older and younger children, to see if there is some kind of shift from using one type of information to using the other, and to see at what age the shift occurs for both males and females. At some point in time both types of information must be integrated into one system. Discrimination learning, for example, involves both a careful examination and memory of the stimuli as well as learning to makea specific response for reinforcement. Perhaps the difficulty in obtaining clear evidences of discrimination learning before six months of age (Reese and Lipsitt, 1970) is partly a result of this lack of integration.

In any event, the model I have presented has been valuable for several reasons. It has summarized a large number of studies on infant attention. It has led us to the development of a new and better procedure for testing infants; and it has been a valuable heuristic tool as well. We expect our future research to go in three related directions. First, we will be conducting developmental studies to see if the model is applicable to infants both younger and older than four months; second, we intend to begin a series of studies on individual differences in Attention-Getting and Attention-Holding Processes; and third, we plan to continue our research on specific parameters within the model in hopes of both refining the model and of increasing our knowledge of infant perception, attention, and memory generally.

Whatever the outcome, William James once stated that the perceptual world of the infant must be a "blooming, buzzing confusion." What our research and other recent research on infant attention has indicated is that the infant's world may be a bit more blooming and a bit less buzzing than James had suspected.

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## Footnotes

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## Figure Captions

Fig. 1: Preliminary version of the model of infant attention and habituation.

Fig. 2: Total fixation times during the habituation phase of the Pancratz and Cohen (1970) study. Each trial block contains two trials. Copyright 1970 by Academic Press. Reprinted by Permission.

Fig. 3: Number of fixations from the Pancratz and Cohen (1970) study. Previously unpublished data.

Fig. 4: Mean fixation durations from the Pancratz and Cohen (1970) study. Previously unpublished data.

Fig. 5: Intermediate version of the model of infant attention showing the separation of Attention-Getting and Attention-Holding Processes.

Fig. 6: Habituation and recovery data from Cohen, Gelber, and Lazar (1971). Copyright 1971 by Academic Press. Reprinted by permission.

Fig. 7: Design of the compound vs. component experiment. If the top two rows in the Test are the same, it indicates responding to components. If the second and third rows are the same, it indicates compounding.

Fig. 8: Fixation duration data from the Cohen and Wetherford study. Only the checkerboard trials are included. Previously unpublished.

Fig. 9: Latency of fixation data from the Cohen and Wetherford study. The figure includes only the red circle trials (i.e., the first two and last two trials in the experiment). Previously unpublished.

Fig. 10: Current version of the model of infant visual attention.

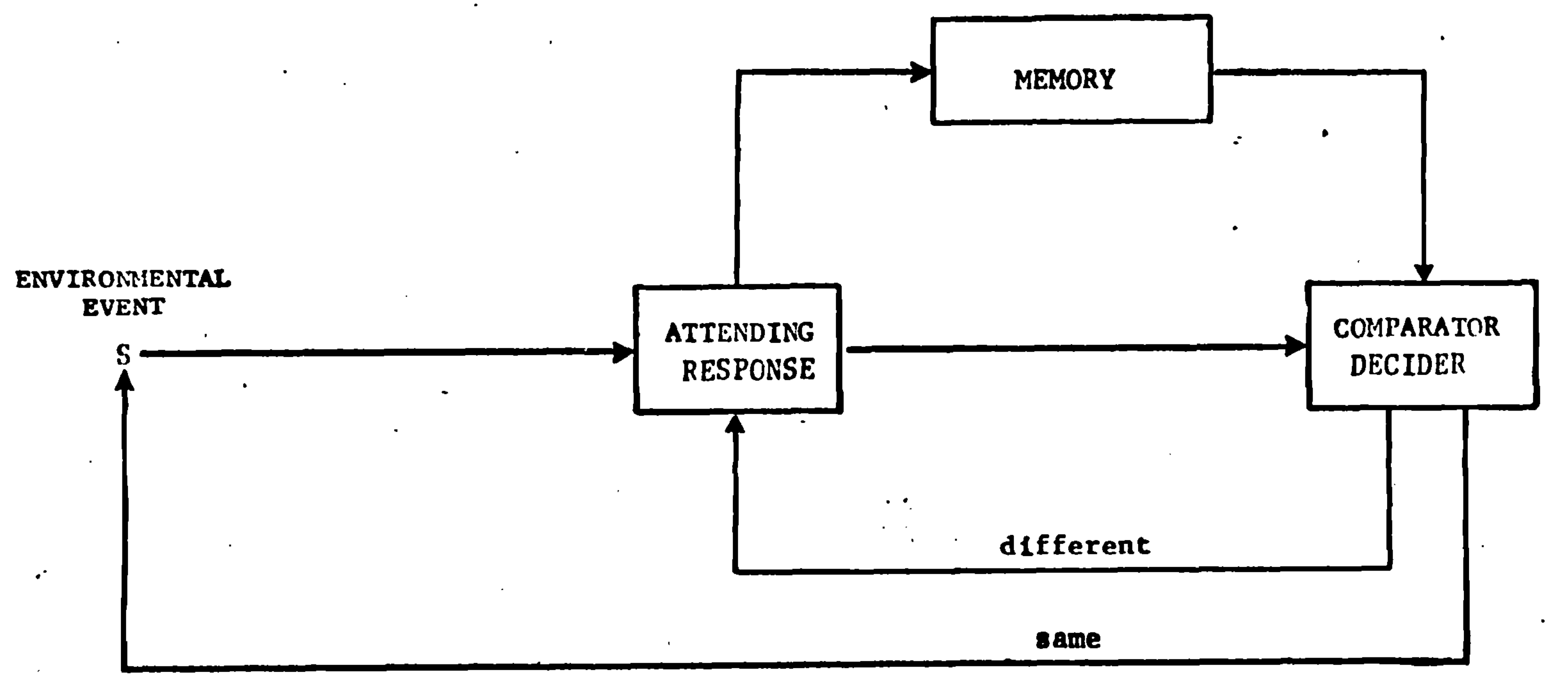
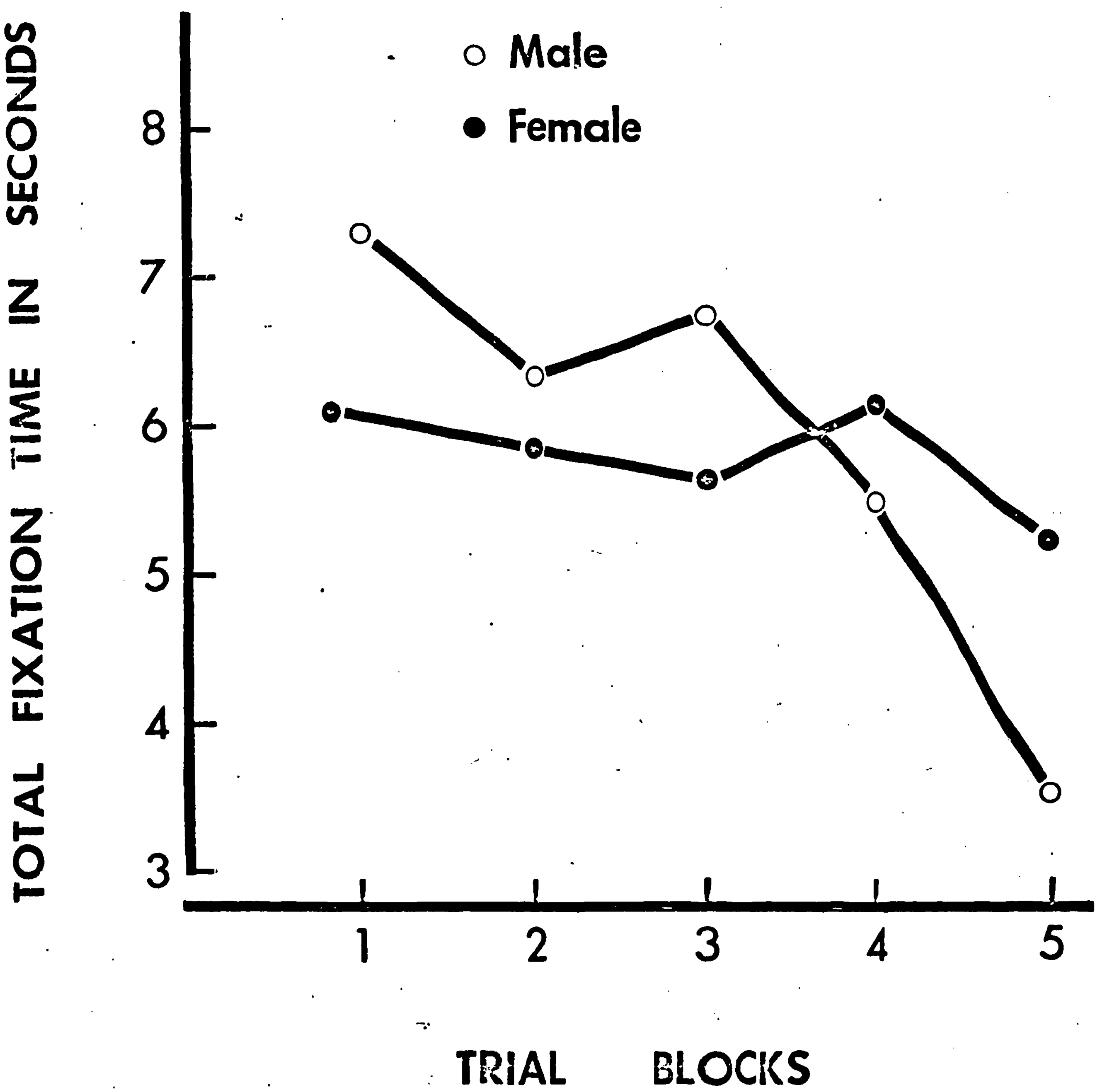

ENVIRONMENTAL
EVENT
S
ATTENDING
RESPONSE
MEMORY
COMPARATOR
DECIDER
different
same

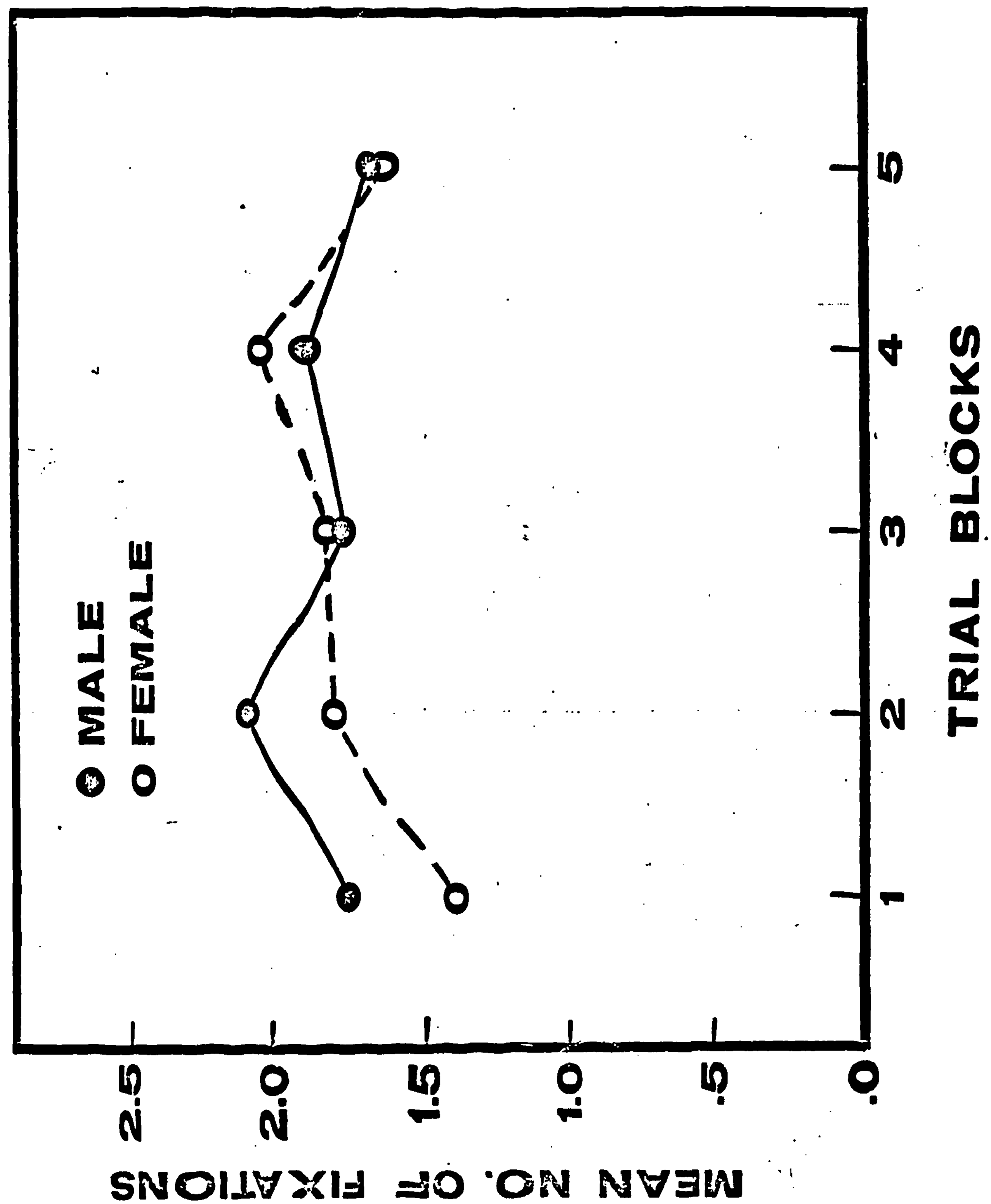
Fig. 4



TOTAL FIXATION TIME IN SECONDS
○ Male
● Female
8
7
6
5
4
3
1
2
3
4
5
TRIAL BLOCKS




Fig. 2


MALE
FEMALE
MEAN NO. OF FIXATIONS
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2.0
1.5
1.0
.5
.0
1
2
3
4
5
TRIAL BLOCKS

Fig. 3

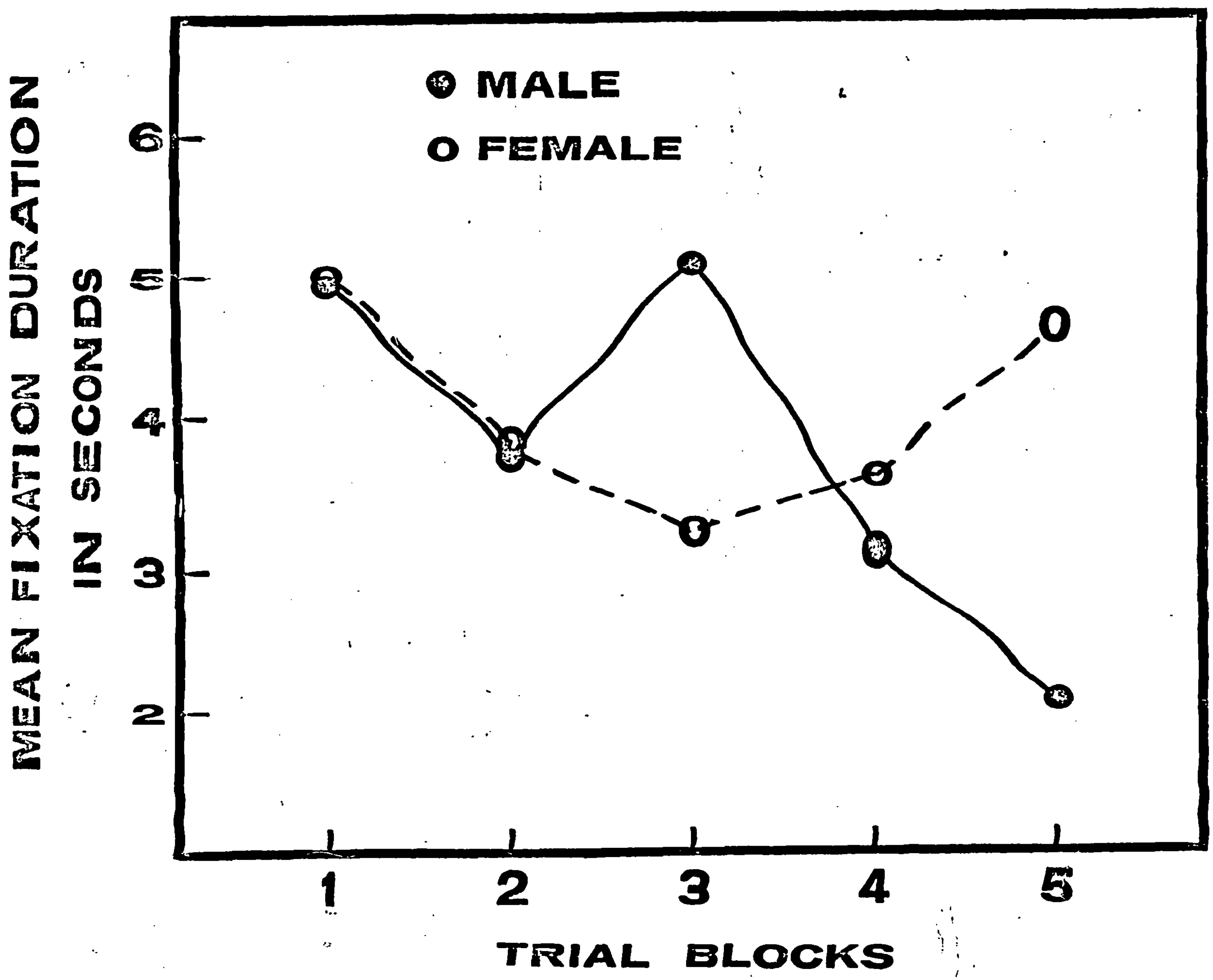
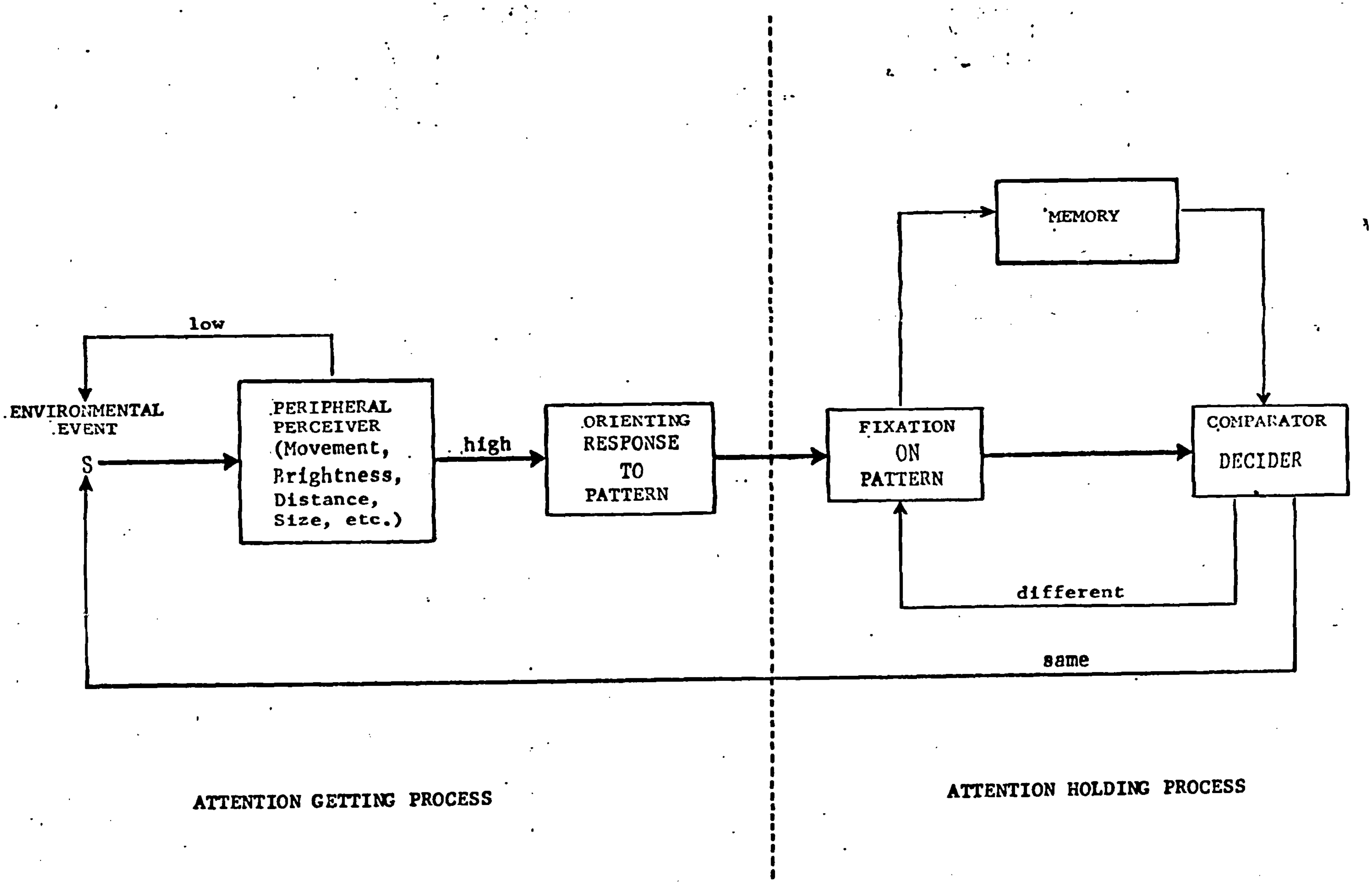

MALE
FEMALE
MEAN FIXATION DURATION
IN SECONDS
6
5
4
3
2
1
2
3
4
5
TRIAL BLOCKS

Fig-4


low
ENVIRONMENTAL EVENT
S
PERIPHERAL PERCEIVER (Movement, Brightness, Distance, Size, etc.)
high
ORIENTING RESPONSE TO PATTERN
FIXATION ON PATTERN
MEMORY
COMPARATOR DECIDER
different
same
ATTENTION GETTING PROCESS
ATTENTION HOLDING PROCESS

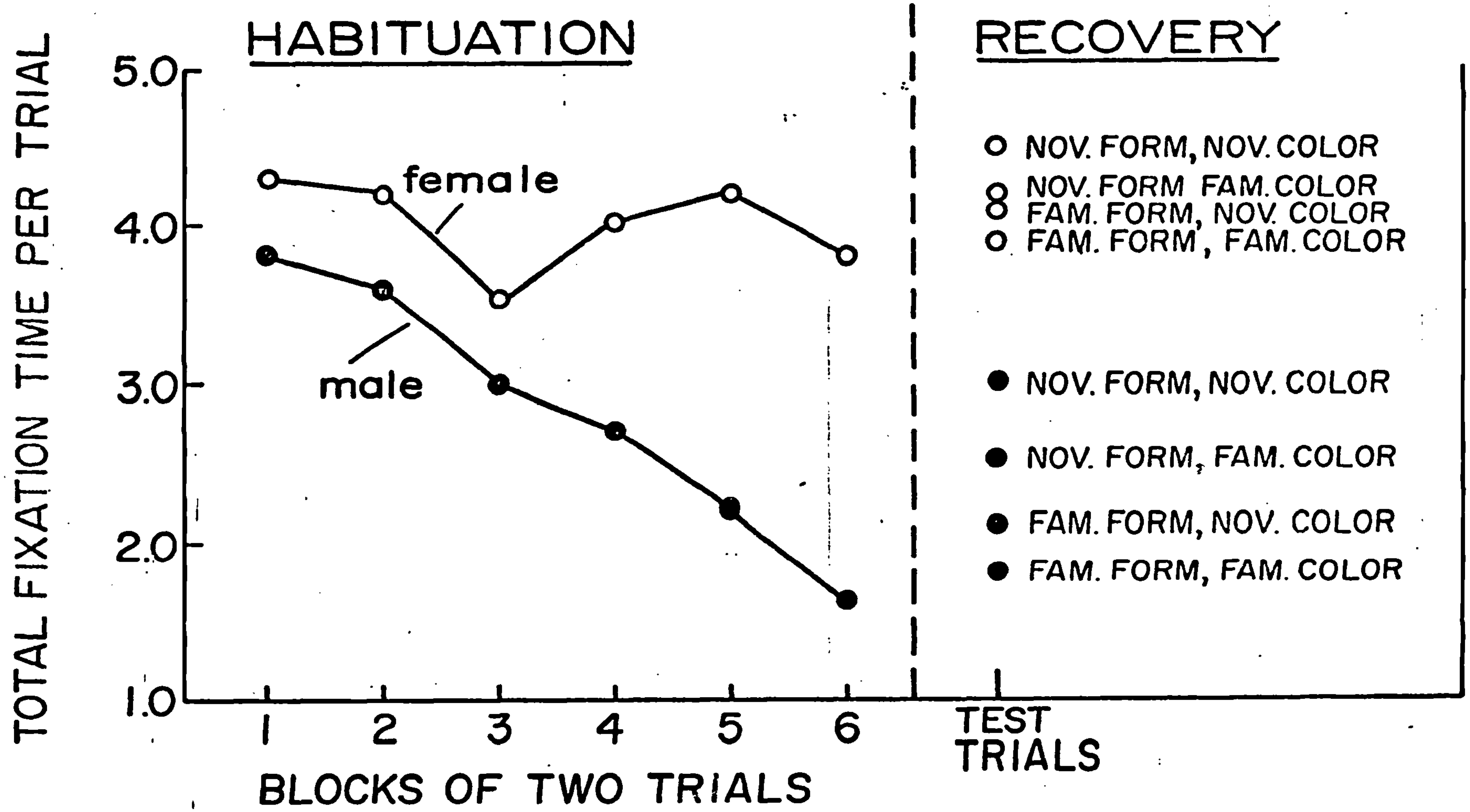

HABITUATION
RECOVERY
TOTAL FIXATION TIME PER TRIAL
5.0
4.0
3.0
2.0
1.0
female
male
1
2
3
4
5
6
BLOCKS OF TWO TRIALS
TEST TRIALS
NOV. FORM, NOV. COLOR
NOV. FORM FAM. COLOR
FAM. FORM, NOV. COLOR
FAM. FORM, FAM. COLOR
NOV. FORM, NOV. COLOR
NOV. FORM, FAM. COLOR
FAM. FORM, NOV. COLOR
FAM. FORM, FAM. COLOR

Fig. 6

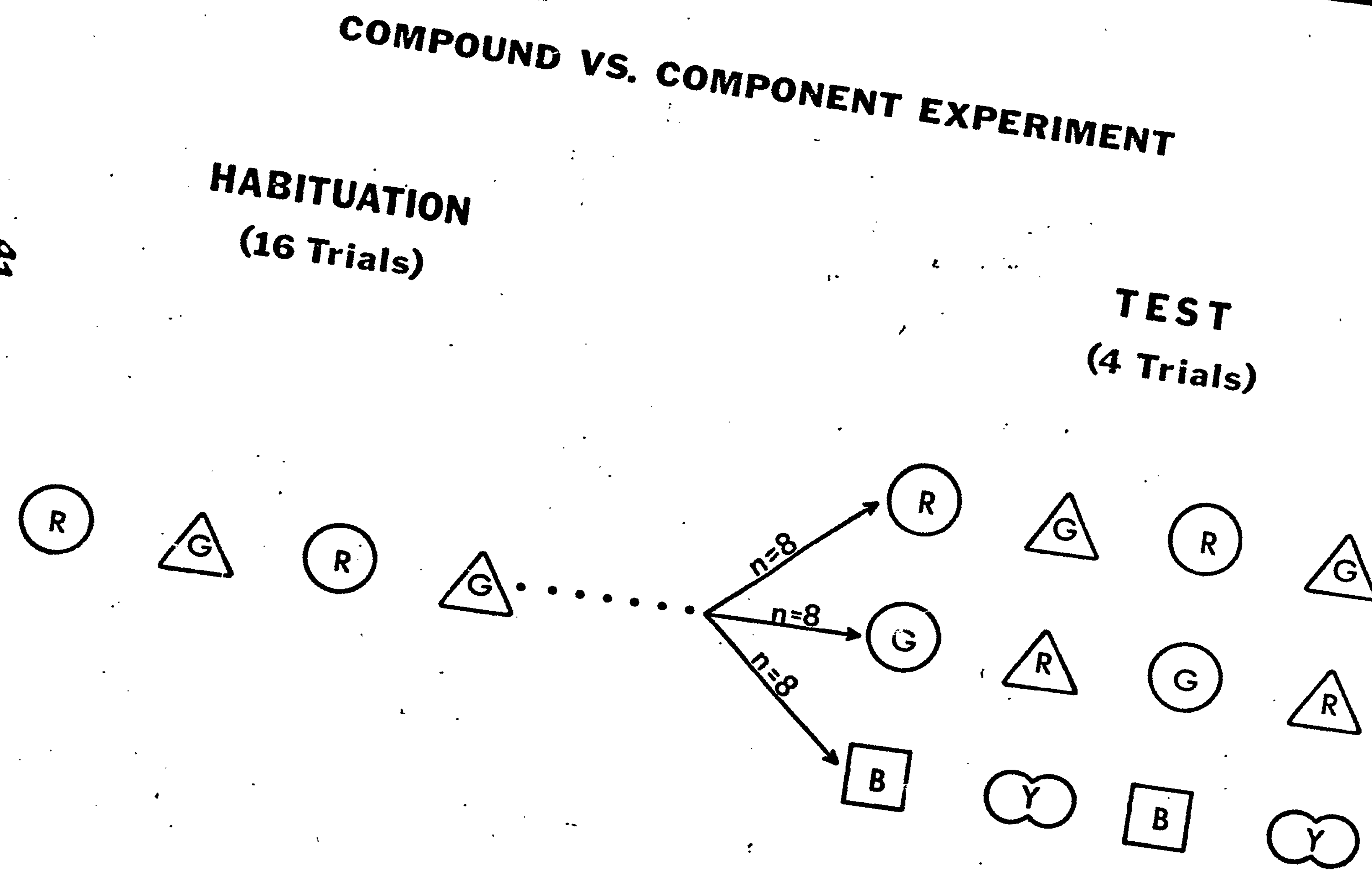
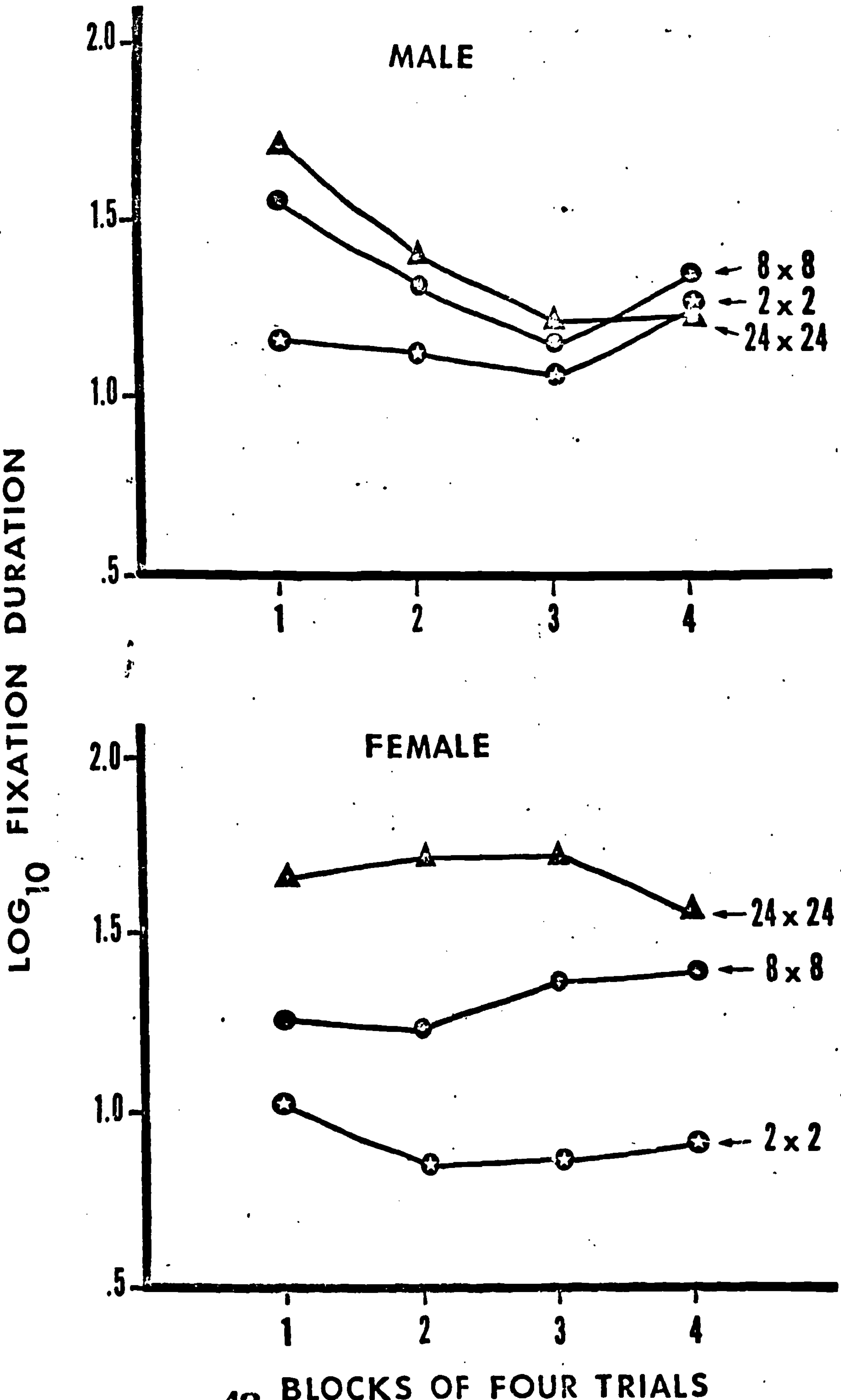

COMPOUND VS. COMPONENT EXPERIMENT
HABITUATION
(16 Trials)
TEST
(4 Trials)
R
G
R
G
n=8
n=8
n=8
R
G
B
G
R
Y
R
G
B
G
R
Y



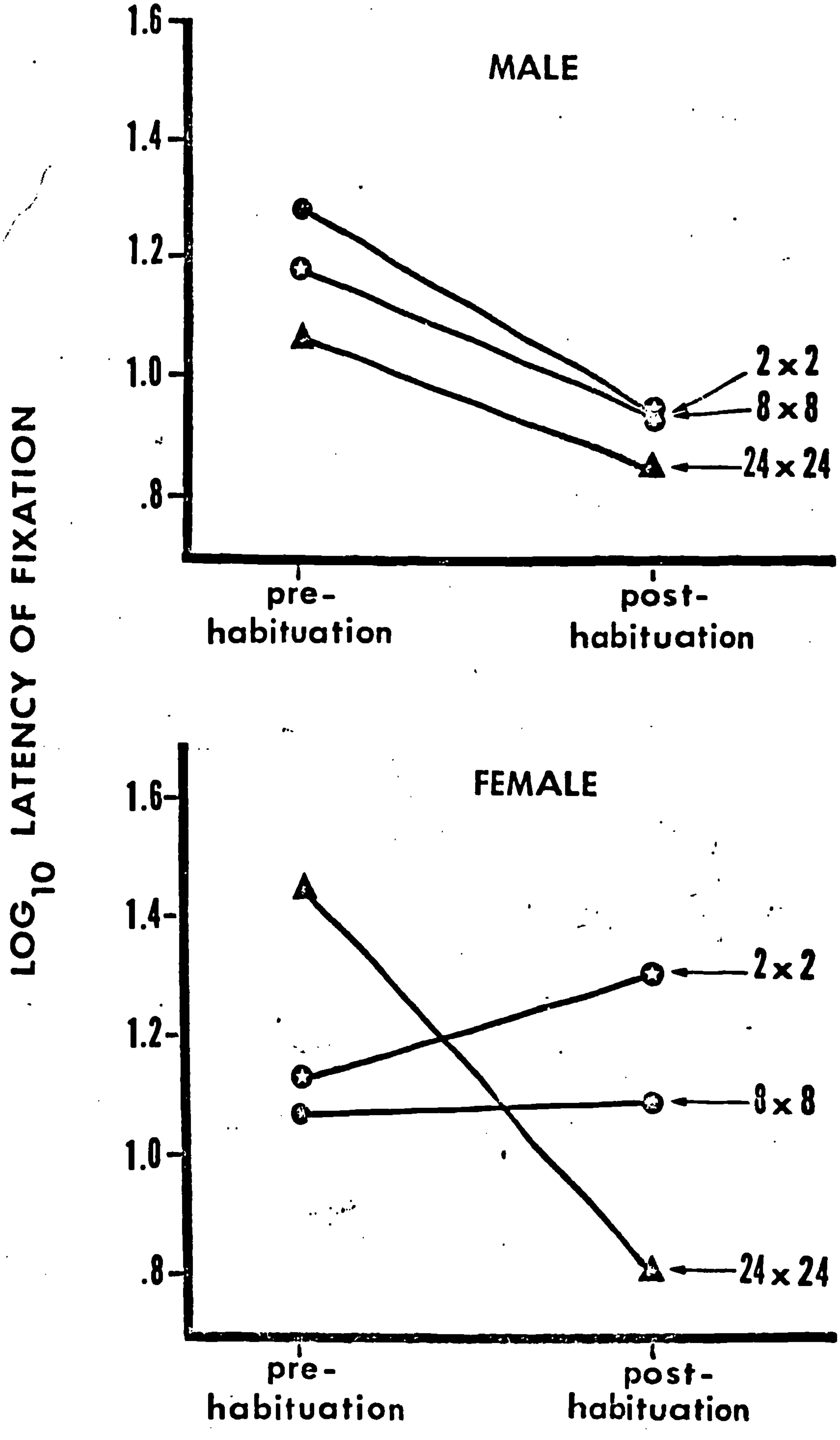
Fig. 7



MALE
2.0
1.5
1.0
.5
1
2
3
4
8 x 8
2 x 2
24 x 24
LOG10 FIXATION DURATION
FEMALE
2.0
1.5
1.0
.5
1
2
3
4
24 x 24
8 x 8
2 x 2
BLOCKS OF FOUR TRIALS




Fig. 8






RED CIRCLE TRIALS

INFANT VISUAL ATTENTION