Ann. Rev. Psychol. 1986. 37:43-75

SELECTIVE ATTENTION

William A. Johnston and Veronica J. Dark

Department of Psychology, University of Utah, Salt Lake City, Utah 84112

CONTENTS

INTRODUCTION 43
Terminology and Basic Concepts 44
Cocktail-Party Problem 45
Scope of Review 45
REVIEW OF EMPIRICAL LITERATURE 45
Priming Effects 46
Early and Late Selection 47
Spatial Attention 49
Processing Outside the Attentional Spotlight 53
Overview of Spatial Attention 56
Object-Based Attention 56
Semantic Processing of Nonselected Objects 59
Automatic and Controlled Attention 62
Schema-Based Attention 63
Summary of Empirical Literature 65
REVIEW OF THEORIES 65
Cause Theories 66
Effect Theories 68
Summary of Theories 70
CONCLUSION 70

INTRODUCTION

In reviewing the literature on attention we were struck by several observations. One was a widespread reluctance to define attention. Another was the ease with which competing theories can accommodate the same empirical phenomena. A third observation was the consistent appeal to some intelligent force or agent in explanations of attentional phenomena. These observations are likely to be causally connected. It is difficult to conceptualize a process that is not well defined, and it is difficult to falsify empirically a vague conceptualization, especially one that relies on a homunculus. As a consequence, the more we

0066-4308/86/0201-0043$02.00

read, the more bewildered we became. At a time of despair and panic we turned to William James (1890), where we found new hope and inspiration. The reader will understand, therefore, if from time to time we betray a reverential awe of James. We believe that James understood attention better than most contemporary theorists; he articulated many of the same phenomena with which current theories are concerned, but he managed to avoid some of the pitfalls of many current theories. We consider these pitfalls and how James avoided them after we accomplish our main goal of reviewing the recent empirical literature.

Terminology and Basic Concepts

Attention has several ordinary-language meanings, the most common of which are mental effort and selective processing (Posner & Boies 1971, Johnston & Heinz 1978). The view of attention as mental effort derives from the common assumption that processing capacity is limited in some central mechanism (Kahneman 1973, Shiffrin & Schneider 1977). This mechanism is associated with consciousness and controlled processing and it delimits divided attention, that is, the extent to which different sources of information can be processed at the same time. However, exceptions to this view range from rejecting the whole notion of limited capacity (Neisser 1976) to postulating multiple pools of limited resources (Navon & Gopher 1979, Wickens 1984). On the other hand, there appears to be no disagreement with the view that processing is selective.

This review concentrates on selective attention. We refer to divided attention and the concept of effort or resources only as they may relate to selective attention. Selective attention refers to the differential processing of simultaneous sources of information. In nature these sources are internal (memory and knowledge) as well as external (environmental objects and events). Whereas James considered both of these, we follow the vast majority of contemporary investigators and consider only external sources.

With respect to the processing of environmental information, it is necessary to distinguish between bottom-up or data-driven processing and top-down or internally driven processing (Norman & Bobrow 1975). In data-driven processing a stimulus activates codes at various levels of analysis ranging from simple physical or sensory analysis to complex semantic and schematic analysis. The level to which processing proceeds is determined by the intensity and clarity of the stimulus and the level of analysis at which codes are available (e.g. as a result of learning) for the stimulus. Stimulus processing is data-limited (i.e. restricted to shallow levels of analysis) to the extent that the stimulus is weak, noisy, and unfamiliar. Thus, bottom-up factors alone can lead to selective processing of concurrent stimuli that have different data limits. However, most research has addressed the top-down control of selective processing. In top-down processing, the individual is internally biased toward particular stimuli.

Cocktail-Party Problem

Cherry (1953) framed the principal questions about selective attention in terms of the "cocktail-party problem." One can listen to a particular conversation at a cocktail party and apparently be oblivious to other conversations. This is the focused-attention aspect of the cocktail-party problem. Yet one will sometimes hear important information, such as one's own name, in other conversations. This is the divided-attention aspect of the cocktail-party problem. How can we tune into particular sources of information and, at the same time, remain sensitive to important information from other sources? How can our attention be both focused and divided at the same time? This question has motivated research on attention ever since Cherry raised it, and we shall see to what extent the empirical literature provides an answer.

Scope of Review

Our main objective in this chapter is to review the evidence with respect to the top-down control of selective processing. The next section of the paper is devoted to this review; in the course of it we draw 11 tentative empirical generalizations. These generalizations are intended to capture the current drift of the literature rather than to describe reality. Our secondary objective is to review and evaluate, in the light of our 11 generalizations, extant theories of selective attention. This objective is pursued in a subsequent section.

Our coverage of the literature is quite restricted. First, it is biased toward recent experiments that clearly illustrate important aspects of selective attention. Second, we do not review in a systematic way research with animals (see Riley & Leith 1976), electrophysiological research (see Hillyard & Kutas 1983), neurophysiological research (see Mountcastle 1978, Harter & Aine 1984), neuropsychological research (see Gummow et al 1983, Posner et al 1984), psychophysiological research (see Anthony 1985), or research on individual differences (W. A. Johnston & V. J. Dark, unpublished observations). Several other reviews of the recent literature on selective attention are available. We have been guided in particular by Broadbent (1982), Kahneman & Treisman (1984), Holender (1985), and Shiffrin (1985).

REVIEW OF EMPIRICAL LITERATURE

The following areas of research are reviewed: Priming effects, early and late selection, spatial attention, processing outside the spatial focus of attention, object-based attention, processing of nonselected objects, automatic attention, and schema-based attention.

Priming Effects

Priming effects are reviewed first because they define a possible basis of the top-down control of selective processing, they help to resolve some apparent contradictions and ambiguities in the literature, and they have theoretical implications that we consider later. Priming is said to occur when one stimulus, the prime stimulus, affects the processing of another stimulus, the test stimulus. Priming can be conceived of as either the activation or the establishment of internal codes by the prime stimulus that correspond in some way to the test stimulus. In principle, priming can occur at any level of stimulus analysis, ranging from low-level sensory analysis to high-level semantic analysis (Rabbitt & Vyas 1979). We review evidence for four types of priming: modality, identity, semantic, and schematic.

MODALITY PRIMING The processing system can be primed toward a specific modality of stimulus input. For example, eye blinks to startle (test) stimuli are larger for stimuli in the modality (e.g. vision) of a prime stimulus on which attention is preengaged than for stimuli in a different modality (e.g. audition). This is found even in infants and is especially pronounced when attention is preengaged on an interesting stimulus (Anthony & Graham 1983). Similarly, very early components of event-related potentials in the brain are greater for stimuli in the modality to which attention is directed than for other stimuli (e.g. Näätänen 1982, Hillyard & Kutas 1983). Priming of one modality may be accompanied by suppression of other modalities. Click-evoked potentials in the auditory nerve are reduced when attention is directed to the visual modality (Oatman 1984). These priming effects occur within 100 msec of presentation of the test stimulus and are thought to result from efferent feedback from prime processing onto afferent pathways needed for test processing.

IDENTITY PRIMING Jacoby and associates (e.g. Jacoby & Dallas 1981, Jacoby 1983a,b, Johnston et al 1985) have shown that reading a word on one occasion (prime) facilitates its visibility under threshold conditions on a subsequent occasion (test). The effect holds up even when several other words intervene between the prime and test presentations of the word (Dannenbring & Briand 1982). However, the effect is attenuated if the prime and test presentations are in different modalities (e.g. Kirsner & Smith 1974) or in different type fonts (e.g. Jacoby & Witherspoon 1982, Feustel et al 1983), or if they are physically similar but morphologically different (e.g. Kempley & Morton 1982). Thus, identity priming implicates a level of analysis somewhere between modality coding and semantic coding. Identity priming increases up to at least four repetitions of the prime stimulus (Feustel et al 1983). The effect is usually interpreted as the establishment of durable physical codes in memory by the prime presentation that benefits processing of the test presentation (e.g. Jacoby & Dallas 1981, Feustel et al 1983).

SEMANTIC PRIMING A voluminous literature demonstrates that the processing of a test word (e.g. BUTTER) can be speeded up by an immediately preceding and semantically related prime word (e.g. BREAD). Semantic priming shows up in terms of disambiguation of homographic test words (e.g. Conrad 1974, Johnston & Dark 1982), speed and accuracy of identification (e.g. Carr et al 1982, Johnston & Dark 1985) or lexical categorization (e.g. Meyer et al 1975) of test words, latency of repeating (shadowing) test words (Underwood 1977), and latency to match two test stimuli (Posner & Snyder 1975a). Semantic priming is generally attributed to the transitory activation by the prime word of semantic codes that correspond to the test word.

SCHEMATIC PRIMING A schema refers to an internal representation of a common spatial (Friedman 1979) or temporal (Bower et al 1979) configuration of objects and events (Taylor & Crocker 1981). A schema may comprise a collection of codes at various levels rather than define a single high level of coding. A schema is thought to develop from frequent processing of different instances of a natural category (e.g. kitchens, doctor's offices, restaurants, salespersons, and even one's self). Schemata activated by prime events (e.g. the name of a category) may bias various levels of analysis toward particular test events (e.g. instances of a category). Research has illustrated the biasing effects that active schemata can have on identification of test stimuli (Biederman et al 1973, Palmer 1975), memory for test stimuli (Bartlett 1932, Snyder & Uranowitz 1978, Bower 1981), and judgments of test stimuli (Snyder & Swann 1978, Higgins et al 1985).

We can summarize the literature on priming effects in the form of our first empirical generalization: 1. *All levels of stimulus analysis can be primed for particular stimuli.*

Early and Late Selection

We turn now to research that deals more directly with selective attention. We begin by examining the empirical phenomena established by three decades of research on a single theoretical issue: Does selection take place early in stimulus processing, before semantic analysis of any stimulus, as Broadbent (1958) originally proposed, or does it take place only late in stimulus processing, after semantic analysis of all stimuli, as Deutsch & Deutsch (1963) later proposed?

Much of the research on this issue has made use of a dichotic-listening task in which different lists of words or other alphanumeric stimuli are played to the two ears of a subject. We introduce a nomenclature for this task that applies to other (e.g. visual) tasks as well. Instructions are to try to listen either to both lists *(divided attention)* or to just one *(focused attention)*. Any list to which the subject is instructed to attend is called *relevant* and any other is called *irrelevant*. Thus, all stimuli are relevant under divided attention, and only some are relevant under focused attention. The task performed on a relevant list might be to respond to (e.g. repeat or shadow) all stimuli or to respond to (e.g. detect) only particular, *target* stimuli.

EVIDENCE FOR EARLY SELECTION Initial (see Broadbent 1958) and subsequent research (e.g. Keren 1976, Johnston & Heinz 1978) on this issue have compared selection based on physical differences between relevant and irrelevant stimuli (sensory selection) with selection based on semantic differences (semantic selection). Sensory selection has consistently proved to be both more accurate and less effortful than semantic selection. These and many similar findings are reviewed elsewhere (e.g. Treisman 1969, Moray 1970, Broadbent 1971), and they establish our second empirical generalization: 2. *Selection based on sensory cues is usually superior to selection based on semantic cues.*

Other evidence in favor of early selection takes a somewhat different form. Ninio & Kahneman (1974) demonstrated that latency of target detection is less when the targets are confined to the relevant list of a focused-attention task than when they are distributed between two lists of a divided-attention task. Treisman & Geffen (1967) and Treisman & Riley (1969) had subjects shadow one of two dichotically presented lists but detect occasional targets in either list. Accuracy of detection was much higher for targets in the shadowed ear than for those in the nonshadowed ear. If selection were not possible until after the semantic analysis of all concurrent stimuli, then why should semantically defined targets be easier to detect under focused-attention instructions or in the shadowed list?

EVIDENCE FOR LATE SELECTION To the extent that early selection of relevant stimuli implies early rejection of irrelevant stimuli, evidence for semantic analysis of irrelevant stimuli would appear to favor late-selection theories. A considerable amount of evidence of this sort has been reported (Broadbent 1971, 1982, Posner & Snyder 1975b, Shiffrin & Schneider 1977). In dichotic listening, a semantic relationship between coincident relevant and irrelevant words affects latency of shadowing the relevant words (Lewis 1970), shadowing sometimes follows a shift to the irrelevant list of a contextually constrained passage (Treisman 1960), a homophone is disambiguated by a coincident irrelevant word (MacKay 1973), autonomic responses can be elicited by semantically defined conditioned stimuli in the irrelevant list (Corteen & Wood 1972), and one sometimes does hear one's own name in the irrelevant list (Moray 1959). Many of these effects are attributable to semantic or schematic priming of the particular irrelevant words on which they are based (Broadbent

1971, 1982, Logan 1980, Johnston & Dark 1982, Shiffrin 1985). Nonetheless, this line of evidence leads to our third empirical generalization: 3. *Irrelevant stimuli sometimes undergo semantic analysis.*

The foregoing review attempts to capture the gist of the massive literature on the controversy between early- and late-selection theories. Selection on the basis of sensory properties of relevant stimuli is usually superior to selection on the basis of semantic properties, but sensory selection does not preclude semantic analysis of irrelevant stimuli. Sensory priming may form the basis of sensory selection and the focused-attention aspect of the cocktail-party problem. Semantic priming may form the basis of semantic selection, the semantic processing of certain irrelevant stimuli in sensory-selection tasks, and the divided-attention aspect of the cocktail-party problem.

This brief review of early and late selection brings us to the present decade. We now examine more contemporary, but not unrelated, issues. Contemporary theorists whose roots are on different sides of this historical controversy now seem to agree that selection is often guided by sensory cues but that irrelevant stimuli can be processed to semantic levels (e.g. Broadbent 1982, Shiffrin 1985). However, these theorists continue to disagree on some of the issues reviewed below.

Spatial Attention

How are relevant stimuli accorded processing priority? Generalization 2 suggests that sensory priming plays an important role. Among the sensory cues by which attention could be guided, spatial cues seem to be especially effective. We review first evidence that spatial attention is important and second evidence on the spotlight characteristics of attention. Our examination of spatial attention concentrates, as does most of the relevant literature, on visual processing.

THE IMPORTANCE OF SPACE When a multielement display is followed by a cue that specifies which elements to recall, accuracy of recall is higher if the cue specifies locations (e.g. middle row) than if it specifies other sensory properties (e.g. red items). Accuracy of recall is especially low if the cue specifies semantic properties (e.g. digits) (von Wright 1968, Coltheart 1980). Spatial cues are particularly effective when they are given in advance of the display. Posner et al (1980, Experiment 2) flashed a particular letter at a particular location in the visual field. Speed of detection was facilitated by advance cueing of the location of the target but not by advance cueing of the shape and identity of the target. Hede (1981) reports an auditory analog of this finding. Nissen (1985, Experiment 2) displayed items that varied in location, color, and shape and then provided one dimension as a cue to report the remaining two dimensions. The upshot was that location proved to be more fundamental than color and shape. That is, subjects could not know the color or the shape of an item without knowing its location, but they could know its color without knowing its shape or vice versa. Woods et al (1984) confirmed the relative importance of space (e.g. ear of entry) in attention to auditory stimuli.

Finally, studies of split-brain patients reveal a processing dissociation between spatial information and other sorts of information. For example, a cue presented to one hemisphere can tell the other hemisphere where, but not what, a stimulus will be in a brief display that is presented to the other hemisphere (Holtzman et al 1984a,b). Our fourth empirical generalization is: 4. *Spatial cues are especially effective cues.*

ATTENTIONAL SPOTLIGHT We now review evidence that spatial attention has the characteristics of a spotlight, that the attentional spotlight is independent of eye fixations, and that the beam of the attentional spotlight can assume various shapes.

Basic findings Consider first an experiment by LaBerge (1983). In one condition a five-letter word, subtending 1.77° of visual angle, was displayed on a screen and subjects had to categorize the center letter. This condition directed attention to the center position. Occasionally, a single probe character appeared in lieu of (or immediately subsequent to) the string of letters. The probe appeared in one of the five display positions. Reaction time to the probe was a V-shaped function of display position; it was fastest in the center position and slowest in the first and fifth positions. LaBerge suggested that an "attentional spotlight" was focused on the center position and facilitated the processing of any stimulus that appeared in that position. Similar findings are reported by Hoffman et al (1983). In another condition, LaBerge had subjects categorize the whole word. This condition was intended to broaden the beam of the attentional spotlight to cover all five display positions. As expected, reaction time to the probe did not vary with display position in this condition.

Other experiments suggest that the spotlight can be moved across space independently of eye movements (Sperling & Reeves 1980, Tsal 1983, Remington & Pierce 1984). William James (1890) cites an experiment by Helmholtz in which a dark stereoscopic view box could be briefly illuminated by a spark. Before illumination, a tiny beam of light passed through a pinhole in each stereoscopic card, and eye fixation was necessary to keep the beams superimposed and seen as one. Helmholtz reported that in advance of the spark we can " . . . keep our attention voluntarily tuned to any particular portion we please of the dark field, so as then, when the spark comes, to receive an impression only from such parts of the picture as lie in this region. In this respect, then, our attention is quite independent of the position and accommodation of the eyes" (James 1890, p. 438). In more recent studies, Posner had subjects fixate on the center of a screen and then presented targets (e.g. light flashes or alphanumeric characters) in various positions as many as 24° to one or the other side of fixation (Posner et al 1980, Posner & Cohen 1984). Subjects were either precued to the spatial position of an impending target or not precued. When they were precued, the cue usually was correct (valid) but sometimes was incorrect (invalid). Detection of the target was facilitated by valid cues and inhibited by invalid cues. Moreover, if the target did not appear in the precued position, detection performance was higher when it appeared in a position adjacent to the precued position than when it appeared elsewhere.

The above research suggests that attention has the properties of an adjustable-beam spotlight. Other findings indicate that the beam of the attentional spotlight can be split (e.g. Shaw & Shaw 1977, Egly & Homa 1984). Egly & Homa (1984, Experiment 3) had subjects fixate on the center point of a "spider-web" grid consisting of three concentric rings with radii of 1°, 2°, and 3° of visual angle, respectively. Two letters were flashed for 30-60 msec and then followed by a pattern mask. One letter appeared in the center of the display and the other, called the displaced letter, appeared in one of eight "clock" positions on one of the rings. Subjects were to name the center letter, which they did with 95% accuracy, and then localize the displaced letter. As in Posner's studies, accuracy of localization of the displaced letter was facilitated by valid precueing of the ring on which it appeared and inhibited by invalid precueing. The most important findings were generated by invalid precueing. Consider the case in which the middle ring is precued but the displaced letter actually is on either the inner ring or the outer ring. If precueing of the middle ring causes the attentional spotlight to expand just enough to embrace the middle ring, then the miscued letter is going to fall either inside or outside the spotlight and accuracy of localization of the letter should vary accordingly. In fact, the cost of miscueing was just as great when the letter was on the inner ring as when it was on the outer ring. These data suggest that the beam of the spotlight can be split to illuminate both a central region and a satellite ring. The data reviewed above support our fifth empirical generalization: 5. *Attention is independent of eye fixation and can assume the characteristics of an adjustable-beam spotlight*. However, both aspects of this generalization are subject to important qualifications.

Qualifications of basic findings Although the attentional spotlight may be able to conform to various spatial configurations, the findings of Podgorny & Shepard (1983) suggest that some configurations are easier than others. Subjects classified a dot as being on or off a "figure" that was composed by shading certain cells in a large matrix. Reaction time was not affected by the number of shaded cells but was strongly affected by their compactness. This effect held true for imagined as well as real figures. Thus, selective processing appears to improve with the coherence of the relevant areas of the visual field. Similar findings are reviewed below in connection with object-based attention.

In addition, although the width of the attentional spotlight may be adjustable, there appears to be a minimum width to which it can be constricted. The minimum width of the spotlight has been estimated by determining how far an irrelevant stimulus (e.g. digit) has to be moved away from a relevant stimulus before it ceases to have a disruptive effect on the response to the relevant stimulus. Various studies using this technique estimate the minimum width of the spotlight to be somewhere between .5° and 1° (e.g. Eriksen & Hoffman 1972, Eriksen & Eriksen 1974). However, the disruptive effect of irrelevant stimuli decreases even from .08° to .23° (Estes 1982). Thus, the intensity of a 1° beam seems to diminish from center to periphery.

The independence between eye fixations and spatial attention also must be qualified. Although attention can be moved away from the center of the fovea, it becomes less efficient the farther away that it moves. For example, using the procedure described above, Humphreys (1981a) found that the minimum beam-width of the spotlight increased from less than .5° to more than 1° when attention was shifted from the center of the fovea to just 1° off center. Furthermore, the resolution of the spotlight appears to decrease sharply as it is directed farther away from the center of the fovea. For example, in the Egly & Homa (1984) research, accuracy of both identification and localization of the displaced letter declined from over 80% to less than 40% as eccentricity of the letter increased from 1° to 3°.

The line of research initiated by Rayner and his associates further elucidates the low resolution of parafoveal attention (e.g. Rayner et al 1978, Schiepers 1980, McClelland & O'Regan 1981, Paap & Newsome 1981, Inhoff 1982, Balota & Rayner 1983). In the Rayner et al (1978) study, subjects attended to a letter string that was presented, for at least 165 msec, 1–5° away from the center of the fovea, and then they named a word that was presented to the fovea. The more similar the parafoveal stimulus was to the foveal word in terms of shared letters, the shorter the latency with which the foveal word was named. This sensory-priming effect indicates that some physical information was extracted by parafoveal attention. However, the magnitude of this effect dropped sharply with degree of eccentricity of the parafoveal stimulus and was essentially nil at 5°. On the basis of different estimates of attentional velocity (Tsal 1983, Remington & Pierce 1984), we may assume that the exposure duration of 165 msec was long enough for attention to move at least 5°.

Finally, processing of the parafoveal stimulus even at 1° of eccentricity appears to be minimal when the set from which the stimulus is drawn is large and unconstrained (McClelland & O'Regan 1981, Paap & Newsome 1981). The latter finding points out an important methodological problem with studies that make repeated use of stimuli from the same small pool. The identity-priming effects of earlier presentations of the stimuli can cause these stimuli to be more perceptible on later presentations and receive more semantic processing than stimuli presented for the first time. We encounter this problem at various points below.

In short, although spatial attention can be directed away from the fovea and assume various shapes, it can do so only at a considerable sacrifice in processing acuity. Processing is most efficient when attention is aligned with the center of the fovea and directed to consolidated regions of space.

Processing Outside the Attentional Spotlight

How much processing takes place for stimuli outside the attentional spotlight? We examine this question with respect to both semantic processing and lower level (nonsemantic) processing. In most of the relevant research, attention is aligned with the fovea so that parafoveal stimuli fall outside the spotlight.

SEMANTIC PROCESSING Semantic processing of stimuli outside the focus of attention has been measured in terms of both the semantic-interference and semantic-priming effects of these stimuli.

Semantic interference Responses to relevant stimuli are impeded by the presence of irrelevant stimuli in the visual field, and the magnitude of this effect is dependent (in different ways in different experiments) on the semantic relationship between the relevant and irrelevant stimuli. However, these effects, which reveal the semantic processing of irrelevant stimuli, are sharply curtailed when the attentional spotlight is predirected to the location of the relevant stimulus (e.g. Underwood 1976, Kahneman et al 1983, Allport et al 1985). Indeed, these effects may be eliminated altogether if the irrelevant stimuli are more than 1° away from fixated relevant stimuli and, thus, fall outside the attentional spotlight (Eriksen & Eriksen 1974).

The Stroop effect defines a special kind of semantic interference from irrelevant stimuli. The original effect is that the latency to name the color of ink in which a word is printed is exceptionally long when the word is the name of a different color (Stroop 1935). The effect occurs even when the ink color (e.g. of a rectangle or neutral word) and the conflicting color name are spatially separated by as much as 12.5° (e.g. Kahneman & Henik 1981, Lowe & Mitterer 1982). However, the effect dissipates with the degree of separation and can be completely eliminated when attention is predirected to the location of the ink color (e.g. Iwasaki 1978, Francolini & Egeth 1980, Kahneman & Henik 1981). Furthermore, the Stroop effect that is engendered when a color name is printed above a colored rectangle is nullified, or diluted, when a neutral word, or even a string of Xs, is printed below the rectangle (Kahneman & Chajczyk 1983). Thus, the Stroop effect is quite fragile when the color name is outside the presumed focus of attention.

Semantic priming In our own laboratory, we have compared words inside and outside the spatial foci of attention in terms of semantic priming (Dark et al 1985, Johnston & Dark 1985). Subjects monitored words presented at relevant locations of a visual display for occasional targets. Both relevant and irrelevant locations fell within 2° of visual angle from the center of the display. On occasion a prime word was inserted in a relevant or irrelevant location. Just after the presentation of the prime word, the attention task was interrupted by a semantically related test word. The test word was severely degraded at first but gradually clarified until it was identified. Priming was measured in terms of speed of identification of the test word. Prime words were exposed for 60–500 msec before being pattern masked. Semantic priming increased directly with exposure duration for words in relevant locations but was nil at all durations for words in irrelevant locations. Semantic processing of all stimuli appears to be data limited when exposure duration is very short. However, when data limits are removed by an increase in exposure duration, semantic processing appears to increase for stimuli inside the spatial foci of attention but remain undetectable for stimuli outside these foci. We have observed similar effects in a study of dichotic listening (Johnston & Dark 1982).

Summary and counterevidence Semantic-interference and semantic-priming effects support our sixth empirical generalization: 6. *Stimuli outside the spatial focus of attention undergo little or no semantic processing*. How can this generalization be squared with evidence that irrelevant stimuli are sometimes semantically processed (Generalization 3)? One possibility is that irrelevant stimuli might sometimes benefit from semantic- or identity-priming effects, and these top-down effects might yield some semantic analysis even for stimuli outside the attentional spotlight. Indeed, when relevant and irrelevant stimuli have been drawn from the same very small pool so that maximal identity priming of irrelevant stimuli was likely, then both semantic-interference and semantic-priming effects of irrelevant stimuli outside the attentional spotlight have been demonstrated (Van der Heijden et al 1984, Allport et al 1985). Other studies that provide apparent evidence for semantic processing of stimuli outside the attentional spotlight are subject to criticism on other counts. Holender (1985) presents an excellent review and critique of these studies. In any case, Generalization 6 receives additional support in the form of evidence that even physical analysis is attenuated for stimuli outside the spotlight.

NONSEMANTIC PROCESSING Evidence bearing on lower-level processing of stimuli outside the focus of attention has derived from studies of identity priming and feature integration.

Identity priming In our own research described above, we also measured the identity priming of words inside and outside the spatial foci of attention. As was the case for semantic priming, identity priming was consistently larger for words in relevant locations than for words in irrelevant locations. However, whereas semantic priming from irrelevant locations was nil at all exposure durations examined (60–500 msec), identity priming from these locations managed to attain significance at the longest duration (500 msec). Eich (1984) observed similar effects in a study of dichotic listening. Although some nonsemantic processing may occur for stimuli outside the attentional spotlight, it appears to be much less than that which occurs inside the spotlight.

Rayner et al (1978, Experiment 3) report additional evidence that even nonsemantic processing is attenuated for stimuli outside the attentional spotlight. They presented different strings of letters to the left and right parafoveas. When the eye started to move toward one of the stimuli (indicating that spatial attention was directed to that stimulus), both stimuli were removed and a test word was presented to the fovea. Only the parafoveal stimulus to which attention had been directed proved to be an effective identity prime for the test word. This is a particularly important finding because it shows that the stimulus to which spatial attention is directed receives more physical analysis than the other stimulus even though the two stimuli are equidistant from the fovea.

Feature integration Recent research suggests that spatial attention is required at the point in bottom-up processing where simple sensory features are conjoined. Duncan (1979, Experiment 1) had subjects search for the letter Q in a circular array (2.33° in diameter) of 8 locations, only 4 of which were relevant. When the letters O and K served as distractors, latency of detection was increased. This effect is attributable to the formation of an illusory Q by the conjunction of an O with the leg of a K. However, this effect obtained only when O and K appeared in relevant locations. When these distractors appeared outside the foci of attention, they apparently did not undergo a sufficient amount of bottom-up processing to produce an illusory conjunction of their sensory features.

Treisman and her colleagues have examined in detail the relationship between spatial attention and processing of physical features. Treisman & Schmidt (1982) found that simple features were correctly conjoined when the stimuli fell within a narrowly focused spotlight but that illusory conjunctions were found when attention was distributed over a wide area of space. Treisman & Gelade (1980) found that detection of feature conjunctions, but not simple features, was necessarily accompanied by correct localization of the targets. In addition, in a multielement display, detection of simple features appears to involve parallel processing, but detection of feature conjunctions appears to require serial processing (e.g. Hoffman 1979, Treisman
Treisman 1982, Egeth et al 1984). Finally, Vaughn (1984) found that accurate

processing could occur farther away from fixation for simple features than for feature conjunctions.

The weight of the evidence points toward our seventh empirical generalization: 7. *Stimulus processing outside the attentional spotlight is restricted mainly to simple physical features*. Although a sudden and intense event outside the attentional spotlight may receive enough bottom-up processing to draw the spotlight to its location (e.g. Posner et al 1980), more detailed physical analysis appears to require that spatial attention be directed to the stimulus.

Overview of Spatial Attention

In spatial attention tasks, processing can be selectively focused on a small region of the visual field subtending about 1° of visual angle. Attention can be directed to the parafovea and even to spatially disparate regions, but only by incurring considerable costs in speed and accuracy of stimulus processing. Stimulus processing outside the foci of attention appears to be confined largely to analysis of simple physical features. Processing of feature conjunctions and meaning appear to require spatial attention. We now consider whether selective processing can take place inside the attentional spotlight.

Object-Based Attention

Selective processing is assisted by factors other than spatial attention. James noted that we can selectively perceive different objects in the same spatial array, such as the sound of the oboe in an orchestral performance. In this section we consider selectivity on the basis of *objectness*. First we discuss the influence of perceptual organization on selection. Then we discuss selection between two objects overlapping in space.

PERCEPTUAL ORGANIZATION Consider the situation in which all stimuli appear around the fixation point but targets are intermixed with distractors. What factors influence selectivity? Selection of targets is strongly determined by Gestalt configuration properties like good continuation and featural similarity (Helson 1933) that produce "good" perceptual groups. These properties are often described as preattentive in the sense that they operate to define objects as candidates for selective processing (Neisser 1967). Identifying a single target is more difficult when the target is embedded among distractors as part of a perceptual group than when it is outside that group (Prinzmetal & Banks 1977, Carter 1982, Treisman 1982, Banks & White 1984). For example, Prinzmetal & Banks (1977) presented a T or F as a target among five similar shapes. Five of the items formed a line while the sixth item was slightly off to the side. Target identification was much faster when the T or F was the odd item than when it was part of the line. Bregman & Rudnicky (1975) showed a similar effect with auditory stimuli. An irrelevant tone interfered with a target sequence when it was perceptually grouped with that sequence but not when it was perceptually grouped with another irrelevant tone.

Similarly, when multiple targets form a perceptual group distinct from distractors, they are easier to identify than when they do not comprise a group (Fryklund 1975, Skelton & Eriksen 1976, Merikle 1980). Treisman et al (1983) presented two targets, a word and a rectangle with a gap in one side, at various positions around fixation. Subjects read the word and reported the position of the gap. When the rectangle surrounded the word and thus formed a single perceptual group, subjects read the word faster and were better able to locate the gap than when the rectangle appeared above or below the word, even though the gap was spatially closer to the word in the latter condition. Treisman et al (1983) interpreted the result as support for object-based attention. If the target information is integrated into one perceptual group, one object, then it will be easily selected. However, if the target information is distributed between two perceptually distinct groups, two objects, then the selection task will be more difficult.

Experience can lead to perceptual segregation based on meaning. A word, for example, appears to be treated as an individual object rather than a string of letters. Prinzmetal (1981) showed that illusory conjunctions are more likely to occur between features from a single perceptual group than between features from two distinct perceptual groups. Prinzmetal & Millis-Wright (1984) argued from that finding that if words are treated as a single object, then there should be more illusory conjunctions between features of words than between features of nonwords. In a series of five experiments, words produced the most illusory conjunctions. Pronounceable nonwords and familiar acronyms also produced more illusory conjunctions than nonwords. These data suggest that familiarity plays a part in parsing stimulus information into perceptual objects.

The controversy concerning local and global features in object perception can be resolved by considering the factors influencing perceptual organization (Hoffman 1980, Ward 1983). Compound letter stimuli (e.g. a large H comprised of small Ss) subtending less than 6° of visual angle produce a perceptual group based on the large letter (Navon 1977, Kinchla & Wolfe 1979) unless the small letters are so widely separated that each one is seen as a separate object (Martin 1979). Compound stimuli subtending more than 6° of visual angle may also produce perceptual groups based on the small letters (Kinchla & Wolfe 1979). Likewise, it is easier to attend to the global features of a triangle than to the component lines because the Gestalt property of closure makes the global figure perceptually more salient (Pomerantz 1983). Ward & Logan (1984) reported that subjects were faster at responding to the level (global vs local) to which they had just responded in a prior stimulus. Thus, the level that produces the quality of objectness appears to be subject to top-down priming effects.

OVERLAPPING OBJECTS We now turn to a related issue. There is a cost to combining relevant information from two perceptually distinct objects occurring close together in space (Treisman et al 1983). There is also a cost in selecting relevant information under conditions of spatial uncertainty when irrelevant objects/events occur in the visual field (Kahneman et al 1983). Is there a cost associated with selection of one of two overlapping objects in a known spatial location? The answer appears to be "no."

Subjects instructed to attend to one of two overlapping but differently colored line drawings (Goldstein & Fink 1981) or nonsense shapes (Rock & Gutman 1981) reveal very little processing of the irrelevant drawings as measured by a recognition test, but memory for the relevant drawings is equivalent to that produced when only one drawing is presented at a time. Rock & Gutman (1981) attempted to measure perceptual processing by occasionally presenting a familiar shape (a tree or a house) as either the relevant or irrelevant stimulus and requesting subjects to identify any familiar object immediately after stimulus offset. Subjects identified 89% of the relevant familiar shapes but none of the irrelevant familiar shapes. Selection between the two spatially overlapping objects appears to have been complete.

Duncan (1984) compared focused-attention and divided-attention conditions in a task involving a rectangle with a line through it. The entire stimulus subtended less than 1° of visual angle and was presented at fixation. In one experiment the rectangle varied in both size and which side contained a gap and the line varied in both texture and tilt. Subjects had to report two of the four dimensions. The two dimensions could be from the same object (rectangle or line) or from different objects. If both dimensions were from the same object, each dimension was reported as well as if it were the only dimension being reported. However, if the dimensions were from different objects, the second dimension was reported less accurately than in the single-report control. Apparently there is a cost associated with dividing attention between two separate objects even when they overlap and occur within 1° of visual angle.

Selection does not depend on the presence of a simple featural difference, like color or shape, between the stimuli. Neisser & Becklen (1975) simultaneously presented films of a handgame and a ballgame on the same screen and instructed subjects to respond whenever a specified event occurred in the relevant game. There was no performance decrement compared to when just one game was shown. Subjects showed little awareness of either predictable or unpredictable events in the irrelevant game (see also Becklen & Cervone 1983). Subjects instructed to attend to both games showed a severe loss in performance. Selection between games was easy but divided attention was difficult.

Dichoptically presented stimuli of sufficiently similar contours may fuse into a single object with features from each stimulus (e.g. Engel 1958), but dissimilar stimuli lead to binocular rivalry in which one of the two stimuli is selectively perceived while the other stimulus is functionally invisible. There may be switching (rivalry) between the stimuli, but the selection is complete. One or the other is seen but not both (see Walker 1978 for a review).

Considering all the evidence in this section, our eighth empirical generalization is: 8. *Overlapping objects can be selectively processed.*

Semantic Processing of Nonselected Objects

According to Generalization 6, there is not much semantic processing of stimuli outside the attentional spotlight. In the case of object-based attention, the issue becomes one of semantic processing of nonselected objects within the spotlight. As discussed in the previous section, selection between objects appears to be fairly complete as measured by memory and identification. Although subjects in the Neisser & Becklen (1975), Goldstein & Fink (1981), and Rock & Gutman (1981) studies indicated that they were aware of the presence of an irrelevant stimulus, they could report very little about the nonselected stimulus and showed no recognition memory for it. In this section we review and evaluate evidence that objects of which subjects are not aware are semantically processed nonetheless. A stimulus may fail to attain awareness because another stimulus is selected instead of it or because it is exposed too briefly. After presenting the evidence for the semantic processing of nonselected objects we critique the methodologies employed and discuss the counterevidence.

EVIDENCE Three lines of evidence will be considered in examining this issue: semantic priming from the irrelevant one of two overlapping objects; semantic priming from stimuli presented at threshold durations; and semantic priming from nonreported primes.

Overlapping objects Allport et al (1985) examined the semantic analysis of the irrelevant member (determined by color) of a pair of overlapping line drawings via its priming effect on the naming of a subsequent test stimulus. Subjects had to attend to the relevant drawing and then recall it after naming the test stimulus. The irrelevant drawing had two semantic-priming effects on latency to name the test stimulus. The priming effect was negative when the relevant drawing was correctly recalled, but it was positive when the relevant drawing was not correctly recalled. Both forms of priming constitute evidence for semantic analysis of nonselected stimuli.

Threshold primes Several recent investigations have examined the semantic-priming potency of relevant stimuli presented at exposure durations intended to be too brief to allow awareness of the stimuli. For example, Fowler et al (1981, Experiment 5) determined an awareness threshold by reducing the interval between a word or blank field and a subsequent pattern mask until the subject was unable to report reliably the presence/absence of the word. The threshold-setting session was followed by the priming sessions in which the subject made lexical decisions to test stimuli. The primes were presented either below or well above the awareness threshold. The amount of semantic priming was the same in the two conditions. Several other studies using similar procedures have produced similar results (Philpott & Wilding 1979, McCauley et al 1980, Humphreys 1981b, Balota 1983, Marcel 1983a).

Nonreported primes Another strategy used to show subliminal semantic analysis is to present primes at a duration that only sometimes allows identification and to look at differences in the amount of priming as a function of whether or not the prime is reported. The report of the prime word is requested immediately after the response to the test word. Both McCauley et al (1980) and Carr et al (1982) found that nonreported primes produced just as much priming as reported primes. Fishler & Goodman (1978) examined semantic priming in a lexical decision task and report a curious result: Reliable priming was obtained for the nonreported primes but not for the reported primes. Finally, Evett & Humphreys (1981, Experiment 1) examined semantic priming via increased correct naming of the test word when a prime was presented for about 33 msec and was followed immediately by the test word which was itself masked after 33 msec. Although subjects very rarely reported the prime words, these words increased identification accuracy of the test word by a statistically significant 12%.

CRITIQUE AND COUNTEREVIDENCE The three lines of evidence described above would seem to present a strong case for semantic processing of objects that fall in the spatial focus of attention but that are not selected into consciousness. However, most of the investigations have been severely criticized on methodological grounds. Though varied in nature, the criticisms all suggest that subjects might have been more aware of the primes than was assumed by the investigators.

Overlapping objects The study by Allport et al (1985) of overlapping objects made repeated use of a small ensemble of objects. A given object was presented many times, sometimes as the relevant object and sometimes as the irrelevant object. Thus, on all but the first few trials, irrelevant objects were likely to have benefitted from massive identity-priming effects. That irrelevant objects can benefit from the identity-priming effects was demonstrated by Wolford & Morrison (1980). Irrelevant words were sandwiched between two relevant digits. Above-chance recognition on a subsequent test was observed for words that had been repeated several times over the course of the experiment (Experiment 1) but not for words that had not been repeated (Experiment 2). The identity-priming problem was obviated in a study of binocular rivalry by Zimba & Blake (1983). A strong semantic-priming effect was observed for dominant (selected) objects but not for suppressed (unselected) objects.

Threshold primes Most of the threshold studies also made repeated use of the same stimuli. Therefore, it is possible that many of the "threshold" primes were themselves physically primed and rendered perceptible. These studies are subject to three additional criticisms as well. First, the threshold-setting procedures may be questioned on the grounds that the number of observations was insufficient and that subjects may have been conservative in reporting barely perceptible words (Merikle 1982). When a more reliable, forced-choice procedure has been used to establish awareness thresholds, no semantic priming has been observed for threshold stimuli (Cheesman & Merikle 1984). Second, stimuli are apt to be more perceptible on priming trials, especially later ones, than on threshold trials because of general practice effects. Wolford & Marchak (1984) observed a large improvement across trials in the identification of words when duration of exposure was held constant. Third, the extra light introduced on the priming trials by the presentation of test words may allow subjects to become light adapted and, therefore, have better visual acuity than they have on the threshold trials. Purcell et al (1983) showed that an exposure duration that allowed only 38% accuracy of word identification under the light-adaptation levels present on the threshold trials allowed 79% accuracy under the levels present on the priming trials. Furthermore, when Purcell et al used the same level of light adaptation on both threshold and priming trials, semantic priming for threshold words was eliminated.

Nonreported primes The demonstrations of semantic priming for nonreported primes are also subject to criticism. First, many of these demonstrations are subject to the identity-priming artifact that is introduced by making repeated use of the same stimuli as semantic primes. We controlled for this artifact in several studies in our laboratory. Stimulus presentation parameters allowed for 58% accuracy of prime report. Reported primes produced large semantic-priming effects but nonreported primes were impotent. Second, a prime may be consciously seen when it is presented but be forgotten during the presentation of and response to the test word (Holender 1985). Carr et al (1982) observed that an exposure duration that allowed for 100% report accuracy in a threshold-setting phase of the experiment supported only 32% report accuracy in a subsequent priming phase in which prime report was delayed until after the response to the test word. Thus, some of the semantic priming observed for nonreported words is attributable to primes that had attained awareness but were forgotten during the test trials.

SUMMARY We agree with Holender (1985) that the evidence on semantic processing of nonselected objects does not warrant rejection of the null hypothesis. Therefore, our ninth empirical generalization is: 9. *Nonselected objects within the spatial foci of attention undergo little or no semantic processing*. However, the evidence is mixed, so this generalization is submitted with some reservation. Indeed, there is evidence that a schema can be activated by repeated subliminal exposures of words that instantiate the schema. Bargh & Pietromonaco (1982) flashed words so briefly that subjects could neither report nor recognize them on a test administered immediately after stimulus presentation. From 0% to 80% of the words connoted hostility. Subsequently, subjects judged an ambiguously described person in terms of hostility and other negative traits. These judgments were a direct function of the number of hostility-related words to which the subjects had been subliminally exposed. It may be that a word exposed subliminally is not sufficient to activate a precise semantic representation of itself but can summate with other such words to activate a general schematic representation that embraces all of the words.

Automatic and Controlled Attention

In the last decade a considerable empirical and theoretical effort has been directed to the distinction between automatic and controlled processing (e.g. LaBerge 1975, Posner & Snyder 1975b, Schneider & Shiffrin 1977, Shiffrin & Schneider 1977). This distinction was well articulated by William James in his chapter on habit in which he provided examples first of controlled processing and then of automatic processing:

> When we are learning to walk, to ride, to swim, skate, fence, write, play, or sing, we interrupt ourselves at every step by unnecessary movements and false notes . . . on the contrary . . . A gleam in his adversary's eye, a momentary pressure from his rapier, and the fencer finds that he has instantly made the right parry and return. A glance at the musical hieroglyphics, and the pianist's fingers have rippled through a cataract of notes (1890, p. 114).

James also brought the distinction to bear on the process of attention: " . . . Attention may be either . . . passive, reflex, nonvoluntary, effortless; or . . . active and voluntary" (1890, p. 416). James noted that attention can be drawn automatically to stimuli by virtue of either their sensory ("immediate") characteristics (e.g. suddeness or intensity) or their semantic ("derived") characteristics. As an example of the latter, James offered the following: "A faint tap per se is not an interesting sound; it may well escape being discriminated from the general rumor of the world. But when it is a signal, as that of a lover on the window-pane, it will hardly go unperceived" (1890, pp. 417–18). Whereas a great deal of research has been directed to the general distinction between automatic and controlled *processing*, relatively little has examined the particular distinction between automatic and controlled *selection*. Much of the work on automaticity of attention has been performed in a series of studies spawned by Schneider & Shiffrin (1977).

In the paradigm developed by Schneider and Shiffrin, subjects detect targets that are embedded among nontargets in briefly exposed displays. In one condition, called consistent matching (CM), the targets and nontargets are always drawn from two different sets of stimuli. In another condition, called variable matching (VM), the targets and nontargets are drawn from the same pool of stimuli such that a stimulus that is a target on one trial can be a distractor on another trial. With sufficient practice at the task, detection of targets can become automatic in the CM condition but not in the VM condition. Among the signs of automatic attention to CM targets are the following (for more thorough reviews see Schneider et al 1984 and Shiffrin 1985): (*a*) detection performance in a CM task is not affected by the number of nontargets on the display (e.g. Schneider & Shiffrin 1977); (*b*) CM training produces severe negative transfer when the target and nontarget stimulus sets are switched (Shiffrin & Schneider 1977); (*c*) detection of a new VM target in relevant locations is disrupted when an old CM target appears nearby in an irrelevant location (Shiffrin & Schneider 1977); and (*d*) performance of a CM task is not disrupted by a concurrent task (Logan 1979, Fisk & Schneider 1983, Schneider & Fisk 1984).

In short, selective processing of CM targets is difficult to either disrupt (e.g. by adding nontargets to the display or imposing a secondary task) or prevent (e.g. by presenting them in irrelevant locations or redefining them as nontargets). By contrast, selective processing of VM targets is slower and less accurate overall, more disruptable, and more preventable. These distinctions hold true only within certain boundary conditions. For example, Hoffman et al (1983) showed that automatic attention to CM targets is diminished to the extent that these targets fall outside the spatial foci of attention. Nonetheless, the distinctions between CM and VM search conditions conform to the distinctions drawn by James between passive and active attention, and they form the basis for our tenth generalization: 10. *Selective processing is sometimes performed passively and sometimes actively.*

Schema-Based Attention

The effects of schemata on stimulus identification, memory, and judgment, and the activation of schemata by subliminal stimuli, were noted earlier. We review here evidence that selective processing can be guided by active schemata. Studies show that stimuli conforming to active schemata are easy to attend to but difficult to ignore.

The Neisser & Becklen (1975) study described in connection with object-based attention demonstrated selective attention to one of two overlapping films of people playing games. Relevant information differed from irrelevant only in terms of the schema to which it belonged. Neisser and Becklen suggest that their subjects selectively processed only information that corresponded to the active schema.

Johnston (1978) measured the effort required to selectively listen to an unfamiliar passage in terms of reaction time to subsidiary visual probes. Subjects had been familiarized with some of the irrelevant passages in a prior phase of the study. The measure of effort increased with the familiarity of the irrelevant passage. One way to interpret this finding is that selective processing of relevant information is difficult when the irrelevant information conforms to active schemata. However, the intrusive effect of familiar irrelevant passages obtained only when they could not be discriminated from the relevant passages on the basis of a simple physical cue (for example, gender of speaker).

Other studies suggest that schemata can render irrelevant material intrusive and disruptive even when subjects can rely on spatial cues (such as ear of entry) to attend to relevant material. Nielsen & Sarason (1981) inserted various classes of words in the irrelevant list of a dichotic listening task. The shadowing performance of their college-student subjects was disrupted when sexually explicit words were presented in the irrelevant list but not when neutral words or words related to hostility, educational evaluation, or university life were presented in the irrelevant list. The disruptive effect of sexually explicit words was correlated with subjects' premeasured level of state anxiety. These results may be diagnostic of the schemata that are most active in college students, especially anxious students.

Bargh (1982) examined the effect of "self schemata" on selective attention. Words related to the personality attribute of independence were inserted in the middle section of either the relevant list or the irrelevant list of a dichotic listening task. Several weeks prior to performing this task, subjects had been categorized as schematic or aschematic with respect to the attribute of independence. Attentional effort was measured in terms of reaction time to subsidiary visual probes. For aschematics, attentional effort was not affected by the presence of independence words in either list. However, for schematics, shadowing required relatively low effort when independence words were presented in the relevant list but relatively high effort when these words were presented in the irrelevant list.

Geller & Shaver (1976) used a color-naming task to study the effect of the self schema on selective attention. Latency to name the ink color in which words were printed was longer when the words were self relevant or self evaluative than when the words were neutral with respect to the self schema. This finding was exaggerated when subjects sat in front of a mirror and thought that their facial expressions were being video recorded, a manipulation designed to elevate the activation of the subjects' self schemata.

Bower (1981) reports two studies by Clore in which subjects were made to feel happy or angry by hypnotic procedures. In the first study, a relevant word was flanked by two irrelevant distractors on a visual display. The task was to classify the relevant word as pleasant or unpleasant. Classification errors were most frequent when the irrelevant words were congruent with the subjects' mood but opposite in emotional tone to the relevant word. In the second study, both happy and angry subjects took longer to name the ink colors of either pleasant words or unpleasant words than to name the ink colors of neutral words. Evidently, active schemata can draw selective processing away from stimuli that are relevant to the task to stimuli that are relevant to the subject. Our eleventh and final empirical generalization is as follows: 11. *Selective attention can be guided by active schemata.*

Summary of Empirical Literature

Our review of the literature can be summarized conveniently by paraphrasing and slightly rearranging our 11 empirical generalizations. Selection on the basis of sensory cues is usually superior to selection on the basis of semantic cues (2); spatial cues comprise a special kind of sensory cue (4); selection on the basis of spatial cues has the properties of an adjustable-beam spotlight (5) that can be focused most sharply at the center of the fovea; processing outside the spotlight is confined mainly to simple sensory features (6 and 7); selection inside the spotlight is based on the configural properties of objects (8); and there is little evidence for semantic processing of nonselected objects inside the spotlight (9). These seven generalizations converge onto the focused-attention aspect of the cocktail-party problem. One can tune into the sensory (especially spatial) and semantic features of a particular conversation and be oblivious to other conversations. However, irrelevant stimuli sometimes receive semantic processing (3), especially if they correspond to active schemata (11). These two generalizations illustrate the divided-attention aspect of the cocktail-party problem. One sometimes hears one's own name when it is mentioned in another conversation.

Both sets of empirical phenomena may be attributable to the priming of various levels of stimulus analysis (1). All levels of stimulus analysis can be biased simultaneously toward the characteristics of most of the relevant stimuli and some of the irrelevant stimuli. In some instances, these biases can be sufficiently strong that attention to the relevant or irrelevant stimuli appears to be automatic (10). Thus, Generalization 1 may help dissolve the apparent contradictions between some of the other generalizations and resolve the cocktail-party problem.

REVIEW OF THEORIES

We now examine and evaluate the major lines of theoretical development in the area of selective attention. A general distinction can be drawn between two classes of theory: those that view attention as a causal mechanism and those that view it as a natural consequence of other processes. We shall follow William James and refer to these as cause theories and effect theories.

Cause Theories

Most contemporary theories of information processing in general and selective attention in particular distinguish between two qualitatively different domains of stimulus processing (e.g. Kahneman 1973, LaBerge 1975, Posner & Snyder 1975b, Shiffrin & Schneider 1977, Lundh 1979, Broadbent 1982, Marcel 1983b). These domains of processing have been assigned various labels including nonconscious and conscious, automatic and controlled, peripheral and central, intraperceptual and extraperceptual, preattentive and attentive, and passive and active. We shall call them Domain A and Domain B. Domain A is the multilevel stimulus-analysis system introduced earlier. It is a relatively large-capacity, nonconscious, and passive system that is responsible for encoding environmental stimuli. Domain B is a relatively small-capacity, conscious, and active system that is responsible for controlling various forms of information processing including selective attention. Domain B can direct some of its limited capacity to the selection of the perceptual products of Domain A for entry or translation into consciousness. Thus, Domain B is, among other things, an attentional mechanism or director, a cause of selective processing.

Theories of this general class differ from one another in terms of the processing fate of nonselected stimuli. A majority of cause theories propose that perceptual encoding of irrelevant stimuli runs to completion regardless of where and how the perceptual records of relevant stimuli have been selected by Domain B. Domain B selects information from Domain A but does not control or modify processing in Domain A. A minority of cause theories propose that Domain B actually controls stimulus analysis in Domain A. Domain B can use its resources to prime different levels of stimulus analysis toward relevant stimuli and away from irrelevant stimuli so that only relevant stimuli undergo complete encoding in Domain A and, as a result, attain consciousness in Domain B. The majority point of view is well represented by Shiffrin & Schneider (1977) and the minority point of view is well represented by Broadbent (1971, 1982). We outline each of these theories and then evaluate the subclasses of cause theory that they represent on both empirical and metatheoretical grounds.

SHIFFRIN AND SCHNEIDER Shiffrin & Schneider (1977) articulate a cause theory of selective attention in the context of their research on controlled and automatic processing. Stimulus encoding by Domain A proceeds automatically and without interference from Domain B. Domain B expends its limited capacity on various sorts of controlled processing. One kind of controlled processing is the search through the perceptual products of Domain A for VM targets, and this defines one kind of selective attention. By contrast, the perceptual records produced by Domain A of CM targets can yield an "automatic attention response" in Domain B, and this defines another kind of selective attention. In short, Domain B sometimes has to execute a controlled search for the perceptual representations of relevant stimuli (e.g. VM targets) but other times can automatically detect these representations (e.g. CM targets). The focused-attention aspect of the cocktail-party problem is attributable to controlled attention to the relevant conversation bolstered by automatic attention to particular relevant stimuli. The divided-attention aspect is attributable to automatic attention to occasional irrelevant stimuli.

Thus, the variable automaticity with which individuals can attend to relevant stimuli is attributed to the variable automaticity with which Domain B can select the perceptual representations of these stimuli. Similar theories have been proposed by LaBerge (1975), Posner & Snyder (1975b), Hoffman (1979), Duncan (1980), and Marcel (1983b). They have in common the assumption that Domain A runs its full data-driven course even for irrelevant stimuli and that selective processing occurs only in and by Domain B.

BROADBENT Broadbent (1971, 1982) proposes that Domain B can bias Domain A toward the distinctive physical characteristics of relevant stimuli. This bias is the logical equivalent of an imperfect sensory filter that attenuates irrelevant information but passes relevant information onto the further levels of encoding. Sensory biases accommodate the focused-attention aspect of the cocktail-party problem. Irrelevant information is unlikely to progress through further levels of encoding unless these levels are biased toward, or primed for, this information. These higher-level biases account for thc divided-attention aspect of the cocktail-party problem. Selective representation in Domain B of relevant and irrclevant stimuli is a by-product of their selective processing through Domain A.

Similar theories have been proposed by Treisman (1964, Treisman & Gelade 1980) and Kahneman (1973, Kahneman et al 1983). They have in common the assumption that selective processing occurs in Domain A as a result of the top-down operation of Domain B. Even Shiffrin and Schneider have recently hinted at a very similar view. Specifically, Schneider et al (1984) suggest that Domain B may provide " . . . some of the stimulus components necessary for automatic processing to take place. Once the appropriate enabling stimuli occur (both external and internal), the automatic processes may take place without additional control or effort by the subject" (p. 11). If Schneider et al mean by this that Domain B can prime Domain A toward, and thereby facilite the encoding of, relevant stimuli, then they are articulating a view very much like Broadbent's.

EVALUATION The subclass of cause theory represented by Broadbent can accommodate most of the generalizations with relative ease. The subclass of theory represented by Shiffrin & Schneider is especially well suited to Generalizations 3 and 10 but runs into serious trouble with Generalizations 6, 7, and 9. The assumption that Domain A always runs its full bottom-up course is difficult to square with evidence that stimuli that are successfully kept out of consciousness undergo only low-level sensory analysis. Thus, the view represented by Broadbent appears to survive the empirical evidence somewhat better than the view represented by Shiffrin & Schneider. However, as recent reviews of the literature by Broadbent (1982) and Shiffrin (1985) clearly attest, both subclasses of cause theory can provide post-hoc explanations of all 11 empirical phenomena.

The ease with which Broadbent and Shiffrin can account for the known phenomena of selective attention betrays a serious metatheoretical problem with the view that selection of stimulus information is controlled by an active mental agent. Specifically, Domain B has all the characteristics of a processing homunculus. This is especially evident in the Shiffrin & Schneider theory. The basic explanation given for the variable automaticity with which subjects detect targets (Generalization 10) is that subjects are equipped with a Domain-B "attention director" that detects targets with variable automaticity. This explanation introduces an infinite regress because the same questions that were asked about how individuals pay attention now have to be asked about how the attention director pays attention. In tracing the history of atomic theory, Heisenberg (1958) notes that "Democritus was well aware of the fact that if atoms should . . . *explain* the properties of matter—color, smell, taste—they cannot themselves have these properties" (p. 69). Likewise, if a psychological construct is to explain the intelligent and adaptive selection powers of the organism, then it cannot itself be imbued with those powers. As we shall see below, William James appears to have recognized this metatheoretical problem.

Effect Theories

We review in this section the theory of selective attention articulated by James in 1890 and then note that similar theories have been advanced by more contemporary theorists. These theories have in common the view that selective processing is the passive by-product of natural priming effects.

WILLIAM JAMES We summarize James's view as much as possible in his own words, beginning with quotations that illustrate the role of sensory and semantic priming in selective attention:

> . . . attention to the idea of a sensible object, is also accompanied with some degree of excitement of the sense organs to which the object appeals . . . The preparation of the

ideational centres exists . . . wherever our interest in the object is derived from, or in any way connected with, other interests, or the presence of other objects, in the mind . . . So that . . . *the two processes of sensorial adjustment and ideational preparation coexist in all our concrete attentive acts*" [p. 434]. . . . When watching 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. The image in the mind is the attention; the preperception . . . is half of the looked-for thing [p. 442].

James dealt directly with the two general classes of attention theory when he asked "Is voluntary attention a resultant or a force?" (p. 447). James went on to articulate in some detail the view of attention as an effect rather than a cause. He explained the focused-attention phenomenon of cocktail parties as follows:

We see how we can attend to a companion's voice in the midst of noises which pass unnoticed though objectively much louder than the words we hear. Each word is *doubly* awakened; once from without by the lips of the talker, but already before that from within by the premonitory processes irradiating from the previous words, and by the dim arousal of all processes that are connected with the "topic" of the talk [p. 450].

Later James stated "The things we attend to *come to us* by their own laws. Attention *creates* no idea; an idea must already be there before we can attend to it" (p. 450);

The stream of thought is like a river. On the whole easy simple flowing predominates in it, the drift of things is with the pull of gravity, and effortless attention is the rule. But at intervals an obstruction, a set-back, a log-jam occurs, stops the current, creates an eddy, and makes things temporarily move the other way. If a real river could feel, it would feel these eddies and set-backs as places of effort . . . Really, the effort would only be a passive index that the feat was being performed [pp. 451–52]. Attention may have to go, like many a faculty once deemed essential, like many a verbal phantom, like many an idol of the tribe . . . No need of it to drag ideas before consciousness or fix them, when we see how perfectly they drag and fix each other there [p. 452].

CONTEMPORARY THEORISTS James's view is explicitly echoed by Hochberg (1978, pp. 158–211) and Neisser (1976, pp. 33–107). Both theorists articulate, primarily in terms of schema theory, a view of attention as a passive by-product of priming effects. Effect theories attribute both aspects of the cocktail-party problem to chronically active schemata and the natural priming effects of prior processing on subsequent processing.

EVALUATION Effect theory accommodates all 11 empirical generalizations with relative ease. It makes explicit use of the first and last generalizations. The view of attention as a consequence of natural priming effects has the important advantage of avoiding the homunculus problem. Moreover, this view lends itself well to practical applications and to an understanding of natural phenomena. A few more quotations from James illustrate this point:

> The only general pedagogic maxim bearing on attention is that the more interest the child has in advance in the subject, the better he will attend. Induct him therefore in such a way as to knit each new thing on to some acquisition already there . . . [p. 424]; . . . a teacher who wishes to engage the attention of his class must knit his novelties on to things of which they already have preperceptions [p. 447]. . . . Geniuses are commonly believed to excel . . . in their power of sustained attention . . . the "power" is of the passive sort. Their ideas coruscate, every subject branches infinitely before their fertile minds . . . *But it is their genius making them attentive, not their attention making geniuses of them* [p. 423].

Summary of Theories

The empirical literature, summarized in the form of our 11 empirical generalities, does not discriminate cleanly between the two general classes of theory. Indeed, it is probably not possible to decide empirically between them. As James suggested "The question is of course a purely speculative one . . . As mere *conceptions,* the effect theory and the cause theory of attention are equally clear; and whoever affirms either conception to be true must do so on metaphysical . . . rather than on scientific . . . grounds" (p. 448). It is somewhat ironic that, after his clear articulation of an effect theory, James revealed his private position:

> Under these circumstances, one can leave the question open whilst waiting for light, or one can do what most speculative minds do, that is, look to one's general philosophy to incline the beam. The believers in mechanism do so without hesitation, and they ought not to refuse a similar privilege to the believers in a spiritual force. I count myself among the latter, but as my reasons are ethical they are hardly suited for introduction into a psychological work [p. 454].

CONCLUSION

Our 11 empirical generalities suggest that the investment of three decades of research on selective attention has paid dividends in terms of knowledge. These gains may be illusory, however, since James and other scholars of the late nineteenth century might well have come up with a similar set of generalities. Reflecting on this possibility and on the skepticism of James himself, we are left wondering if the attempt to elucidate the nature of selective attention empirically is ultimately a futile one. Our own inclination is to continue the effort in the context of an effect theory. We suspect that it would be instructive to see how much we can understand about selective attention without appealing to a processing homunculus. Still, a dull, sinking feeling comes with the acknowledgment that James was much brighter than we and that he eventually abandoned psychology altogether.

Literature Cited

Allport, D. A., Tipper, S. P., Chmiel, N. R. J. 1985. Perceptual integration and post-categorical filtering. See Posner & Marin 1985, pp. 107–32

Anthony, B. J. 1985. In the blink of an eye: Implications of reflex modification for information processing. In *Advances in Psychophysiology, Vol. 1*, ed. P. K. Ackles, J. R. Jennings, M. G. H. Coles. Greenwich, CT: JAI Press. In press

Anthony, B. J., Graham, F. K. 1983. Evidence for sensory-selective set in young infants. *Science* 220:742–44

Balota, D. A. 1983. Automatic semantic activation and episodic memory encoding. *J. Verb. Learn. Verb. Behav.* 22:88–104

Balota, D. A., Rayner, K. 1983. Parafoveal visual information and semantic contextual constraints, *J. Exp. Psychol: Hum. Percept. Perform.* 9:726–38

Banks, W. P., White, H. 1984. *Perceptual grouping and lateral masking.* Presented at Ann. Meet. Psychon. Soc., San Antonio

Bargh, J. A. 1982. Attention and automaticity in the processing of self-relevant information. *J. Pers. Soc. Psychol.* 3:425–36

Bargh, J. A., Pietromonaco, P. 1982. Automatic information processing and social perception: The influence of trait information presented outside of conscious awareness on impression formation. *J. Pers. Soc. Psychol.* 43:437–49

Bartlett, F. C. 1932. *Remembering: A Study in Experimental and Social Psychology.* London: Cambridge Univ. Press

Becklen, R., Cervone, D. 1983. Selective looking and the noticing of unexpected events. *Mem. Cognit.* 11:601–8

Biederman, I., Glass, A. L., Stacy, E. 1973. Searching for objects in real world scenes. *J. Exp. Psychol.* 97:22–27

Bower, G. H. 1981. Mood and memory. *Am. Psychol.* 36:129–48

Bower, G. H., Black, J. B., Turner, T. J. 1979. Scripts in memory for text. *Cognit. Psychol.* 11:177–220

Bregman, A. S., Rudnicky, A. I. 1975. Auditory segregation: Stream or streams? *J. Exp. Psychol: Hum. Percept. Perform.* 1:263–67

Broadbent, D. 1958. *Perception and Communication.* London: Pergamon

Broadbent, D. 1971. *Decision and Stress.* London: Academic

Broadbent, D. 1982. Task combination and selective intake of information. *Acta Psychol.* 50:253–90

Carr, T. H., McCauley, C., Sperber, R. D., Parmelee, C. M. 1982. Words, pictures, and priming: On semantic activation, conscious identification, and automaticity of information processing. *J. Exp. Psychol: Hum. Percept. Perform.* 8:757–77

Carter, R. C. 1982. Visual search with color. *J. Exp. Psychol: Hum. Percept. Perform.* 8:127–36

Cheesman, J., Merikle, P. 1984. Priming with and without awareness. *Percept. Psychophys.* 36:387–95

Cherry, E. C. 1953. Some experiments on the recognition of speech, with one and two ears. *J. Acoust. Soc. Am.* 25:975–79

Coltheart, M. 1980. Iconic memory and visible persistence. *Percept. Psychophys.* 27:183–228

Conrad, C. 1974. Context effects in sentence comprehension: A study of the subjective lexicon. *Mem. Cognit.* 1:63–72

Corteen, R. S., Wood, B. 1972. Autonomic responses to shock associated words in an unattended channel. *J. Exp. Psychol.* 94:308–13

Dannenbring, G. L., Briand, K. 1982. Semantic priming and the word repetition effect in a lexical decision task. *Can. J. Psychol.* 36:435–44

Dark, V. J., Johnston, W. A., Myles-Worsley, M., Farah, M. J. 1985. Levels of capacity limitation and selection. *J. Exp. Psychol: Gen.* In press

Deutsch, J. A., Deutsch, D. 1963. Attention: Some theoretical considerations. *Psychol. Rev.* 87:272–300

Duncan, J. 1979. Divided attention: The whole is more than the sum of this parts. *J. Exp. Psychol: Hum. Percept. Perform.* 5:216–28

Duncan, J. 1980. The locus of interference in the perception of simultaneous stimuli. *Psychol. Rev.* 87:272–300

Duncan, J. 1984. Selective attention and the organization of visual information. *J. Exp. Psychol: Gen.* 113:501–17

Egeth, H. E., Virzi, R. A., Garbart, H. 1984. Searching for conjunctively defined targets. *J. Exp. Psychol: Hum. Percept. Perform.* 10:32–39

Egly, R., Homa, D. 1984. Sensitization of the visual field. *J. Exp. Psychol: Hum. Percept. Perform.* 10:778–93

Eich, E. 1984. Memory for unattended events: Remembering with and without awareness. *Mem. Cognit.* 12:105–11

Engel, E. 1958. Binocular fusion of dissimilar figures. *J. Psychol.* 46:53–57

Eriksen, B. A., Eriksen, C. W. 1974. Effects of noise letters upon the identification of a target letter in a nonsearch task. *Percept. Psychophys.* 16:143–49

Eriksen, C. W., Hoffman, J. E. 1972. Temporal and spatial characteristics of selective encoding from visual displays. *Percept. Psychophys.* 12:201–4

Estes, W. K. 1982. Similarity-related channel interactions in visual processing. *J. Exp. Psychol: Hum. Percept. Perform.* 8:353–82

Evett, L. J., Humphreys, G. W. 1981. The use of abstract graphemic information in lexical access. *Q. J. Exp. Psychol.* 33A:325–50

Feustel, T. C., Shiffrin, R. M., Salasoo, A. 1983. Episodic and lexical contributions to the repetition effect in word identification. *J. Exp. Psychol: Gen.* 112:309–46

Fishler, I., Goodman, G. D. 1978. Latency of associated activation in memory. *J. Exp. Psychol: Hum. Percept. Perform.* 4:455–70

Fisk, A. D., Schneider, W. 1983. Category and word search: Generalizing search principles to complex processing. *J. Exp. Psychol: Learn. Mem. Cognit.* 9:177–95

Fowler, C. A., Wolford, G., Slade, R., Tassinary, L. 1981. Lexical access with and without awareness. *J. Exp. Psychol: Gen.* 110:341–62

Francolini, C. M., Egeth, H. 1980. On the non-automaticity of "automatic" activation: Evidence of selective seeing. *Percept. Psychophys.* 27:331–42

Friedman, A. 1979. Framing pictures: The role of knowledge in automatized encoding and memory for gist. *J. Exp. Psychol: Gen.* 108:316–55

Fryklund, I. 1975. Effects of cued-set spatial arrangement and target-background similarity in the partial-report paradigm. *Percept. Psychophys.* 17:375–86

Geller, V., Shaver, P. 1976. Cognitive consequences of self-awareness. *J. Pers. Soc. Psychol.* 12:99–108

Goldstein, E. B., Fink, S. I. 1981. Selective attention in vision: Recognition memory for superimposed line drawings. *J. Exp. Psychol: Hum. Percept. Perform.* 7:954–67

Gummow, L., Miller, P., Dustman, R. E. 1983. Attention and brain injury: A case for cognitive rehabilitation of attentional deficits. *Clin. Psychol. Rev.* 3:255–74

Harter, M. R., Aine, C. J. 1984. Brain mechanisms of visual selective attention. See Parasuraman & Davies 1984, pp. 293–321

Hede, A. J. 1981. Perceptual selection in dichotic listening. *Acta Psychol.* 49:189–200

Heisenberg, W. 1958. *Physics and Philosophy*. New York: Harper

Helson, H. 1933. The fundamental propositions of Gestalt Psychology. *Psychol. Rev.* 40:13–32

Higgins, E. T., Bargh, J. A., Lombardi, W. 1985. Nature of priming effects on categorization. *J. Exp. Psychol: Learn. Mem. Cognit.* 11:59–69

Hillyard, S. A., Kutas, M. 1983. Electrophysiology of cognitive processing. *Ann. Rev. Psychol.* 34:33–61

Hochberg, J. E. 1978. *Perception*. Englewood Cliffs, NJ: Prentice-Hall

Hoffman, J. E. 1979. A two-stage model of visual search. *Percept. Psychophys.* 25:319–27

Hoffman, J. E. 1980. Interaction between global and local levels of a form. *J. Exp. Psychol: Hum. Percept. Perform.* 6:222–34

Hoffman, J. E., Nelson, G., Houck, M. R. 1983. The role of attentional resources in automatic detection. *Cognit. Psychol.* 51: 379–410

Holender, D. 1985. Semantic activation without conscious identification in dichotic listening, parafoveal vision, and visual masking: A survey and appraisal. *Behav. Brain Sci.* In press

Holtzman, J. D., Sidtis, J. J., Volpe, B. T., Wilson, D. H., Gazzaniga, M. S. 1984a. Dissociation of spatial information for stimulus localization and the control of attention. *Brain* 104:861–72

Holtzman, J. D., Volpe, B. T., Gazzaniga, M. S. 1984b. Spatial orientation following commissural section. See Parasuraman & Davies 1984, pp. 375–94

Humphreys, G. 1981a. On varying the span of visual attention: Evidence for two modes of spatial attention. *Q. J. Exp. Psychol.* 334:1–15

Humphreys, G. 1981b. Direct vs. indirect tests of the information available from masked displays: What visual masking does and does not prevent. *Br. J. Psychol.* 72:323–30

Inhoff, A. W. 1982. Parafoveal word perception: A further case against semantic preprocessing. *J. Exp. Psychol: Hum. Percept. Perform.* 8:137–45

Iwasaki, S. 1978. The limits of attention and its expansion. *Jpn. Psychol. Res.* 20:133–42

Jacoby, L. L. 1983a. Perceptual enhancement: Persistent effects of an experience. *J. Exp. Psychol: Learn. Mem. Cognit.* 9:21–38

Jacoby, L. L. 1983b. Remembering the data: Analyzing interactive processes in reading. *J. Verb. Learn. Verb. Behav.* 22:485–508

Jacoby, L. L., Dallas, M. 1981. On the relationship between autobiographical memory and perceptual learning. *J. Exp. Psychol: Gen.* 3:306–40

Jacoby, L. L., Witherspoon, D. 1982. Remembering without awareness. *Can. J. Psychol.* 36:300–24

James, W. 1890/1950. *The Principles of Psychology*. New York: Dover

Johnston, W. A. 1978. The intrusiveness of familiar nontarget information. *Mem. Cognit.* 6:38–42

Johnston, W. A., Dark, V. J., 1982. In defense of intraperceptual theories of attention. *J. Exp. Psychol: Hum. Percept. Perform.* 8:407–21

Johnston, W. A., Dark, V. J. 1985. Dissociable domains of selective processing. See Posner & Marin 1985, pp. 567–83

Johnston, W. A., Dark, V. J., Jacoby, L. L. 1985. Perceptual fluency and recognition judgments. *J. Exp. Psychol: Learn. Mem. Cognit.* 11:3–11

Johnston, W. A., Heinz, S. P. 1978. Flexibility and capacity demands of attention. *J. Exp. Psychol: Gen.* 107:420–35

Kahneman, D. 1973. *Attention and Effort*. Englewood Cliffs, NJ: Prentice-Hall

Kahneman, D., Chajczyk, D. 1983. Tests of the automaticity of reading: Dilution of Stroop effects by color-irrelevant stimuli. *J. Exp. Psychol: Hum. Percept. Perform.* 9:497–509

Kahneman, D., Henik, A. 1981. Perceptual organization and attention. In *Perceptual Organization*, ed. M. Kubovey, J. R. Pomerantz, pp. 181–211. Hillsdale, NJ: Erlbaum

Kahneman, D., Treisman, A. 1984. Changing views of attention and automaticity. See Parasuraman & Davies, pp. 29–61

Kahneman, D., Treisman, A., Burkell, J. 1983. The cost of visual filtering. *J. Exp. Psychol: Hum. Percept. Perform.* 9:510–22

Kempley, S. T., Morton, J. 1982. The effects of priming with regularly and irregularly related words in auditory word recognition. *Br. J. Psychol.* 73:441–54

Keren, G. 1976. Some considerations of two alleged kinds of selective attention. *J. Exp. Psychol: Gen.* 105:349–74

Kinchla, R. A., Wolfe, J. M. 1979. The order of visual processing: "Top-down," "bottom-up," or "middle-out." *Percept. Psychophys.* 25:225–31

Kirsner, K., Smith, M. C. 1974. Modality effects in word identification. *Mem. Cognit.* 2:637–40

LaBerge, D. 1975. Acquisition of automatic processing in perceptual and associative learning. See Rabbitt & Dornic 1975, pp. 50–64

LaBerge, D. 1983. Spatial extent of attention to letters and words. *J. Exp. Psychol: Hum. Percept. Perform.* 9:371–79

Lewis, J. 1970. Semantic processing of unattended messages using dichotic listening. *J. Exp. Psychol.* 85:225–28

Logan, G. D. 1979. On the use of concurrent memory load to measure attention and automaticity. *J. Exp. Psychol: Hum. Percept. Perform.* 5:189–207

Logan, G. D. 1980. Attention and automaticity in Stroop and priming tasks: Theory and data. *Cognit. Psychol.* 12:523–53

Lowe, D. G., Mitterer, J. O. 1982. Selective and divided attention in a Stroop task. *Can. J. Psychol.* 36:684–700

Lundh, L. G. 1979. Introspection, consciousness, and human information processing. *Scand. J. Psychol.* 20:223–38

MacKay, D. G. 1973. Aspects of a theory of comprehension, memory and attention. *Q. J. Exp. Psychol.* 25:22–40

Marcel, A. J. 1983a. Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognit. Psychol.* 15:197–237

Marcel, A. J. 1983b. Conscious and unconscious perception: An approach to the relations between phenomenal experience and perceptual processes. *Cognit. Psychol.* 15:238–300

Martin, M. M. 1979. Local and global processing: The role of sparsity. *Mem. Cognit.* 7:476–84

McCauley, C., Parmelee, C. M., Sperber, R. D., Carr, T. H. 1980. Early extraction of meaning from pictures and its relation to conscious identification, *J. Exp. Psychol: Hum. Percept. Perform.* 6:265–76

McClelland, J. J., O'Regan, J. K. 1981. The role of expectations in the use of parafoveal information in reading. *J. Exp. Psychol: Hum. Percept. Perform.* 7:634–44

Merikle, P. M. 1980. Selection from visual persistence by perceptual groups and category membership. *J. Exp. Psychol: Gen.* 109:279–95

Merikle, P. M. 1982. Unconscious perception revisited. *Percept. Psychophys.* 31:298–301

Meyer, D. E., Schvaneveldt, R. W., Ruddy, M. G. 1975. Loci of contextual effects on visual word-recognition. See Rabbitt & Dornic 1975, pp. 98–118

Moray, N. 1959. Attention in dichotic listening: Affective cues and the influence of instructions. *Q. J. Exp. Psychol.* 11:56–60

Moray, N. 1970. *Attention: Selective Processes in Vision and Hearing*. New York: Academic

Mountcastle, V. B. 1978. Brain mechanisms for directed attention. *J. R. Soc. Med.* 71:14–27

Näätänen, R. 1982. Processing negativity: An evoked-potential reflection of selective attention. *Psychol. Bull.* 92:605–40

Navon, D. 1977. Forest before trees: The precedence of global features in visual perception. *Cognit. Psychol.* 9:353–83

Navon, D., Gopher, D. 1979. On the economy of the human processing system. *Psychol. Rev.* 86:214–55

Neisser, U. 1967. *Cognitive Psychology*. New York: Appleton-Century-Crofts

Neisser, U. 1976. *Cognition and Reality*. San Francisco: Freeman

Neisser, U., Becklen, R. 1975. Selective looking: Attending to visually specified events. *Cognit. Psychol.* 7:480–94

Nielsen, L. L., Sarason, I. G. 1981. Emotion, personality, and selective attention. *J. Pers. Soc. Psychol.* 41:945–60

Ninio, A., Kahneman, D. 1974. Reaction time in focused and in divided attention. *J. Exp. Psychol.* 103:394–99

Nissen, M. J. 1985. Accessing features and objects: Is location special? See Posner & Marin 1985

Norman, D. A., Bobrow, D. B. 1975. On data-limited and resource-limited processes. *Cognit. Psychol.* 7:44–64

Oatman, L. C. 1984. *Auditory evoked-potential amplitude during simultaneous visual stimulation*. Presented at Ann. Meet. Psychon. Soc., San Antonio

Paap, K. R., Newsome, S. L. 1981. Parafoveal information is not sufficient to produce semantic or visual priming. *Percept. Psychophys.* 29:457–66

Palmer, S. E. 1975. The effects of contextual scenes on the identification of objects. *Mem. Cognit.* 3:519–26

Parasuraman, R., Davies, D. R., eds. 1984. *Varieties of Attention*. Orlando, FL: Academic

Philpott, A., Wilding, J. 1979. Semantic interference from subliminal stimuli in a dichoptic viewing situation. *Br. J. Psychol.* 70:559–63

Podgorny, P., Shepard, R. N. 1983. Distribution of visual attention over space. *J. Exp. Psychol: Hum. Percept. Perform.* 9:380–93

Pomerantz, J. R. 1983. Global and local precedence: Selective attention in form and motion perception. *J. Exp. Psychol: Gen.* 112:516–40

Posner, M. I., Boies, S. W. 1971. Components of attention. *Psychol. Rev.* 78:391–408

Posner, M. I., Cohen, Y. 1984. Components of visual orienting. In *Attention and Performance*, ed. H. Bouma, D. Bowhuis, 10:531–56. Hillsdale, NJ: Erlbaum

Posner, M. I., Marin, O. S. M., eds. 1985. *Mechanisms of Attention: Attention and Performance*, Vol. 11. Hillsdale, NJ: Erlbaum. In press

Posner, M. I., Snyder, C. R. R. 1975a. Facilitation and inhibition in the processing of signals. See Rabbitt & Dornic 1975, pp. 669–82

Posner, M. I., Snyder, C. R. R. 1975b. Attention and cognitive control. In *Information Processing and Cognition: The Loyola Symposium*, ed. R. L. Solso, pp. 55–85. Hillsdale, NJ: Erlbaum

Posner, M. I., Snyder, C. R. R., Davidson, B. J. 1980. Attention and the detection of signals. *J. Exp. Psychol: Gen.* 109:160–74

Posner, M. I., Walker, J. A., Friedrich, F. J., Rafal, R. D. 1984. Effects of parietal injury on covert orienting of attention. *J. Neurosc.* 4:1863–74

Prinzmetal, W. 1981. Principles of feature integration in visual perception. *Percept. Psychophys.* 30:330–40

Prinzmetal, W., Banks, W. P. 1977. Good continuation affects visual detection. *Percept. Psychophys.* 21:389–95

Prinzmetal, W., Millis-Wright, M. 1984. Cognitive and linguistic factors affect visual feature integration. *Cognit. Psychol.* 16:305–40

Purcell, G., Stewart, L., Stanovich, K. E. 1983. Another look at semantic priming without awareness. *Percept. Psychophys.* 34:65–71

Rabbitt, P. M. A., Dornic, S., eds. 1975. *Attention and Performance*, Vol. 5. New York: Academic

Rabbitt, P. M. A., Vyas, S. 1979. Memory and data-driven control of selective attention in continuous tasks. *Can. J. Psychol./Rev. Can. Psychol.* 33:71–87

Rayner, K., McConkie, G. W., Ehrlich, S. 1978. Eye movements integrating information across fixation. *J. Exp. Psychol: Hum. Percept. Perform.* 4:529–44

Remington, R., Pierce, L. 1984. Moving attention: Evidence for time-invariant shifts of visual selective attention. *Percept. Psychophys.* 35:393–99

Riley, D. A., Leith, C. R. 1976. Multidimensional psychophysics and selective attention in animals. *Psychol. Bull.* 83:138–60

Rock, I., Gutman, D. 1981. The effect of inattention on form perception. *J. Exp. Psychol: Hum. Percept. Perform.* 7:275–85

Schiepers, C. 1980. Response latency and accuracy in visual word recognition. *Percept. Psychophys.* 27:71–81

Schneider, W., Dumais, S. T., Shiffrin, R. M. 1984. Automatic and control processing and attention. See Parasuraman & Davies 1984, pp. 1–27

Schneider, W., Fisk, D. 1984. Automatic category search and its transfer. *J. Exp. Psychol: Learn. Mem. Cognit.* 10:1–15

Schneider, W., Shiffrin, R. M. 1977. Controlled and automatic human information processing: I. Detection, search, and attention. *Psychol. Rev.* 84:1–66

Shaw, M., Shaw, P. 1977. Optimal allocation of cognitive resources to spatial location. *J. Exp. Psychol: Hum. Percept. Perform.* 3:201–11

Shiffrin, R. M. 1985. Attention. In *Stevens' Handbook of Experimental Psychology*, ed. R. C. Atkinson, R. J. Herrnstein, G. Lindsey, R. D. Luce. New York: Wiley. In press

Shiffrin, R. M., Schneider, W. 1977. Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychol. Rev.* 84:127–90

Skelton, J. M., Eriksen, C. W. 1976. Spatial characteristics of selective attention in letter matching. *Bull. Psychon. Soc.* 7:136–38

Snyder, M., Swann, W. B. Jr. 1978. Hypothesis testing processes in social interaction. *J. Pers. Soc. Psychol.* 36:1202–12

Snyder, M., Uranowitz, S. W. 1978. Reconstructing the past: Some cognitive consequences of person perception. *J. Pers. Soc. Psychol.* 36:941–50

Sperling, G., Reeves, A. 1980. Measuring the reaction time of a shift of visual attention. In *Attention and Performance,* ed. R. S. Nickerson, 8:347–60. Hillsdale, NJ: Erlbaum

Stroop, J. R. 1935. Studies of interference in serial verbal reactions. *J. Exp. Psychol.* 18:643–62

Taylor, S. E., Crocker, J. 1981. Schematic bases of social information processing. In *Social Cognition: The Ontario Symposium,* ed. E. T. Higgins, C. P. Heiman, M. P. Zanna, pp. 89–134. Hillsdale, NJ: Erlbaum

Treisman, A. M. 1960. Contextual cues in selective listening. *Q. J. Exp. Psychol.* 12:242–48

Treisman, A. M. 1964. Verbal cues, language and meaning in selective attention. *Am. J. Psychol.* 77:206–19

Treisman, A. M. 1969. Strategies and models of selective attention. *Psychol. Rev.* 76:282–99

Treisman, A. M. 1982. Perceptual grouping and attention in visual search for features and for objects. *J. Exp. Psychol: Hum. Percept. Perform.* 8:194–214

Treisman, A. M., Geffen, G. 1967. Selective attention: Perception or response? *Q. J. Exp. Psychol.* 19:1–17

Treisman, A. M., Gelade, G. 1980. A feature-integration theory of attention. *Cognit. Psychol.* 12:97–136

Treisman, A. M., Kahneman, D., Burkell, J. 1983. Perceptual objects and the cost of filtering. *Percept. Psychophys.* 33:527–32

Treisman, A. M., Riley, J. G. A. 1969. Is selective attention selective perception or selective response? A further test. *J. Exp. Psychol.* 79:27–34

Treisman, A. M., Schmidt, H. 1982. Illusory conjunctions in the perception of objects. *Cognit. Psychol.* 14:107–41

Tsal, Y. 1983. Movements of attention across the visual field, *J. Exp. Psychol: Hum. Percept. Perform.* 9:523–30

Underwood, G. L. 1976. Semantic interference from unattended printed words. *Br. J. Psychol.* 67:327–38

Underwood, G. L. 1977. Facilitation from attended and unattended messages. *J. Verb. Learn. Verb.Behav.* 16:99–106

Van der Heijden, A. H. C., Hagenaar, R., Bloem, W. 1984. Two stages in postcategorical filtering and selection. *Mem. Cognit.* 12:458–69

Vaughn, J. 1984. *Distance of attention switch affects RT only for some stimuli.* Presented at Ann. Meet. Psychon. Soc., San Antonio

von Wright, J. M. 1968. Selection in immediate visual memory. *Q. J. Exp. Psychol.* 20:62–68

Walker, P. 1978. Binocular rivalry: Central or peripheral selective process? *Psychol. Bull.* 85:376–89

Ward, L. M. 1983. On processing dominance: Comment on Pomerantz. *J. Exp. Psychol: Gen.* 112:541–46

Ward, L. M., Logan, G. 1984. *Setting the "focus" parameter of the covert attentional gaze.* Presented at Ann. Meet. Psychon. Soc., San Antonio

Wickens, C. D. 1984. Processing resources in attention. See Parasuraman & Davies 1984, pp. 63–102

Wolford, G., Marchak, F. 1984. *Improvement in a backward masking paradigm.* Presented at Ann. Meet. Psychon. Soc., San Antonio

Wolford, G., Morrison, F. 1980. Processing of unattended visual information. *Mem. Cognit.* 8:521–27

Woods, D. L., Hillyard, S. A., Hansen, J. C. 1984. Event-related brain potentials reveal similar attentional mechanisms during selective listening and shadowing. *J. Exp. Psychol: Hum. Percept. Perform.* 10:761–71

Zimba, L. D., Blake, R. 1983. Binocular rivalry and semantic processing: Out of sight, out of mind. *J. Exp. Psychol: Hum. Percept. Perform.* 9:807–15