Acknowledgments

Many people contributed to this project. Of these the most essential were the graduate students and research assistants at the New School for Social Research and the University of California at Berkeley without whom the research simply would not have been done. Their participation began with the programming of the experiments and designing of the stimuli, and extended to performing the experiments and collaborating in the analysis and explanation of the results. Indeed, the only misgivings we had about our decision to write a book about this work rather than to report it in a series of research and review articles was that it would deprive our young collaborators of the recognition they deserved. Had we written articles, their names would have appeared among the list of authors, providing some of them with not one but a number of publication credits. We have tried to make up for this by indicating in the text in which laboratory particular experiments were done and by whom, but this does not adequately convey the extent of their contribution.

There were a group of assistants whose contributions, however, can not be adequately acknowledged by a mere footnote. In this group are Willann Stone, Teresa Hartmann, Jack Hoppenstand, and Michael Silverman at the New School for Social Research, and Christopher Linnett, Tony Ro, Harris Ingle, and Diane Beck at the University of California, Berkeley. Willann Stone was an active collaborator in the early days of the research and extended our understanding of the relevance this work might have for children suffering from an Attention Deficit Disorder. Teresa Hartmann joined the New School perception laboratory not long after the research began and remained throughout the writing of this book. She participated in almost every aspect of the project and probably—more than anyone else—was essential to it. She not only designed and performed many of the important experiments done at the New School, she drafted the originals of most of the figures and tables in this book as well. Jack Hoppenstand designed and ran all the auditory experiments, worked diligently to improve the graphic representations of our data, and most important, thought long and hard about the conclusions that seemed might follow from our results. Michael Silverman not only ran his share of the experiments, but extended our research in an important new direction that is likely to link it to new research areas.

In Berkeley Tony Ro and Christopher Linnett designed much of the research done there and helped clarify many difficult issues. Harris Ingle and Diane Beck, also at Berkeley, were essential resources during the period in which the book was being written, when it was no longer possible to discuss the Berkeley work with Irvin Rock. Without them and without Ethan Newby and Dan Kuang, who did the last research on this project done at Berkeley, it would not have been possible to complete or coherently describe this work.

I would also like to thank the staff at the San Francisco Exploratorium and the New Jersey Liberty Science Center for generously allowing us to run our experiments in their institutions. Our need for subjects was virtually insatiable and both institutions provided us with access to an endless supply. Thanks are due as well to the thousands of people who participated as subjects.

Two other people were extremely important both during the research and writing phases of this work. Stephen Palmer and Bill Prinzmetal, both of whom are on the Berkeley Psychology faculty, were always ready to talk about our findings and to provide invariably thoughtful comments and advice. Both of them read the original drafts of each chapter and their comments surely helped me to avoid many potential errors. They also shared with me the pain of watching the progression of Irvin Rock's illness and stood by me and this work after his death. I will forever be grateful to them. No one could replace him as a colleague and collaborator, but Steve Palmer came as close as anyone could.

The entire research project was generously supported by the National Institutes of Mental Health, and I am particularly grateful to Howard Kurzman for his understanding during the period of Irvin Rock's illness and after his death. Thanks are due as well to Amy Pearce Brand, our editor at MIT Press, and to Guenevere Nelson-Melby, who did an heroic job of copyediting the book manuscript. Finally I would like to acknowledge my debt to the Graduate Faculty of the New School where I have taught since 1966. This institution has given me the freedom to do my research in perception, to edit *Social Research,* and has supported me in all the other things that I have been lucky enough to be able to do as a faculty member there.

Chapter 1
An Overview

Motivation for the Research

What is the relationship between attention and perception? How much, if anything, of our visual world do we perceive when we are not attending to it? Are there only some kinds of things we see when we are not attending? If there are, do they fall into particular categories? Do we see them because they have captured our attention or because our perception of them is independent of our attention?

Most people have the impression that they simply see what is there and do so merely by opening their eyes and looking. Of course, we may look more closely at some things than at others, which is what we ordinarily mean by "paying attention," but it probably seems to many people as if we see nearly everything in our field of view.

However, many have experiences that seem to contradict the belief that, to one degree or another, we perceive everything in view and that our attention merely permits us to see some things in more detail than others. Almost everyone at one time or another has had the experience of looking without seeing and of seeing what is not there. The experience of looking without seeing is most likely to occur during moments of intense concentration or absorption. During these moments, even though our eyes are open and the objects before us are imaged on our retinas, we seem to perceive very little, if anything. For example, most people who drive have experienced these brief moments of not seeing, that is, of "functional blindness," which produce astonishment and alarm when awareness returns. Similar moments of "sighted blindness" can occur during particularly absorbing conversations or in moments of deep thought. Why do we have these experiences if perceiving only requires opening our eyes?

There is an opposite experience that also raises questions about the relation between perception and attention. When we are intently awaiting something, we often see and hear things that are not there. For example, many people have had the experience of hearing footsteps or seeing someone who is anxiously awaited even though the person is not there, and there are no footsteps. On these occasions, it is as if our intense expectation and riveted attention create or at least distort a perceptual object. Here, instead of not seeing (or hearing) what is there when we are distracted, we are seeing (or hearing) what is not there, or perhaps more accurately, misperceiving what may actually be there, but which we are anxiously awaiting. Both experiences appear to implicate attention in the act of perceiving. This kind of experience was eloquently described by William James.

> When waiting for the distant clock to strike, our mind is so filled with its image that at every moment we think we hear the longed-for or dreaded sound. So of an awaited footstep. Every stir in the wood is for the hunter his game; for the fugitive his pursuers. Every bonnet in the street is momentarily taken by the lover to enshroud the head of his idol. (1981, 419)

Grouping and Attention

The body of research we describe here is concerned with the relationship between visual perception and attention. Our initial motivation for studying this relationship developed from two independent but related sources. One was our interest in perceptual organization and the question of whether, as has generally been believed on the basis of principles first uncovered by the Gestalt psychologists, that the organization of the visual field into separate objects occurs automatically, at an early stage in the processing of visual information, or at some later stage, possibly after attention has been engaged. We already had reason to doubt that the grouping of the visual field on the basis of these principles is as early and spontaneous as most theorists believed. These doubts stemmed from the results of research done by one of us (IR) and his coworkers on the question of whether grouping by proximity or by similarity of lightness or shape is based on the retinal (proximal) attributes of units or rather on their perceived attributes.

This research established that these kinds of grouping in fact do not occur at the earliest stages of visual processing but, rather, occur later, after the processing that underlies perceptual constancy has been accomplished.[1] Because constancy processing generally depends upon available information about distance and/or surface lightness, constancy can occur only after this information has been taken into account. Thus, changing the relative retinal proximity of an array of elements from one in which the vertical elements are closer together than are the horizontal elements, to one in which the horizontal elements are closer, by slanting the array in depth, does not change the perceived grouping of the elements into vertical columns as long as

A.

B.

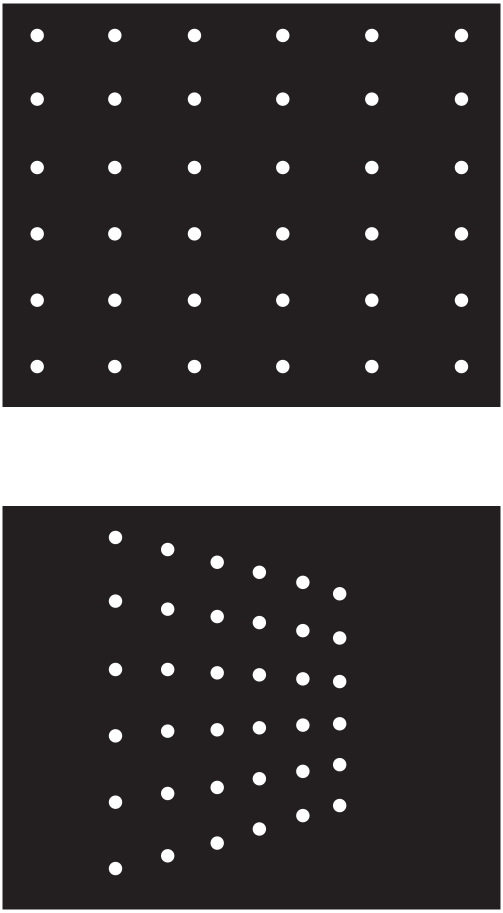


Figure 1.1
Grouping of elements by proximity.
A. Pattern of lights as they appear in frontal plane.
B. Same pattern as it appears when rotated in depth.

sensory information about slant in depth is available (Rock and Brosgole 1964) (figure 1.1). Thus the grouping of elements in a scene on the basis of their closeness is not a function proximity on the retina, but of their *perceived* proximity.[2] Consequently, grouping cannot occur automatically at the lowest level of perceptual processing, and this leaves open the possibility that it might fail to occur without attention.

However, although there is good reason to doubt that grouping based on Gestalt principles is an early achievement of visual processing, there seemed to be a compelling reason to believe that at least one product of organization, namely the formation of the elementary units that provide the basis for grouping, was an early achievement of the visual system and therefore occurred without attention. As others have previously noted (Treisman 1982; Neisser 1967), attention is inherently intentional. It must be directed to some *thing,* and whatever that thing is, it must exist prior to the activation of attention, for only then is there something to which we can turn our attention. A surprising consequence of the research this book describes is that this view, which at the outset appeared to have the force of logic, was contradicted by the results.

Pop Out and Attention

The second source of our initial motivation for investigating the relation between perception and attention stemmed from concern with the methods most researchers have used to decide whether a perceptual process requires attention or instead is preattentive. Prior research into the relation between perception and attention has been based on a method that not only fails to eliminate attention, but in fact depends upon it. In all this research observers are required to perform some sort of visual search task. For example, they may be asked to report, as quickly as possible, whether a particular target—say a red circle—is present in a visual array consisting of green circles (see Treisman and Gelade 1980; Treisman 1988). In a variation of this design, subjects are not given a predefined target but rather are asked to report only whether an odd object is present in an array that is either homogenous or contains a single odd object (for example, see Julesz 1981). These arrays generally consist of a variable number of nontarget objects that are called "distractors." The relationship between the time it takes the subject to report the presence or absence of the target and the number of distractor elements is considered to be the indicator of whether the target stimulus is processed without attention. If, on trials in which a target is present an increase in the number of distractor elements causes no corresponding increase in the time it takes to report the target, the target stimulus is said to be processed "preattentively" (i.e., without attention). Or, if the time to report the presence of the target increases as the number of distractors increase, the stimulus is said to require focused attentional processing (see, for example, Treisman and Gelade 1980).

The reasoning here seems quite straightforward. If a target "pops out" (i.e., if the number of distractors does not affect how quickly it is seen), then it would seem that its perception does not require a serial search through each item in the array. If, however, the time to report that target increases with the number of distractors, then it seems equally plausible to conclude that the target does require searching through the array sequentially. Arrays in which targets pop out are said to be processed in parallel (i.e., all the objects are thought to be processed simultaneously), whereas arrays in which objects fail to pop out are believed to require serial processing. It was initially believed that the targets that pop out compose the set of basic or primitive features of perception, which are distinguished by the fact that they are perceived without attention, whereas the combination of these features into more complex objects requires serial processing and focused attention. (See Treisman 1985.)

Another less widely used technique for identifying the primitive features of perception thought to be perceived without attention entails presenting visual arrays very briefly, for example, for 50 msec. or less. Here too the subjects are given a search task. They are asked to report whether a target, which can either be a single object or a patch of segregated texture (Julesz 1981), is present in the array. If the observers are able to detect the target in these multielement arrays more or less effortlessly in the brief time allowed, the conclusion is drawn that it is detected without attention. The reasoning here also seems quite straightforward. If the target is detected when the entire array is presented very briefly, it cannot depend upon either a sequential search involving either a series of eye fixations that require significantly more time to execute than is provided in these experiments, or a sequential shifting of attention without changes in fixation, which also would require considerable more time to effect.

This very brief summary of the experimental methods widely used for studying preattentive perception should make clear why these methods do not successfully eliminate the possible contribution of attention. In every case the observers are engaging in a visual search which, by definition, is an activity requiring attention. To look and try to find something is to attend to the array in which it might be present and to *intend* to see it. How then can one conclude that attention has been eliminated? Thus doubts about these methods of studying perception without attention were part of the motivation for this research. To study perception without attention a new method is required that effectively eliminates it. Any method that involves deliberate search is, therefore, ruled out in advance.

The Inattention Paradigm

Because no adequate method was available, a new one had to be devised. It had to guarantee that the observer would neither be expecting nor looking for the object of interest, but would be looking in the general area in which it was to be presented. We also thought it might be necessary to engage the subject's attention with another task, because without some distraction task, it seemed possible that by default attention might settle on the only object present. The method we devised, a version of which has been used in most of the research, meets these criteria.[3]

Observers were asked to report the longer arm of a cross briefly presented on the screen of a personal computer usually viewed from a distance of 76 cm. The cross that served as the distraction stimulus or, rather, as the object of the distraction task, was centered either at fixation or in the parafovea within 2.3 degrees of fixation. One of the arms of the cross was horizontal and the other was vertical. The cross dimensions changed from trial to trial, with the length of a cross arm ranging from 2.7 degrees to 4.5 degrees, and the length differences between the arms of the cross ranging from 0.1 degree to 1.8 degrees.[4] In all the early experiments the cross was centered at fixation. Only later was it centered in the parafovea. The cross was presented on the screen of a computer for 200 msec., which is less time than it generally takes to move the eyes from one location in space to another, that is, to make a saccadic eye movement. Thus we could be reasonably certain that the observers were not changing their fixation during the time the cross was visible.[5]

In most cases, as soon as the cross disappeared, a pattern mask appeared for 1500 msec. that covered the entire area of the visible screen, a circular area about 8.9 degrees in diameter (10.6 cm) in which the cross was displayed. The mask was meant to eliminate any processing of the visual display after it disappeared from the screen. Before each presentation of the cross, a fixation mark was displayed at the center of the screen, and the subjects were asked to keep their eyes focused on it until the mask appeared. When the mask disappeared, subjects reported which line of the cross seemed longer. This procedure was followed on the first two or three trials (figure 1.2a). On the third or fourth trial, a *critical stimulus* was presented in a quadrant of the cross within 2.3 degrees of fixation (figure 1.2b). (In experiments in which the cross was located in the parafovea, this stimulus was most often presented at fixation (figure 1.3). What qualified this stimulus as critical was the fact that it was presented to subjects quite close to fixation (or at fixation) while their attention was engaged by the cross task and they were neither searching for nor expecting it.

Immediately following the trial in which the critical stimulus was presented, the subjects were asked whether they had seen anything on the screen other than the cross figure, that is, anything that had not been present on previous trials. This question was asked throughout the research, even though it had the potential of increasing the likeli-

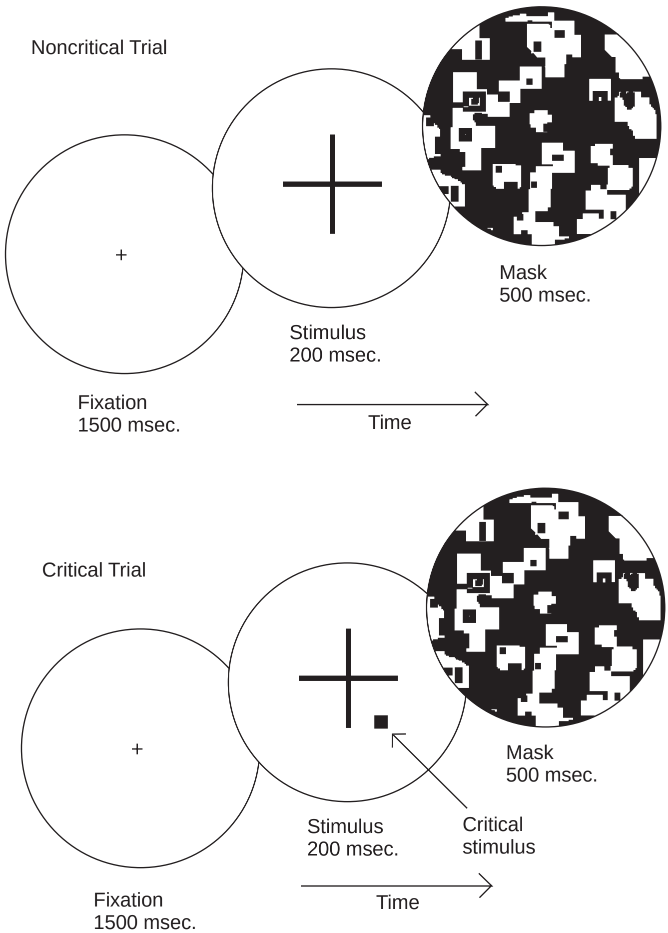


Figure 1.2a & b
Critical stimulus in parafovea: noncritical and critical trial display.

hood of positive responses when nothing else had actually been seen.[6] The answer to this question provides the data about what is perceived without attention. If the subjects reported seeing something, they were asked to identify it either by describing it or by selecting it from a set of alternatives presented to them in a recognition test. In many experiments, even if subjects had not seen the critical stimulus, they were asked to select it from a set of alternatives. We reasoned that if many subjects who reported seeing nothing new on the trial in which the critical stimulus was presented (hereafter called the "critical trial") guessed correctly, it would indicate that the stimulus in fact either had been "perceived" without awareness or was perceived and quickly forgotten, despite the subject's report to the contrary.

An important feature of the inattention method is that it permits only one critical trial per subject, although subjects were given a few more trials thereafter for reasons to be made clear shortly. This feature of the inattention paradigm is crucial because once subjects have been asked about something on the screen other than the cross (and possibly seen it as well), it is likely that they now will be actively looking for something else and thus no longer view the critical stimulus under conditions of inattention. Two consequences of this limit of one inattention trial per subject are that each experiment requires a large number of subjects, and each new experiment demands a new, naive group of subjects. However, fortunately each subject takes only a few minutes to test. Approximately 5,000 subjects were tested in our two laboratories during a period of seven years.

Following the three or four trials that constituted the inattention condition of the experiment, other trials were run which differed only in the instructions to the observer. In the New School for Social Research laboratory (hereafter the New School laboratory), the next set of trials were explicit divided attention trials in which subjects were asked to report the longer line of the cross while at the same time reporting the presence of anything else on the screen. Again, the critical stimulus was presented with the cross on the third of these divided attention trials. In the laboratory at the University of California at Berkeley (hereafter the Berkeley laboratory), the subjects were given an additional four trials, on the third of which the critical stimulus was again presented; they were again asked after this trial whether they had seen anything in addition to the cross. This was an implicit divided attention trial, because subjects now probably had reason to expect another stimulus and to be questioned about it. The divided attention trials provide information about the subjects' ability to see both the longer line of the cross and the critical stimulus and thus tell us whether both are perceptible *with* attention.

The last trials (one in the Berkeley laboratory, three in the New School laboratory) served as the full attention control trials. At this point subjects were told to continue to maintain fixation on the central mark, to ignore the cross, and to report only what else they saw on the screen when the cross was present. On the last trial in the Berkeley laboratory, the cross and critical stimulus were presented together. In the New School laboratory, the critical stimulus was presented along with the cross only on the third trial of the final, control triad of trials. In the first and second of these trials only the cross was present. (Table 1.1 summarizes the general procedure followed in the two different

Table 1.1
Procedures: New School and Berkeley Experiments.

New School conditions:

Inattention trials:
(Report distraction task only)
1. Distraction task
2. Distraction task
3. Distraction task and critical stimuli

Explicit divided attention trials:
(Report both distraction task and presence of something else)
1. Distraction task
2. Distraction task
3. Distraction task and critical stimuli

Full attention trials:
(Ignore distraction task; report only the presence of something else)
1. Distraction task
2. Distraction task
3. Distraction stimulus and critical stimuli

Berkeley conditions:

Inattention trials:
(Report distraction task only)
1. Distraction task
2. Distraction task
3. Distraction task
4. Distraction task and critical stimuli

Implicit divided attention trials:
(No new instructions)
1. Distraction task
2. Distraction task
3. Distraction task
4. Distraction task and critical stimuli

Full attention trials:
(Ignore distraction task; report only the presence of something else)
1. Distraction stimulus and critical stimuli

laboratories.) The control trial was important in establishing the perceptibility of the critical stimulus under conditions of brief, masked, and often parafoveal (rather than foveal) presentation when attention was allowed. Throughout our experiments subjects virtually always succeeded in seeing and correctly identifying the critical stimulus and its location in the control trials. It is important to note that the location of the critical stimulus was randomly varied from one quadrant of the cross to another in experiments in which the cross was centered at fixation and the critical stimulus appeared in the parafovea, so that its position was never predictable. In contrast, when the critical stimulus was presented at fixation and the cross appeared in the parafovea, it was the location of the cross that varied from trial to trial.

The comparison of greatest interest is between reports of the critical stimulus on the inattention trial and those on the full attention control trial because this indicates what, if anything, is contributed by attention. If there is no difference, that is, if the perception of the critical stimulus on the inattention trial is indistinguishable from its perception on the full attention control trial, then it is clear that attention is not required for its perception. Conversely, if the perception of the critical stimulus on the inattention trial differs significantly from its perception on the control trial, then attention *is* required for its perception. If, on the inattention trial, the critical stimulus is either not seen at all or is detected without being correctly identified, whereas on the control trial it is both seen and identified, then attention clearly is implicated in its perception.

In the case of experiments on grouping and pop out in which an entire array served as the critical stimulus, the array was not confined either to a quadrant of the cross or to fixation, so the exact procedure used in these experiments differs somewhat and is described in detail in chapter 2.

Subjects

Even though we tested approximately 5,000 subjects in the course of this research, they tended to share several general characteristics. For the most part, subjects were recruited from the student populations at the New School or the University of California at Berkeley, and so they tended to be of normal student age—between 17 and 35—and fairly evenly divided between men and women. Our insatiable need for naive subjects caused us to run some experiments at the Exploratorium in San Francisco and in the Liberty Science Center in New Jersey because they offered access to large and previously untapped subject pools. These subjects were visitors to the museums and tended to be somewhat older than the students, but very few were older than 45. All subjects had either normal or corrected to normal eyesight.

Because most of the experiments were extremely brief, it was possible to ask subjects at the Exploratorium and the Liberty Science Center to participate out of a sense of curiosity. Subjects at the New School and Berkeley, however, were modestly rewarded. At the New School subjects were given the option of receiving $2 for their time or entering a lottery in which they had a one in fifty chance of winning $100. Most participants chose the lottery. Subjects tested in Berkeley were offered candy bars as a token of our appreciation—a reward that when tried, failed to satisfy their New School counterparts.

Summary of Findings

The story of this research, perhaps like all research stories, is one of surprises and changing hypotheses. We began with one prediction about what our results would look like and why, and ended with quite a different set of results and interpretations. This book relates the story of this research journey. In this chapter we begin by giving the reader an overview of where we began and where we ended up. The subsequent chapters provide fuller descriptions of what we found and what we believe it means.

We began with the problem of grouping first described by the Gestalt psychologists (Mack et al. 1992). They recognized that the parsing of the visual array into objects was not dictated simply by the presence of the image on the retina, and therefore must be the result of activities carried out by the perceptual system. In their view, the operations that yielded grouping were spontaneous and automatic, (autochthonous, to use their term) and were a function of how the brain processes operate. Although the Gestalt view of the brain has been superseded, the view that grouping occurs spontaneously at an early stage of visual processing is very much alive (Treisman 1982; Neisser 1967; Julesz 1984). Because we doubted the Gestalt account of these grouping processes, which made them independent of attention and based them on retinal stimulation, our research began with a set of experiments designed to explore grouping under conditions of inattention. The Gestalt grouping arrays constituted the critical stimuli in these experiments.

Our doubts about the independence of grouping from attention were confirmed overwhelmingly. Texture segregation failed to be perceived without attention even when based on a vertical-horizontal difference in the orientation of elements, which is known to be one of the most effective segregators. In addition, grouping by proximity, similarity of lightness, and common fate also failed to be perceived without attention. In contrast, with attention directed to the grouping patterns, grouping and texture segregation were generally perceived.[7] In these experiments the grouping patterns consisted of small elements that filled the area surrounding the cross and even though the subjects did not perceive the grouping without attention, they were aware of the multiple elements. We now believe that this was because large displays of elements filling so much of the field attract attention.

Attention and Object Properties

In parallel with our experiments on grouping, another set of experiments (Rock et al. 1992a) explored whether various properties of perceptual objects are perceived without attention. Because we began with the belief that there must be features of objects that exist prior to attention, if only because attention must have an object, it seemed important to determine what these preattentive features were. The properties chosen for examination were: the presence and location of an individual element, color, numerosity, motion, flicker, and shape. These, rather than other properties, were chosen because they seemed likely candidates for early preattentive processing and were assumed to be so by other investigators (Treisman 1986; Yantis and Jonides 1990; Yantis 1993; Folk, Remington, and Wright 1994; Jonides and Yantis 1988; Theeuwes 1991; Theeuwes 1992). For example, color, motion, and very simple shapes were found to pop out and were thus thought to be independent of attention (Treisman 1988). The perception of location, which has been the subject of dispute between those who think it is perceived without attention and those who think it is not (Treisman and Gelade 1980), seemed to us a property that might be perceived without attention. We came to this conclusion because it provides the basis for the execution of saccadic eye movements and because it seems to be the basis for the deployment of attention and so ought to be independent of it.[8]

These experiments examining various properties of perceptual objects yielded results different from those of the experiments on grouping. In these experiments, the critical stimulus was a single, small object (with the exception of the numerosity experiments). It was presented in a quadrant of the cross within about 2.0 degrees of its center, which coincided with fixation. When the property under examination was color, the critical stimulus was a small, brightly colored square. When the property was location, the critical stimulus was the same small square in black. In the case of numerosity, multiple small black squares served as the critical stimulus. With motion the critical stimulus was a small black bar or square that moved stroboscopically from one quadrant to another. In the case of shape, the critical stimulus was a solid black or colored, simple geometric shape, either a circle, square, diamond, or cross. When flicker was explored, the critical stimulus was repetitively pulsed on and off during the time it was present on the screen.

With the exception of shape, each of these stimuli were perceived under conditions of inattention by about 75% of the observers, which is a percentage that is not only significantly greater than chance, but is also not significantly different from the results obtained in the full attention control condition. At this point in our research, we took these results to mean that motion, location, color, and at least the gross perception of numerosity were perceived without attention. Because the perception of shape failed under conditions of inattention, however, we concluded that it required attention, particularly because subjects in the divided and full attention control conditions had no difficulty reporting it. It should be noted that about 75% of the subjects detected the presence, color, and location of the critical shape stimulus in the inattention condition, even though they were unable to identify its shape. The interim conclusion we reached was that the perception of shape, unlike the perception of motion, color, location, and numerosity, requires attention.

Inattentional Blindness

A puzzling and surprising aspect of all the experiments examining the perception of a small number of critical stimuli under conditions of inattention was that, on average, 25% of the observers *failed* to detect their presence. In answer to the question "Did you see anything on the screen on this trial that had not been there on previous trials?" about 25% of the observers answered "no" and, when queried further, continued to assert that they had seen only the cross. Furthermore, when asked to pick out the critical stimulus from an array of alternatives, their performance did not differ from chance. This was true whether the stimulus was a moving bar, a black or colored small square, or some colored, geometric form. In contrast, virtually no subject failed to perceive the critical stimulus in the control condition, and most perceived it on the divided attention trial. The consistency of this result made it difficult to ignore, and before long it was clear that it was a highly predictable, robust phenomenon, which was potentially of great theoretical significance. Because this inability to perceive, this *sighted blindness,* seemed to be caused by the fact that subjects were not attending to the stimulus but instead were attending to something else, namely the cross, we labeled this phenomenon *inattentional blindness* (IB). A suprathreshold stimulus present for 200 msec. within 2 degrees of fixation was not detected when the subjects were not expecting it and were attending to some other object. IB was a startling, and to our knowledge, heretofore unrecognized and unstudied phenomenon.

The discovery of this phenomenon and the finding that IB was often much greater than 25% not only altered the direction of the research but led to a drastically revised hypothesis. The discovery of IB raised serious questions about whether in fact anything at all is perceived without attention and ultimately led us to adopt the working hypothesis that *there is no perception without attention.* We will attempt to justify and support this hypothesis as we examine the evidence in the remainder of this book, but it is essential to bear in mind at the outset that the term *perception* here refers to explicit conscious awareness and is to be distinguished from what is referred to as subliminal, unconscious, or implicit *perception,* that is, perception without awareness. Thus the hypothesis that we believe the evidence presented in this book supports is that there is no *conscious* perception without attention.

Early Results Reinterpreted

The discovery of IB and the adoption of this new hypothesis provoked a reinterpretation of our original results. At the outset we believed that the experiments examining the fate of various perceptual properties under conditions of inattention would reveal which ones were perceived without attention. We were certain that one or more of these properties would be perceived because, as we have noted, we believed that attention demanded a preexisting perceptual object. Since we found that color, numerosity, motion, flicker, and location were properties of objects that subjects generally reported under conditions of inattention in our original experiments, we had concluded that at least these properties were perceived without attention. However, once one concludes that there is *no* perception without attention, it of course follows that anything that is perceived must be perceived because attention is engaged. If some critical stimulus is perceived in our inattentive condition, it must be because it has captured or attracted attention. Thus these early data were reinterpreted to mean that numerosity, location, color, and motion were properties of a stimulus that could capture attention. However, even this proposition did not survive the final analysis.

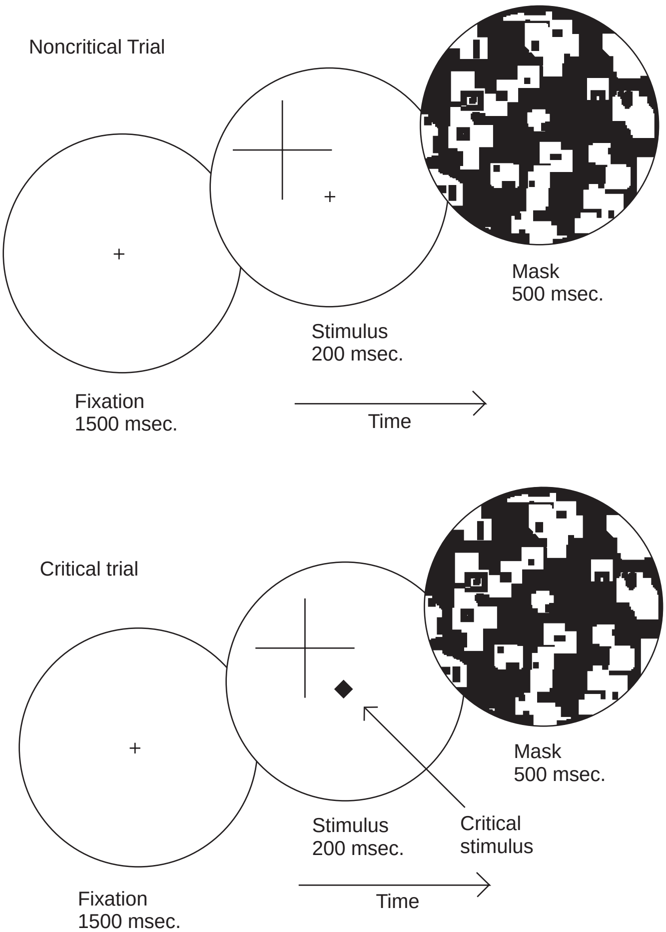
Having discovered IB, we changed the focus of the research from an exploration of the aspects of objects that are perceived without attention to an exploration of IB and a search for what properties of a stimulus attract attention. The set of questions that emerged were all related to achieving a fuller understanding of this phenomenon. Could the degree of IB be increased? Was it possible to demonstrate more conclusively that IB was an inattentional phenomenon that could be increased or decreased by manipulating attention? If nothing is perceived without attention, what sorts of objects capture attention? What is the fate of stimuli that are not perceived under conditions of inattention? Do they simply drop out at some early stage in the processing of visual information or are they processed more fully, yet not consciously perceived? These and other questions set our research agenda.

Inattention Blindness at Fixation

The concept of IB emerged from the recurrent finding that about 25% of the subjects in our many early experiments failed to detect the presence of the critical stimulus when it was a single object or a set of objects presented within 2.3 degrees of fixation in a quadrant of the cross when the cross was centered at fixation. However, its full strength was most powerfully revealed by the finding that IB is much greater for stimuli presented *at* fixation. Early experiments revealed that a colored spot that is seen about 75% of the time when it is presented parafoveally in a quadrant of the cross may be seen only 15% of the time if it is presented at fixation when the cross is located parafoveally. This will no doubt surprise the reader, as it initially did us.

We originally switched the positions of the cross and critical stimulus in order to determine whether the 25% of the subjects who failed to see the critical stimulus under conditions of inattention when it was about 2 degrees from fixation did so because fixation is privileged with respect to perceiving. Thus we thought that by placing the critical stimulus at fixation and centering the cross about 2 degrees from fixation in one of the positions previously occupied by the critical stimulus, IB might be completely eliminated. We never expected that the opposite would occur. We assumed that with the critical stimulus imaged on the fovea while attention was directed to the cross centered in the parafovea, any failure to detect or identify the critical stimulus *had* to be a function of inattention (see figure 1.3).

The reasonable expectation, of course, was that this change would eliminate IB, for how could an observer fail to detect a suprathreshold stimulus presented for 200 msec. at fixation? Moreover, even though it is well known that attention can be separated from fixation, that is,



Figures 1.3
Critical stimulus at fixation: noncritical and critical stimulus displays.

with some effort we can attend to a region other than the one fixated, it nevertheless seemed likely that some residue of attention might invariably remain attached to an object at fixation. This was another reason to expect IB to decrease for objects at fixation. Oddly, even though it has long been known that attention can be separated from fixation, it seems that no one has ever investigated whether it is possible to completely resist the impulse to attend to an object at fixation. It not only seemed reasonable to assume that placing the critical stimulus at fixation would increase the frequency with which it was seen, but also would increase the frequency with which it was correctly identified.

Exactly the opposite occurred! Not only did the observers *not* identify the critical stimulus more often, but the amount of IB more than doubled. When the critical stimulus was a simple geometric shape, either solid black or outlined, identical to those that had served as critical stimuli earlier, between 60% and 80% of the observers *failed* to detect it. Subjects repeatedly (in separate experiments) reported that they had not seen anything other than the cross on the critical trial even though a completely familiar, high-contrast, geometric shape subtending at least 0.6 degree of visual angle had been present at fixation for 200 msec. This result, quantitatively far greater than the original results from which the discovery of IB emerged, vividly illuminated the causal connection between perceiving and attending. The hypothesis that without attention there is no perception now seemed strongly supported by the data.

Inhibition of Attention

Evidence that IB is greater at fixation suggested that attention could be actively inhibited from operating on input from some particular spatial location, and this was confirmed in a series of experiments. If we assume that attention normally is paid to objects at fixation, which seems highly likely, then when a visual task requires attending to an object placed at some distance from fixation, attention to objects at fixation might have to be actively inhibited. This then could explain why IB is so much greater when the inattention stimulus is present at fixation. In the original procedure, with the cross centered at fixation and the critical stimulus appearing in a parafoveal region defined by a quadrant of the cross, there is no reason for the subjects to inhibit attention to any particular region surrounding the cross.[9]

This inhibition of attention was verified in a series of experiments described in chapter 4. In one of these experiments it was possible, by presenting a small black square in each of the four quadrants of the cross, to create as much IB for a critical stimulus located in the parafovea as for the same stimulus at fixation. These squares were located in each of the positions in which the critical stimulus could appear. On the critical inattention trial, the critical stimulus replaced one of these squares. The rationale for this variation was that because the four squares were always present and were clearly irrelevant to the subject's task, the subject might tacitly learn to not pay attention to them, that is, to inhibit attention to them just as we presumed he or she did with the region around fixation. If so, the results should show a significant increase in the frequency of IB for the critical stimulus; this was precisely what occurred. This result suggests that subjects tacitly learn to inhibit attention from particular spatial locations, and that this leads to a significant increase in IB.[10]

IB and Attentional Focus

If IB results from the failure of a stimulus to attract attention, then it should be possible to manipulate the frequency of IB by manipulating the area to which attention is paid and its relation to the critical stimulus. For example, decreasing the area of attentional focus should lead to an increase in IB for objects outside that focus, even if their position relative to fixation remains unchanged. This hypothesis was supported by a series of experiments.

These experiments and others described in chapter 4 provide strong additional support for the view that there is no perception without attention. When the inattention stimulus falls outside the area to which attention is paid, it is much less likely to be seen. Moreover, if, for whatever reason, the observer inhibits attention to a particular spatial location (for example, the area at and around fixation), this too will decrease the likelihood that the critical stimulus will be seen. As will become clear, with both these factors operating, IB is virtually 100%.

IB and Salient Stimuli

The accumulating and compelling evidence of IB and of its relation to attention engendered a question about whether there might be some visual stimuli that would capture attention reliably even under conditions in which other stimuli went undetected. If perception requires attention, and attention, when otherwise engaged, must be captured before perception can occur, then it seems highly likely that a stimulus that is important might be a candidate for such capture. Because one's name seemed like such a stimulus, it seemed a reasonable tool with which to begin exploring this conjecture. In addition, it is known that one's name is one of the few stimuli most likely to be heard when it is presented to the unattended ear in a selective listening experiment (Moray 1959). We wondered whether there was a visual analogue to this effect. Somewhat surprisingly, given the visual complexity of a name, we found that there was. Observers almost invariably see their own names under conditions of inattention when it is presented at fixation and attention is directed to the cross task or even to a lexical distraction task. Under the same exact conditions, a highly familiar word like *Time* yields strong IB, as does someone else's name, a brightly colored spot, or a shape.

Even more surprising than the "own name effect" was the finding that observers are largely blind to a stimulus that is almost identical to their own names with the only difference being that the first vowel is replaced by another vowel; for example the name *Jack* is transformed to *Jeck.* This finding clearly points to a high level of analysis of the critical stimulus even when it is not consciously perceived.

There are a few other stimuli that we discovered will also capture attention under conditions of inattention. They seem to share with one's own name the characteristic of having high signal value and a high degree of familiarity. One of these is a cartoon-like happy face that generally is seen and identified under conditions of inattention. Just as a mildly doctored version of one's own name is not likely to be seen, a scrambled or sad version of the face generally will not be seen without attention. Presenting this altered version under exactly the same conditions as the happy face produces frequent IB.

Other Stimuli

Up to this point we have summarized only the evidence revealing that there are at least a few meaningful stimuli that can attract attention under conditions of inattention and that are thus consciously perceived. It is our assumption that the perception of these stimuli that are presented at fixation entails the overcoming of the inhibition that otherwise would be likely to lead to IB. But our data also indicate that there is at least one other factor that may facilitate the capture of attention.

Size

One of these is size. We have some evidence, reviewed in chapter 7, that a black disc subtending an angle of 1 degree or more will be seen most of the time under conditions of inattention, even when located at fixation, whereas a similar but smaller disc, for example, one which is only 0.6 degree in diameter, will be perceived infrequently. Because these stimuli differ only in size, size would appear to be the critical difference.[11] Moreover, multi-element displays covering a large area, like those used in the exploration of grouping, also are perceived under conditions of inattention, even though the grouping is not. This too implies that large size is an attribute that can capture attention. Because in both of these cases, attention seems to be attracted by a physical characteristic of the stimulus—namely its size—any general explanation of what is likely to capture attention under conditions of inattention must take this into account.

Familiarity

The fact that one's own name and a happy face icon are likely to be seen under conditions of inattention suggests the possibility that the familiarity of a stimulus by itself might be a factor in the capture of attention, since both one's name and a happy face icon are not only meaningful, they are also highly familiar. However, a direct exploration of this issue failed to yield any clear evidence that this was so. Familiarity by itself does not seem to be responsible for the capture of attention.

Deep Processing

The discovery that there are complex stimuli such as names and faces that are able to overcome the inhibition of attention at fixation suggests that stimuli that suffer IB may be processed extensively by the perceptual system. If, for example, a happy face or one's name is perceived while a scrambled face and slightly altered name is not, then it seems reasonable to assume that the bottleneck or filter that is responsible for limiting the contents of perception is located at a late stage of processing. (Bear in mind that it is not that these modified stimuli are not correctly identified, which might not be surprising given their novelty, but rather that their very presence goes undetected.) How else can one explain why *Jack* is seen by Jack, but *Jeck* goes undetected as if it were not present at all?

The hypothesis generated by these findings and others like them is that retinal input from stimuli that are not the focus of attention is subjected to extensive processing and, only those objects to which attention is either voluntarily directed or that capture attention at a late stage of processing are perceived. It is as if attention provides the key that unlocks the door dividing unconscious from conscious perception. Without this key, there is no awareness of the stimulus.

This hypothesis shares many of its features with the account of the role of attention in perception known as the *late selection theory* (Deutsch and Deutsch 1963). This theory stands in opposition to the *theory of early selection* (Broadbent 1958; Treisman 1969) that locates the bottleneck or filter at an early stage in the processing of visual input. According to this theory the reason why one's own name is perceived even when not attended is because it, unlike most other stimuli, has an extremely low perceptual threshold, so that only the coarsest kind of information is required for it to be perceived (Treisman 1969). The early selection theory, however, has no ready explanation for the finding that an apparently trivial modification in a stimulus has such profound perceptual effects. The coarse information that is deemed to be sufficient for recognition when presented on the unattended channel should get through the early attentional filter and ought to lead to at least false recognition. In contrast, a late selection theory has no difficulty with these results, and in fact takes them as evidence of its validity. If attention is captured at a high level of processing, then it is reasonable to assume that only a "valid" instance of the stimulus will succeed in capturing attention.

The balance shifts towards an early selection theory when it comes to accounting for the fact that size matters in the capture of attention, although this might not be true if it is perceived rather than retinal size that is the important factor. In either case, our results appear to support a flexible selection theory, that is, one that allows for selection on the basis of either high- or low-level attributes of stimuli depending on the nature of the stimulus. It may be that the system operates to minimize effort and so will select on the basis of a low-level attribute like size if possible but, if not, will process the input more deeply, as seems to be the case with lexical stimuli.[12]

Evidence from Priming Studies

The hypothesis that even unattended stimuli are processed extensively received additional support from priming experiments described in chapter 8. These experiments were designed to determine whether stimuli to which subjects either were inattentionally blind or failed to see accurately nevertheless were tacitly perceived and encoded. The question the priming experiments explored was whether stimuli that are undetected demonstrably influence a subject's performance on a subsequent task.

Lexical stimuli were chosen as the critical stimuli for the priming studies because they were the kinds of stimuli primarily used in studies of priming (see, for example, Schacter 1987). Evidence of priming was sought by means of a stem completion task that followed immediately upon the completion of the critical inattention trial, that is, after the subjects had reported their observations. In the stem completion task, subjects were given the first few letters of the critical stimulus word and asked to complete this "stem" with the first word or words that occurred to them. If observers who were blind to the critical word stimulus presented on the inattention trial, offered the word as a stem completion significantly more often than subjects not previously exposed to it, this constituted evidence of tacit high-level processing and encoding of the stimulus. This is precisely what the priming experiments revealed. These results added strong support to a late selection theory of perceptual processing and were taken as evidence that unattended and unperceived stimuli may be processed to the semantic level.[13] It is only at this late stage that they either capture or fail to capture attention and are consequently either perceived or go undetected.

The Role of Expectation

There is a certain ambiguity about our method concerning what aspect or aspects of it are essential in creating the condition of inattention that leads to IB or other kinds of inadequate perception. One aspect of the method is the requirement to attend to a difficult task, such as the judgment of the longer line in the cross figure. But that aspect alone has been emphasized by many other investigators seeking to ascertain the effect of inattention. The other aspect of our method is the creation of a mental state in which nothing other than the cross is expected on a trial. This lack of expectation eliminates any intention to process the critical stimulus. It is logically possible that the lack of expectation alone can lead to IB and other failures of perception. This question is addressed in chapter 9.

Perception or Memory

There is also the question of whether IB and the failure to describe a stimulus correctly, for example to identify its shape or grouping, are failures of perception or of immediate memory. This question has arisen repeatedly in cognitive psychology and is very difficult to resolve. It is possible that the critical stimulus that unexpectedly occurs is fleetingly perceived, but not encoded in such a way as to survive over the next several seconds until the subject is asked "Did you see anything else on that trial besides the cross?" To address this question we developed a method that we believe is sensitive to it. The basic idea was to present a second stimulus, identical to the critical one, and in close temporal contiguity with the critical one, but under conditions where it would be consciously perceived. If the critical stimulus is perceived in addition to this second one, then the subject should either have the experience of duality, that is, of two stimuli, or the experience of apparent motion, from the critical stimulus to the additional one or vice versa. We address this question in chapter 9.

The Perseveration of IB

In the experiment just referred to in which a second stimulus was presented after the first, critical stimulus disappeared from the screen, we found a startling amount of blindness for this second stimulus. Because this stimulus was presented following the 200 msec. presentation of the critical stimulus and was a discrete event, we expected it to be consciously perceived. To our surprise, however, we found that many subjects failed to see it. A series of experiments were carried out to explore this *perseveration effect.* We found that the second stimulus could remain on the display screen for a surprisingly long interval following the offset of the cross, in other words, following the actual trial, without being perceived. IB occurred here even though there was no longer any task to which the subject had to continue to attend. We interpret this effect to mean that the state of inattention to anything but the cross was maintained over time. These findings are also described in chapter 9.

Conspicuity

We also investigated the question of the role of conspicuity of the critical stimulus. In most (but not all) of our experiments, the critical stimulus is a single circumscribed entity. It appears on a relatively homogeneous background (except for the presence of the cross) so that under conditions of attention one might regard it as conspicuous. If, as we believe, the sequence of events is one in which the critical stimulus either does or does not attract attention, then it ought to follow that its conspicuousness would be relevant to such attraction. Therefore we performed a few experiments in which we created "visual noise" in the background to lower conspicuity. Chapter 3 details these experiments.

Auditory Deafness and Tactile Insensitivity

Because there seemed some anecdotal reasons to believe that analogues to IB might occur in other sensory modalities, we designed a few experiments (described in chapter 10) to explore this possibility. Although we did not study these modalities in any systematic way, we did find clear evidence of both auditory deafness and tactile numbness in situations in which the subjects were attending to some other task involving the same sensory modality. Subjects reported that they did not hear a tone or a word that was presented to one ear while they carried out a version of a shadowing task with stimulation in the other ear. Similarly, subjects were unaware of a puff of air delivered to one forearm while they were attempting to report what letter was being written upon the other. In both these cases, subjects had no difficulty localizing and describing the unexperienced stimulus under conditions of both full and divided attention. These data, which must be considered preliminary, suggest that attention may be necessary for perception in all sensory modalities.

Unresolved Questions

The research described in this book is incomplete. It raises more questions than it answers and the explanations we provide are not fully adequate. Nevertheless, we chose to describe it now rather than wait for a fuller understanding, because that understanding may not be achieved, at least not in the near future, and the phenomenon of inattentional blindness seems sufficiently important so that interest in it ought not depend on the particular theory employed to explain it.

The apparent inconsistencies in some of our results pose questions to any attempted explanation. These will be taken up in some detail in the concluding chapter but some forewarning may be useful. Although the majority of the evidence this research has yielded appears to support a late selection theory of attention, some aspects of the data are not obviously compatible with it—one of which already has been mentioned. The fact that there are cases in which the critical inattention stimulus is detected but not identified (e.g., a shape) or not fully identified, presents a problem for a theory of late selection. If all retinal input is processed to a high level, then why should anything be detected, if it is not identified? In experiments in which a familiar, colored, geometric shape appears in a quadrant of a cross centered at fixation, many instances occur in which the subjects correctly report the color of the stimulus and its quadrant location but fail to identify its shape. If retinal input is processed to the level of recognition and perhaps meaning, why this failure of shape perception? There are also other troubling cases in which the critical stimulus is detected—that is, the subjects report they have seen something that was not present on earlier trials—but they are unable to identify it. If it is detected, an occurrence that, according to the theory of late selection, entails the involvement of attention at the late level of processing, why is its identity not perceived? In subsequent discussions an attempt is made to account for these apparent counterinstances to our proposed explanation, but it seems appropriate to alert the reader early to the fact that the data to be presented are not completely consistent and that there remain problems in need of resolution.

It is probably not too soon, however, to give the reader a summary of how the theory of late selection will be adapted to make provision for these sorts of problematic data. If the critical stimulus falls within the zone of attention, the probability that it will receive some benefit from attentional processing seems high. If, however, the critical stimu-