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Varieties of Attention

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Changing Views of Attention and Automaticity

Daniel Kahneman and Anne Treisman

Introduction

There are two main interpretations of the adaptive function of selective attention, corresponding to two problems that an organism must solve. One view emphasizes the richness and complexity of the information that is presented to the senses at any one time and the consequent risk of confusion and overload (Broadbent, 1958). The other view emphasizes the diverse and incompatible response tendencies that may be instigated at any one time and the consequent risks of paralysis and incoherence (Posner, 1978; Shallice, 1972). The function of attention in the first view is to ensure adequate perceptual processing of the currently important sensory messages; in the second view, it is to ensure adequate execution of the currently most important action. The main mechanism of attention in the first view is selective processing; in the second, it is the adoption of an appropriate set.

It is of course quite possible—indeed likely—that organisms are threatened both by perceptual overload and by response incoherence, and that different selective processes must be employed to control the two threats. However, the emphasis on each of these problems tends to suggest a different approach to the study of attention. The revival of interest in attention in the 1950s was motivated at least in part by the discovery of surprising limitations in the handling of simultaneous messages by air-traffic controllers and by subjects in dichotic listening tasks. Perceptual overload seemed to be the problem, and the experimental situations of the time were designed to induce overload in order to explore the efficacy with which limited resources could be directed to the most relevant information. However, subsequent studies raised doubts about the existence of perceptual limits because subjects were sometimes able to monitor several input channels at once with little or no impairment (e.g., Shiffrin, 1975; Shiffrin & Grantham, 1974). In the simpler experimental situations that were widely adopted for the study of attention, perceptual processing often appeared to be independent of attention, and the two major treatments of attention in the late 1970s both emphasized automaticity in information processing (Posner, 1978; Shiffrin & Schneider, 1977).

Indeed, the study of attention underwent a significant paradigm shift during

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the decade of the 1970s, almost a reversal of figure and ground: the null hypothesis for research was inverted as the focus of interest moved from the nature of attention limits to the exploration of automatic processing. Thus, several studies in the early 1970s tested and rejected the claim that stimuli presented to an unattended channel receive no semantic processing at all (Corteen & Wood, 1972; Lewis, 1970; MacKay, 1973; von Wright, Anderson, & Stenman, 1975). A few years later, the reversal of figure and ground was evident in a spate of reports describing effects of attention on operations that had previously been thought automatic (Francolini & Egeth, 1980; Hoffman, Nelson, & Houck, 1983; Johnston & Dark, 1982; Kahneman & Henik, 1981; Paap & Ogden, 1981). The belief in automaticity and late selection had become general enough to be worth testing and challenging. Consider an illustrative case history: in 1960, it was shown that on 6% of trials, subjects reported a word presented to the unattended ear if that word was highly probable in the attended message (Treisman, 1960). This finding was important in 1960 as a challenge to an early-selection theory. It was subsequently cited by several authors without mention of the rarity of intrusions from the rejected ear, in statements that began with "Subjects . . ." or even "Subjects frequently . . .". If the same paper were to be rewritten now, it would have to stress the newly surprising fact that on 94% of trials, the highly probable word was not reported.

We begin this chapter by a brief review of the abrupt change in the dominant theory of attention. We make no attempt to be comprehensive in our treatment; our aim is simply to sketch with broad strokes a view of some of the main trends in attention research since 1950, giving examples of experiments rather than listing all the relevant papers. For comprehensive reviews of the field, see Broadbent (1982) and Keele and Neill (1979). We argue that changes occurring in the late 1970s and early 1980s resulted in part from the adoption of new experimental paradigms to study attention, which, in turn, were anchored in a new view of the relation between perception and long-term memory (LTM). We also describe several series of experiments in which we tested null hypotheses derived from the notion of automatic semantic processing. Our results indicate a substantial susceptibility of "automatic" processes to attention effects. Finally, we sketch a framework for the study of attention that may accommodate the different lines of evidence from which "early-selection" and "late-selection" models of attention have drawn support.

The Disputed Nature of Attention

Research Paradigms in Attention: Trends and Consequences

Studies of attention fall into two broad classes, which are concerned respectively with divided and with focused (or selective) attention. Divided attention

tasks are used to establish limits to performance and to measure the extent to which different tasks can be combined without loss. They are also used to analyze the causes of dual-task decrements and to locate the stages of processing that limit performance. Tasks of selective or focused attention are used to study resistance to distraction and to establish the locus beyond which relevant and irrelevant stimuli are treated differentially (see also Davies, Jones, & Taylor, Chapter 11, this volume).

Early studies of attention (reviewed by Broadbent, 1958) typically involved complex competing messages, often speech, which constituted a high perceptual load. People appeared to do quite poorly in dividing attention between such messages, but they were very successful in focusing attention at will on one of them. Attention was viewed as selecting messages arriving on a "channel." The main experimental problems were the effectiveness of selective attention in protecting the relevant messages and the quality of processing of the information presented to rejected channels. Table 2.1 lists some characteristics of the filtering paradigm which was developed to study these problems. This paradigm is compared to the research methods that became popular in the 1970s and that we label the "*selective-set*" paradigm. (Note that there were also studies of "selective set" in the 1960s and earlier and that studies of "filtering" still continue to appear. We summarize what seems to us to be a statistical shift in the dominant approach.)

We define the *filtering paradigm* by three features: (1) the subject is exposed simultaneously to relevant and irrelevant stimuli, (2) the relevant stimuli control a relatively complex process of response selection and execution, and (3) the property that distinguishes the relevant from the irrelevant stimuli is usually a simple physical feature and is different from the property that determines the appropriate response. Thus a filtering task comprises two distinct functions that are controlled by different aspects of the information presented to subjects: *stimulus choice*, the segregation of relevant items from irrelevant ones, must be guided by some identifying property such as the color of a row of letters or the location of an auditory source; *response choice*, for example in reading or shadowing the relevant message, is controlled by other properties of the relevant items, such as their shape or sound. The two classic examples of the filtering paradigm are the selective shadowing task, which Cherry (1953) invented in his pioneering studies of the cocktail-party effect, and the partial-report technique introduced by Sperling (1960) to study short-term visual storage.

In the *selective-set paradigm*, the subject is prepared for particular stimuli and is instructed to indicate by a speeded response the detection or recognition of those stimuli. Thus, the subject chooses which of several *possible* stimuli to expect or search for rather than which of several *actual* stimuli to analyze. The main variants of the set paradigm are studies of search (e.g., Schneider, Dumais, & Shiffrin, Chapter 1, this volume) and studies of the costs and benefits of

TABLE 2.1

Differences between the Filtering and Selective-Set Paradigms

Characteristic	Filtering paradigm	Selective-set paradigm
Designs	Selective listening Partial report	Search Priming
Modality	Auditory or visual	Visual
Vocabulary of stimuli	Large	Small
Response choice	Large	Small
Memory load	High	Low
Measure	Accuracy	Reaction time
Items selected	Subset of presented stimuli	Subset of possible stimuli
Null hypothesis	Perfect early selectivity	Full automaticity
Standard interpretation	Selective attention prevents or reduces perceptual processing of unattended stimuli	Selective attention selects and speeds responses to expected targets

expectations (Posner, 1978). In both variants, attention is set, either by intention or by spreading excitation, to detect one or more potential targets.

Filtering and set differ sharply in the simplicity of the experimental situation and of the subject's task. The response vocabulary is minimal in studies of set, often comprising only "yes" and "no" key presses and sometimes only a "yes" response. Furthermore, a single response is usually obtained on each trial, in contrast to the continuous shadowing or complex reports often used in earlier filtering tasks. The transition from filtering to set was motivated largely by the wish to study selective attention with a minimal involvement of memory and response load. A cascade of technical improvements led investigators from selective shadowing to auditory monitoring (Moray & O'Brien, 1967), and eventually to visual search (usually for letters or digits) as modal designs for the study of selective attention. There is no assurance, of course, that the same mechanisms of selection and the same limits to performance are relevant in visual search for single letters and in selective shadowing of continuous speech.

The model situations investigated by Posner and his associates (Posner, 1978, 1982) are especially austere. Posner has generally studied attention in displays that include a single stimulus, in contrast to the multielement displays used in search and filtering studies. The experimental manipulations control the subject's readiness for the imperative stimulus by providing advance cues of variable validity. This design involves selection only in the sense that the subject is selectively prepared for some events rather than for others. Here again it appears plausible that the processes and mechanisms involved in these simple tasks may be different from those involved in the more complex filtering tasks.

Results and Conclusions of Filtering Experiments

The standard experimental results in the filtering paradigm and in the selective set paradigm suggest different views of the mind. Subjects in a filtering study appear to focus attention efficiently on the relevant stimuli and to perceive little of the unattended stimuli (Cherry, 1953; Moray, 1959; Neisser & Becklen, 1975). The successes of focused attention are matched by dramatic failures in some attempts to divide attention between two tasks, channels, or messages although the extent of the decrement varies in different studies. These observations suggested an early-selection model of attention. In his original statement of filter theory, Broadbent (1958) assumed that stimuli are briefly stored and analyzed in parallel for elementary characteristics at the preattentive level, or S-system, with only a selected subset allowed by the filter into the higher level processing offered by the P-system.

The first version of filter theory was quickly amended when it was shown that people (sometimes) respond to their name on a rejected channel (Moray, 1959) and (occasionally) respond to the meaning of items on that channel (Treisman, 1960). The modified filter-attenuation version assumed that the filter only reduces the information available on a rejected channel and that this reduced information is sometimes sufficient to activate highly primed entries in the mental dictionary (Treisman, 1960). The operation of priming was assumed to be involuntary and unconscious, features later stressed in theories of selective-set (Posner, 1978).

Subsequent demonstrations that divided attention is possible and that interference is reduced or eliminated when concurrent tasks differ sufficiently from one another provided evidence against the idea of a single central bottleneck (Allport, Antonis, & Reynolds, 1972; Kleiman, 1975; Rollins & Hendricks, 1980; Shaffer, 1975; Treisman & Davies, 1973). Thus speech and music, or auditory and visual words, can more easily be processed in parallel than two auditory or two visual messages of the same type. These observations suggest that the brain is organized as a modular system (Allport, 1980; Allport *et al.*, 1972; Navon & Gopher, 1979; Treisman, 1969; see also Wickens, Chapter 3, this volume) and that interference arises chiefly within rather than between the separate, semi-independent subsystems. If this is the case, then the need for early selection should also arise only when concurrent activities engage the same processing mechanisms or resources. Whether there is in addition some central shared resource or limit (Kahneman, 1973) remains an open question. In this chapter, we discuss only tasks that would be expected to share the same subsystems, and do not distinguish general from specific capacity.

Results and Conclusions of Selective-Set Experiments

In marked contrast to the filtering paradigms, results in the selective-set paradigm often reveal a rather impressive ability to process multiple stimuli, even in the same modality and of the same type. In many search tasks, for example, the target appears to "pop out" of the field of distractors regardless of their number (Egeth, Jonides, & Wall, 1972; Schneider & Shiffrin, 1977). This finding suggests that the processing of distractors is performed in parallel over the entire array and is not subject to attention limits. Observations of slow or serial search in some conditions can often be attributed to a combination of local feature interactions among similar stimuli (Bjork & Murray, 1977; Estes, 1972, 1975) and overloading of a decision mechanism (Estes, 1972, 1975; Hoffman, 1978, 1979).

Some results in both priming and search also contrast with the successful resistance to distraction observed in filtering. Involuntary processing of priming stimuli may disrupt the subject's intended response to targets (Neely, 1977; Warren, 1974). Involuntary processing can also be demonstrated in search, after prolonged practice with particular targets. The set to attend to these targets eventually becomes automatized and voluntary control over attention is lost (Schneider & Shiffrin, 1977). It seems fair to conclude that the subjects in set paradigms resemble automatic processors more than do the subjects in standard filtering studies.

The evidence for automatic processing in studies of set has often been interpreted as supporting the late-selection model of attention, first proposed by Deutsch and Deutsch (1963), in which perceptual processing to the semantic level is automatic and entirely independent of attention, and where attention merely controls the choice of stimuli that will be remembered and acted on (Duncan, 1980). However, we see some reasons to doubt inferences from automaticity in studies of set to the locus of selection in filtering.

First, the marked differences between the paradigms make it unlikely that the same type of perceptual processing is required. In many search studies, the target is defined by a simple feature; once this has been detected, the response is immediately determined. Such studies effectively curtail the required perceptual processing to a stage that filter theory considers preattentive. Selection seems to occur late, since all relevant perceptual activity precedes it, and the processing of rejected distractors is accepted as a model of perceptual analysis in general. In the more complex filtering design, however, further processing of relevant stimuli is required before a response can be chosen. It is natural in this context to describe selection as occurring "early" because most of the significant perceptual processing follows attentional selection.

The dependent variables typically differ too: priming and search studies commonly measure the speed of response to primed targets and the delays caused by distractors or by the presentation of unexpected targets; filtering studies measure the accuracy of continuous responses to selected incoming stimuli and the occurrence or nonoccurrence of responses to unattended stimuli. An increase in response latency can readily be attributed to a late stage of decision or of response

selection; a failure to "see" or to "hear" an unattended item more strongly suggests a perceptual loss (although work on subliminal perception, which is discussed in a subsequent section of this chapter, has questioned this assumption).

Finally, the focus of attention is differently directed in the filtering and in the set paradigms. In filtering studies, subjects select a subset of presented stimuli for further processing; in search and priming studies, a subset of possible targets is primed or expected. It is logically quite possible that the concurrent processing of multiple incoming stimuli and the concurrent priming or preactivation of multiple nodes or logogens are subject to quite different limitations.

Automaticity of Semantic Processing: Some Evidence

We have argued in the preceding sections that some standard observations in the selective set paradigm suggest a different view of the mind from that suggested in filter theory, but that neither parallel search nor passive priming provide substantive evidence against the possibility that attention affects perception in the filtering paradigm. We now discuss in greater detail three major findings that have contributed substantially to the growing popularity of generalized late-selection models: semantic processing of unattended material, the category effect, and subliminal perception. None of the three, we believe, provides compelling support for the view that perceptual processing is completely automatic.

Semantic Processing of Unattended Material

The first line of evidence comprises demonstrations of semantic processing of material presented on unattended channels. Many such demonstrations have been reported. Some of the best known are by Corteen and Wood (1972), Corteen and Dunn (1974), Lewis (1970), MacKay (1973), and von Wright *et al.* (1975). The study by Corteen and Dunn (1974), in particular, suggested an important dissociation between the significant effects of unattended shock-associated words on skin conductance and the nearly total lack of effect of these words in controlling instrumental responses. Although some doubts have been raised (Dawson & Schell, 1982; Treisman, Squire, & Green, 1974; Wardlaw & Kroll, 1976), the basic facts are reasonably well established. What is not clear is how far the new results go beyond the early observations of semantic processing of unattended items that led to the formulation of the attenuation version of filter theory (Treisman, 1960, 1964a).

The effect is typically a small one; in 12 papers (4 measuring galvanic skin responses, 4 measuring target detection, and 4 measuring biased interpretation of a concurrent attended homonym) reasonable estimates of the proportion of trials showing semantic processing of unattended words ranged from about 2% to about 38% and averaged 16% (Bookbinder & Osman, 1979; Corteen & Dunn, 1974; Corteen & Wood, 1972; Dawson & Schell, 1982; Johnston & Wilson, 1980; Lackner & Garrett, 1972; MacKay, 1973; Moray & O'Brien, 1967; Newstead & Dennis, 1979; Treisman & Geffen, 1967; Treisman & Riley, 1969; Wardlaw & Kroll, 1976). The evidence suffices to reject the null hypothesis that stimuli on an unattended channel are never processed semantically. It appears quite insufficient to justify the acceptance of the converse null hypothesis, that attention does not affect perception.

The same conclusion applies to other demonstrated failures of selective attention, including the elicitation of Stroop-like effects by stimuli at some distance from the focus of attention (Gatti & Egeth, 1978; Eriksen & Eriksen, 1974; Eriksen & Hoffman, 1973; Eriksen & Schultz, 1979). Here again, one may choose to be impressed either by the fact that irrelevant stimuli are processed, sometimes and to some degree, or by the remarkable ability to focus visual attention without moving the eyes. Indeed, the fact that the effectiveness of irrelevant stimuli often varies with their distance from the relevant stimuli appears to support some form of early selection, although the observed interference has been cited as evidence for automatic processing.

On the other hand, there is evidence that appears inconsistent with complete semantic processing on every trial. Treisman and Riley (1969) compared the detection of a target defined by a physical property (voice quality) and by a semantic category (digit rather than letter). The physically defined targets were always detected, even when they appeared on a rejected channel; but the direction of attention had a very large effect on the detection of semantically defined targets. Johnston and Dark (1982) showed a clear difference between attended and unattended auditory words in the degree to which they primed one meaning of occasional visually presented homonyms. Perhaps the most dramatic contrast is one of the first reported (Cherry, 1953), that between detection of a change of voice in the unattended message (almost inevitable) and detection of a change of language (almost impossible). The effects of attention on semantic processing in these studies cannot easily be attributed to factors of response or memory.

The Category Effect

The second line of evidence for late selection is known as the category effect. This effect was initially observed by Brand (1971) and then extended and analyzed in an impressive series of studies (Egeth *et al.*, 1972; Gleitman & Jonides, 1976, 1978; Jonides & Gleitman, 1972, 1976; Taylor, 1978). The essential result is that it is much easier to find any letter among digits, or any digit among letters than it is to find either a specified digit or a specified letter among items of the same category. In some studies, although not in others (Francolini & Egeth, 1979), the target item "pops out" of an array of distractors of a different category and the display size function is flat. The category effect has often been taken to imply that the category label (digit or letter) is produced automatically and in parallel for all items in the search display. An item of the target category could then be distinguished from its background by a category code, just as a red target can be segregated by its color from a field of blue distractors.

It appears possible to account for the category effect without invoking the radical assumption that all items in a display are automatically encoded to a semantic level. Assume instead that a highly familiar and perceptually unitized item that has been adopted as a target has a high probability of attracting attention in a field of distractors—much as a red item does in a field of other colors—provided that the distractors are not confusable with the target and that they do not compete with it in attracting attention. In this view, "pop out" or very rapid search is the normal state of affairs with targets that are simple, familiar, and adequately distinguishable from the background items. Another condition for rapid search is that the distractors should also be familiar, perhaps because unfamiliar characters attract attention (Richards & Reicher, 1978; Reicher, Snyder, & Richards, 1976). What requires explanation, then, is not why a target digit is found quickly in a field of letters, but why it is so hard to find in a field of digits, assuming that discriminability of these simple shapes is approximately equal within and between categories.

A possible explanation was suggested by Deutsch (1977), who pointed out that the categories of digits and letters are small, and that the associative connections among their members are exceptionally strong. Because of these internal associations, the designation of any digit or letter as a target is likely to prime all members of its category (Taylor, 1978). As a consequence, items other than the target will tend to attract and to hold attention, almost as if they were also targets. We assume that a distractor that has attracted attention will only be rejected by time-consuming further analysis, thus slowing down the search. A target digit is hard to find among other digits because they compete with it for attention. The search for a digit among letters is fast because the letters have not been primed, not because they are all simultaneously coded as letters. As Deutsch (1977) noted, the involuntary spread of priming from the target to other members of its category could explain the well-known "oh–zero" effect. A target that has been designated as "zero" is harder to find among digits than among letters and the same target when designated as "oh" is harder to find among letters than among digits (Jonides & Gleitman, 1972). This observation is easily explained as a consequence of the spread of priming from a designated target to other members of its category.

A crucial prediction of this analysis has been tested and confirmed. When the subject is searching for target digits among digits, an isolated trial on which the background items are letters yields a "pop-out" effect (Gleitman & Jonides, 1978). However, this effect is abolished when the subject is assigned a dual-search set, for example, "Search for *D* or *7*." In that case, an isolated trial in which the target digit appears on a background of letters does not yield unusually fast detection. The elimination of "pop out" is expected because the dual set primes items in both categories.

There is much evidence for the key assumption that the designation of a target primes its associates, and that rejection of primed distractors is slower than rejection of unprimed ones. For example, Bruce (1979) has shown that subjects instructed to look for a picture of one politician are relatively slow to reject pictures of other well-known political figures. A similar analysis can be applied to other studies that have demonstrated facilitatory or disruptive effects of semantic categories in search (Henderson & Chard, 1978; Karlin & Bower, 1976), or "automatic" encoding of irrelevant words in categorization (Shaffer & LaBerge, 1979). The only mechanism that is required to explain these observations is the automatic priming of words that are associated with the target of search. Primed items, we suppose, are recognized faster and are more likely to attract and hold attention than unprimed ones. An alternative view, compatible with Eriksen and Schultz's (1979) analysis of search tasks, is that members of the target category elicit response tendencies that must be suppressed. (Other studies that make similar points are reviewed by Rabbitt, Chapter 7, this volume). Semantic effects in search could perhaps be used to probe the organization of LTM, much as the release from proactive inhibition has been used for the same purpose (Wickens, 1970). We conclude, contrary to many discussions in the literature, that the category effect does not provide compelling proof that category labels are produced automatically and in parallel for all items in an array.

Subliminal Perception

The third source of support for the notion of automatic semantic encoding, the demonstration of semantic encoding of material that is presented subliminally, is only indirectly related to the issue of selective attention, but is nevertheless quite suggestive. The revival of interest in subliminal perception is due in large part to some widely discussed experiments by Allport (1977) and Marcel (1983; Marcel & Patterson, 1978), in which stimuli that the subject does not consciously "see" as distinct objects, let alone recognize, nevertheless prime semantic associates. Priming by subliminal words has been shown to affect the speed of lexical decisions (Balota, 1983, Fowler, Wolford, Slade, & Tassinary, 1981; Marcel, 1983), Stroop performance (Marcel, 1983), and picture naming (McCauley, Parmelee, Sperber, & Carr, 1980). A new "New Look" is arising (Dixon, 1981) 30 years after the first flurry of excitement about subliminal perception in the 1950s.

The history of the first "New Look" suggests that the provocative observations of semantic processing of subliminal stimuli will be subjected to searching, often hostile scrutiny (e.g., Merikle, 1982). We are not here concerned with the validity of the positive results. Our concern is with the significance of these results, if they are valid, with respect to the issues of automaticity and attention. Would they demonstrate complete automaticity of perceptual analysis and support late selection? We are not sure. The reason for doubt is simply that demonstrated subliminal effects indicate a dissociation between perception and consciousness that is not necessarily equivalent to a dissociation between perception and attention. In the wave of studies published since 1975, the relevant stimuli have been rendered subliminal by a pattern mask, often presented dichoptically. To establish that the presentation is subliminal, the experimenter ensures that the subjective experience of a display that includes a word cannot be discriminated from the experience produced by the mask on its own. The mask, however, is focally attended. Any demonstration that an undetected aspect of an attended stimulus can be semantically encoded is theoretically important, but a proof of complete automaticity would require more. Specifically, the priming effects of a masked stimulus should be the same regardless of whether or not that stimulus is attended, and regardless of the number of stimuli simultaneously presented. These predictions have yet to be tested. Until they are confirmed, observations of subliminal effects will bear on the relation of perception and attention to consciousness, but not necessarily on the relation of perception to attention.

The Display-Board Model of the Mind and the Explanation of Filtering

What is the outcome of perceptual processing? And what is selected by selective attention? For filter theory, perceptual processing consists of tests and measurements on messages that originate in events or objects in the environment. Attention selects for detailed processing one of these messages, which is identified by the "channel" on which it is delivered. The view that selective attention is concerned with messages (Broadbent, 1958), inputs (Treisman, 1969), or perceptual objects (Kahneman, 1973) is consistent with naive phenomenology. In terms of everyday language, the perceiver "listens to that voice" or "looks at that spot."

Other analyses of information processing on the other hand, have emphasized identification and labeling, at the expense of any contact with the phenomenology of object perception. As we shall see, the emphasis on identification has important implications for models of attention. Identification requires structures that are tuned for the detection of specific events. In the standard models of identification, properties and familiar objects or events (recurrent clusters of properties) are all represented by connected nodes in LTM. These nodes are assumed to be activated by the presence of an appropriate stimulus or by excitation derived from other nodes, and mental life consists of the succession of patterns of activation in LTM. This view has perhaps been articulated most clearly by Shiffrin and Schneider (1977) and by Johnston and Dark (1982), but it is implicitly accepted in many discussions of cognitive processes. We call it the *display-board model of the mind.* Imagine a board with numerous bulbs that can be individually turned on, perhaps at different brightness levels. The presentation of an object will turn on the lights that designate its various properties, the light that designates its name, and perhaps also the lights that encode associated events, intentions, and responses. In the version of the model that Shiffrin and Schneider (1977) have developed, the activity that is automatically produced by a stimulus is very short-lived unless it is supported by internal sources of excitation, such as intentions or expectations.

The display-board model provides an elegantly simple representation of the hierarchical encoding of stimuli, of the spreading of activation through the associative network, and of the permanently or temporarily lowered activation thresholds of selected nodes. It provides a useful model for the mechanisms of selective set: expectancies and late selection. Expectancies facilitate the activation of particular psychological pathways (Posner, 1978) or alter the activation thresholds of nodes in LTM (LaBerge, 1975; Shiffrin & Schneider, 1977). Other selective effects occur at a later stage of controlled retrieval, comparison and decision, which is concerned with the production of responses appropriate to the subject's intentions and circumstances.

The existence of expectancies and response selection is not controversial. Indeed, the notion of a dictionary with units that have variable thresholds had been used earlier to explain apparent failures of perfect filtering within the general context of a filter theory (Broadbent, 1971; Treisman, 1960, 1964b). However, filter theory also included a selective device that could be controlled by the elementary physical properties detected in an early, parallel, and automatic stage of processing. What devices in the new display-board models perform the function of a filter in a filter theory? There appear to have been two answers to this question, which put the burden respectively on the expectancy mechanism and on the late-selection device.

LaBerge (1976) proposed that attention can be directed to a particular node in the information-processing sequence, with the effect that the activation of that node by appropriate signals is facilitated. It is easily seen that such a mechanism could explain, for example, the speedy detection of the word HOUSE. LaBerge also proposed that attention to the node that represents the feature *red* could allow the subject to select the red letters in a display. Our impression is, however, that in this system attending to the *red* node can facilitate only the perception that there is red in the display, but not the processing of other properties of the red items, for example, the reading of the word HOUSE if it is printed in red. An expectancy device can search, but it cannot filter.

For a further demonstration of the independence of filtering and expectancies, consider the ancient studies of selective listening in which the subject was instructed to shadow a message presented to the right ear and to ignore a message simultaneously presented to the left ear. This task is easy even when the messages consist of randomly selected words so that the listener cannot predict the words that will be included in the relevant message. Effective filtering clearly does not require the support of expectancies.

An alternative approach attributes filtering to a late-selection device (Duncan, 1980; Shiffrin & Schneider, 1977). According to such models, the same device functions in both the following tasks: (1) "Shadow all you hear in your left ear, animal names as well as furniture items." (2) "Shadow all the animal names, regardless of which ear you hear them in." Performance would be mediated in both tasks by late selection, perhaps aided in the second task by priming of the animal names. This analysis suggests that performance with semantic selection should be better than in filtering by ear, but in fact selection by ear is very much easier. It is a major advantage of filter theory that it can explain this fact, by the assumption that the control of selection by a physical attribute is assigned to a preattentive system, whereas selection by semantic category requires attentive processing. The rule that selection by stimulus set is easier than by response set (Broadbent, 1970) is surely one of the most salient and robust observations of the filtering paradigm (Johnston & Heinz, 1978, 1979; Keren, 1976; Treisman & Riley, 1969). There is also a clear difference in the latency and origin of the components of the evoked response that are affected by stimulus set and by response set (Hink, Hillyard, & Benson, 1978; see also Harter and Aine, Chapter 8, this volume). Late-selection models provide no explanation beyond an attempt to dismiss observed differences in selective efficacy as a "purely empirical matter" (Duncan, 1981, p. 92).

There are two related problems for the current theories of attention that take the display board as their dominant model and selective set as their dominant paradigm. First, the great simplification of experimental designs has lent credence to theories that do not adequately explain the basic observations of the more complex filtering paradigm. Second, it appears difficult to represent *all* of perception by the selective activation of semipermanent structures in LTM. Objects can be perceived without being identified, and the various properties of a perceived object are bound together by more than mere temporal synchrony. The display-board model provides no simple way of representing the perceptual unity of objects and events, and we therefore suspect that it is not an adequate model for either perception or attention.

New Experimental Tests of Automaticity

The previous sections outlined and assessed the evidence that led to the hypothesis of complete automaticity of perceptual analysis. In the second part of the present chapter we describe some specific tests of this hypothesis. We begin with a discussion of some conceptual issues that arise in devising such tests.

Criteria of Automaticity

There is general agreement on the criteria by which a mental operation can be recognized as automatic (Hasher & Zacks, 1979; Logan, 1980; Posner, 1978; Regan, 1981; see also Schneider *et al.*, Chapter 1, this volume). An *automatic process* is involuntary; that is, it can be triggered without a supporting intention and, once started, cannot be stopped intentionally. An automatic process does not draw on general resources, is not subject to interference from attended activities, and does not interfere with such activities. In addition, automatic processes do not interfere with one another, and several such processes can operate in parallel without capacity limits. Finally, some authors note that automatic processes are often unconscious. The criteria probably covary in most situations, but they may be separable. Regan (1981) has noted a particularly important distinction between two senses of "automatic": involuntary and effortless. These need not coincide: an effortful activity can be elicited without voluntary control (Paap & Ogden, 1981).

Three levels of automaticity can be distinguished in perception: (1) An act of perceptual processing is *strongly automatic* if it is neither facilitated by focusing attention on a stimulus, nor impaired by diverting attention from it (Shiffrin, 1975; Shiffrin & Grantham, 1974). (2) It is *partially automatic* if it is normally completed even when attention is diverted from the stimulus, but can be speeded or facilitated by attention (LaBerge, 1973, 1975). (3) A perceptual process is *occasionally automatic* if it generally requires attention but can sometimes be completed without it.

Strong and partial automaticity have not been sharply distinguished by proponents of automatic perceptual processing; statements that appear to imply a belief in the stronger claim are often found in close proximity to statements that allow for some beneficial effects of attention (Duncan, 1980; Posner, 1978; Shiffrin, 1976, 1977; Shiffrin & Schneider, 1977). Unfortunately, partial automaticity is quite difficult to prove or reject. It differs only in degree from the occasional automaticity allowed by believers in early selection (Johnston & Heinz, 1978; Treisman, 1960, 1964a; Kahneman, 1973). The claim that *all* presented items automatically activate nodes representing their identity (Posner, 1978; Shiffrin & Schneider, 1977) is difficult to distinguish experimentally from the possibility that only some do so, particularly when the speed of identification is allowed to vary with attention. What remains of the theoretical debate is a significant difference in emphasis. Early-selection theories emphasize contrasts in the depth of processing of attended and unattended stimuli, whereas proponents of partial

automaticity stress the possibility of deep and extensive analysis without conscious attention. It is easier for theorists on each side to embarass one another than to prove one another wrong, and even the embarrassment is fairly mild because the contrasting positions are not held dogmatically (Shiffrin, 1977). The experiments we report in this section certainly conflict with claims of strong automaticity; we believe that the consistent attention effects that we obtain in a variety of paradigms impose restrictions even on milder claims concerning the automaticity of perceptual processing.

Filtering in the Stroop Design

Reading familiar words is often invoked as the prototype of a highly automatized skill, and the Stroop task is often cited to illustrate the automaticity of reading. The subject tries to identify the color of the ink in which a word is printed, but the shape of the word quickly and automatically activates its node or logogen, thus causing interference (Morton, 1969; Posner & Snyder, 1975). Stroop interference demonstrates the automaticity of reading because subjects appear to read uncontrollably even when it is in their best interest not to do so. That reading the color words in the Stroop task is involuntary we can surely grant. However, we question the far-reaching implications that are drawn for the automaticity of semantic processing. In this section, we show that an attended stimulus produces much more Stroop interference than an unattended one. In the next section, we demonstrate that potential sources of Stroop effects are subject to mutual interference.

Imagine a display that is tachistoscopically presented. The display consists of a square and a circle that appear unpredictably on either side of the fixation point. The words RED and GREEN are printed, respectively, in the circle and in the square. The word RED is printed in green ink, and the word GREEN is printed in red ink. Now imagine a display that is similar in all respects to the one just described, except that the words RED and GREEN exchange places, so that the color in which each word is printed corresponds to the meaning of that word. Consider a subject who is assigned the task of naming, as quickly as possible, the color of the ink in the circle. The correct response is *red* in both cases. Will the response be made more easily and quickly to one of these displays than to the other?

The answer people give to this question varies strongly with psychological sophistication. The lay person merely smiles because the result is intuitively obvious. Not so most attention theorists. Indeed, it is not at all obvious how a theory that contains the strong version of automaticity can explain a difference between the two conditions. Note that the subject is assumed to be fixating at the center, so that the quality of the sensory inputs is the same for both cards. If reading is automatic, then the logogens for *red* and *green* must both be activated

TABLE 2.2

Mean Correct Reaction Time and Percentage Errors for Different Conditions of Color-Word Naming in the Stroop Task[a]

Conditions[b]	Mean reaction time (msec)	Errors (%)
Neutral–neutral	906	3
Neutral–compatible	944	4
Neutral–conflicting	956	2
Compatible–neutral	858	1
Conflicting–neutral	1108	15

[a]From Kahneman and Henik (1981).
[b]The first word in each pair controlled the color-naming response.

by the printed words, equally on the two trials. Any facilitation or interference that is produced by such automatic activation should also be the same.

Several versions of this experiment have been run (Kahneman & Henik, 1981). The results clearly favor the common-sense answer. In one of the experiments, the words in the display could be neutral, compatible with the correct response, or conflicting. The results are given in Table 2.2. They show significant interference by a color word (even a compatible one, in this case) that is distant from the area to which attention is directed. However, this effect is quite small in comparison to the effect of an incompatible word that is physically conjoined with the relevant color.

These results lend themselves readily to interpretation as an example of filtering in a discrete task. As in any instance of filtering, several stages of processing are involved. The relevant circle is found at an early stage. Attention is paid to it. The allocation of attention to the circle facilitates the processing of all aspects of that object and their associated responses. In particular, attention facilitates the responses that belong to the set of color names because these responses have also been primed by the color-naming instruction. Thus, there appears to be no specific control over the reading of the attended word, which is in that sense automatic. This automatic process, however, is shown to depend on the allocation of attention by the finding that a conflicting word in the unattended square produces much less interference than the same word in the attended circle. It seems appropriate to ask how automatic an automatic process is, if it depends on attention. These results are obviously incompatible with the claim that the reading of words in the Stroop task is strongly automatic. A similar conclusion has been reached by Francolini and Egeth (1980) on the basis of rather similar experiments.

The interpretation that we suggest assumes that visual attention is especially effective when it selects an input (Treisman, 1969) or an object (Kahneman,

1973). After an object has been selected, an additional selective operation must be invoked to determine which of its properties will be allowed to control responses. In general, the priming of a response category is enough to do most of the work of selection because different properties of an object are rarely linked to different members of the same class of responses. Thus, the tendency to read a neutral word is relatively weak in the Stroop situation because the subject is set to say color words. Color names are much more likely to be read than other words, because they are primed by the task. In general, interference is expected to occur when an irrelevant property of the selected object evokes a strongly primed response. A similar argument can be applied to parts of objects as well as to their properties. Attention to irrelevant parts of relevant objects is obligatory. The visual suffix effect, and perhaps the auditory suffix effect as well, could be interpreted in the same vein: If an irrelevant member of a relevant group of items is not perceptually separated from its relevant neighbors, it is processed as if it were relevant (Kahneman, 1973; Kahneman & Henik, 1977, 1981).

Visual filtering is a robust effect, which we have demonstrated in several experiments. In one of the studies in this series we presented two words on either side of the fixation point. One of the words was always printed entirely in black. The other word was printed in colored ink, and the subject's task was to report that color. Here again, Stroop interference was much more pronounced when the colored ink and an incompatible color name were conjoined than when they were spatially separated (Kahneman & Henik, 1981).

The results of these experiments illustrate the concept of filtering in visual presentation. They present some difficulties both for the claim that reading is strongly automatic and for the interpretation of Stroop interferences as evidence of such automaticity. The major conclusion is that it is essential to distinguish selection of inputs, or objects, from selection of properties. As we have seen, observers are capable of efficient rejection of irrelevant objects, but the irrelevant properties (and perhaps parts) of an attended object cannot be prevented from contacting their nodes and from activating irrelevant responses. The distinction between selection of objects (or inputs) and selection of properties (or analyzers; Treisman, 1969) seems salient and fundamental; yet it is often ignored in psychological research and theory.

The difference between objects and properties was lost to psychology with the adoption of the ambiguous term "stimulus": both an object (for example, a red *O*) and a property (redness or circularity) can be called a stimulus. In the behaviorist tradition, the term was applied to "whatever controls a response." Because discriminative responses are controlled by properties ("Peck the key if the cage is illuminated, not if it is dark"), it is most natural in that tradition to think of stimuli primarily in terms of properties and to ignore the notion of objects altogether. This legacy has influenced the study of information processing. It is illustrated by treatments that interpret Stroop interference as a failure of selective attention and as evidence of the automaticity of processing. In fact, the Stroop effect only demonstrates that people do not easily ignore irrelevant *properties of an attended* object. On the other hand, our results further support the conclusion of other studies of filtering that irrelevant *objects* can be rejected quite effectively.

The Dilution Effect

The series of experiments discussed in the preceding section tested whether automatic reading is affected by the voluntary direction of attention. We now turn to another way of testing the notion of automatic activation, which we label *the dilution effect*. The experiments discussed in this section test whether automatic reading is affected by the mere presence of other stimuli. According to the strong version of automaticity, the activation of a node by a familiar stimulus does not compete with the concurrent processing of other objects in the field. It is therefore of interest to ask whether the reading of color words in the Stroop situation is impaired by the presence of other irrelevant stimuli. The strong claim of automaticity allows no mechanism, other than sensory interference, that could produce such an effect.

This question has been studied in a series of experiments (Kahneman & Chajczyk, 1983). In a typical study the subjects are shown for 200 msec a colored bar centered on the fixation point and are asked to name its color. A single word is presented on some trials above or below the bar. The word is sometimes unrelated to the color-naming task, sometimes congruent with the correct response for that trial, and sometimes it is the name of another color. As has been previously reported (Dyer, 1973; Gatti & Egeth, 1978), the presentation of a color name affects the speed at which the color of the bar is named. Interference and facilitation are both obtained, although the magnitude of the effects is smaller than when the subjects are asked to name the ink in which a color word is printed.

The occurrence of Stroop interference in this situation represents at least a partial failure of selective attention to objects. The relevant color bar is presented at the fixation point and the subject is encouraged to focus attention on that area; the word is irrelevant to the task and its reading is presumably involuntary and is automatic in that sense. To determine whether this reading is also automatic in another sense, we used a minimal variation of display size: In several *dual* conditions, a neutral word was added to the display on the other side of the relevant color bar. Our question was whether the presentation of the added neutral word would affect the amount of interference or facilitation produced by the color word.

The basic outcome of this series of studies is illustrated in Table 2.3. The 12 subjects in this particular experiment had 48 trials in each of the six conditions.

TABLE 2.3

Mean Color-Naming Times for Each of Six Conditions of a Stroop Interference Task[a]

Condition	Mean reaction time (msec)	Color-word effect	Dilution
Single conflicting	682	72	—
Conflicting–neutral	650[b]	36	36
Single neutral	610	—	—
Dual neutral	614[c]	—	—
Single congruent	561	49	
Congruent–neutral	585[d]	29	20

[a] From Kahneman and Chajczyk (1983, Experiment 1).
[b] $t = 3.11, p < .01$.
[c] *ns*.
[d] $t = 3.01, p < .01$.

As can be seen by comparing the conflicting and congruent conditions to the neutral condition, the color words have a substantial effect on the speed with which the color of the bar is named. We use the term *color-word impact* for the difference in color-naming time between conflicting and congruent conditions. The impact of a single word is 121 msec; it is reduced to 65 msec by the concurrent presentation of a neutral word on the opposite side of the bar. This pattern of results defines the dilution effect: the neutral word dilutes both the interference and the facilitation produced by color names.

Another experiment in this series established that the dilution effect is not eliminated when the words are presented quite far from the fovea. Only conflicting color names were used in this experiment, to ensure the subjects' incentive to avoid attending to the color word. Stroop interference was 74 msec for a word shown 2° above or below the bar; the diluted interference at that distance was 27 msec. The corresponding values at 4° eccentricity were 40 and 19 msec. The larger distance was associated with less interference but the proportional dilution did not change significantly. The dilution effect is thus unlikely to arise from peripheral interactions between the words. A central effect is involved.

Some words cause greater dilution than others, but we do not yet have an explanation of this variation, which was discovered accidentally. Most of our experiments used a small set of colors (red, green, blue, and brown) and of neutral words (cute, most, long, and shoe). We accidentally discovered a much smaller effect with another set of words (shy, few, time, angle, and brave). An experiment was then run to establish whether the dilution effect is the rule or the exception when a representative pool of words is used. Sixty high-frequency words were selected from the Kučera–Francis norms (40 four-letter and 20 five-letter words). In this experiment the displays were presented on a color terminal

(Intecolor 8001) controlled by a computer that randomly assigned words to experimental conditions. The dilution effect was replicated: Adding a neutral word slowed color naming in the congruent condition (from 588 to 607 msec) and speeded color naming in the conflicting condition (from 706 to 669 msec). Both results were highly significant.

A dilution effect can be obtained even when the diluting stimuli are not words at all. We found substantial dilution by a row of *X*s, although less than by a neutral word. The demonstration of dilution with unreadable stimuli eliminates conflict or coactivation in the reading system (Miller, 1982) as an interpretation of dilution. The pattern of results looks much like distraction; the diluting stimulus distracts the subject from the color word, and a neutral word is a more effective distractor than is a row of *X*s. This distraction effect is paradoxical, however, because it occurs entirely outside the focus of attention. Clearly, the dilution effect is not compatible with the idea that the reading of peripherally presented words is automatic and free of capacity limits.

Intentional Reading and an Early-Interference Effect

It seems from the Stroop studies that words presented outside the focus of attention do not automatically achieve their full potential to affect behavior. The impact of an irrelevant word, whether for good or for bad, is reduced by the presence of other objects in the field. We now ask what happens when reading is the primary task. Is intentional reading also subject to interference from the mere presence of other stimuli? If so, what variables determine the interference?

In the following series of experiments, we show that intentional reading of a single word is impaired by the presence of any other object in the field whenever there is prior uncertainty about their locations. Interference occurs even when the competing object is so different from the word that selection should be no problem. Thus we further limit the concept of automatic reading: The response to a word is affected by the presence of other visual objects in a manner that makes it unlikely that the printed word automatically activates its perceptual and motor representation in LTM.

Filtering Cost in Reading

In several experiments (Kahneman, Treisman, & Burkell, 1983), our subjects' task was simply to read as quickly as possible a word that appeared unpredictably above or below the fixation point. On half the trials, another object was presented on the opposite side of fixation; the resulting delay in reading time was measured. We label this delay a filtering cost because it appears when attention must be narrowed down onto one of the stimuli presented to permit a specific response.

In one version of the experiment, two words were presented and subjects were told to read whichever word they wished. If reading is entirely automatic, the response to these dual displays could only be faster than the reading of a single word because the more rapidly processed member of the pair should be read. In fact, the presentation of two words caused a slight, but highly consistent slowing of the reading time: from 570 to 595 msec. The distance of the words from the fixation point was not critical. An interference effect of 18 msec was still found when the nearest contours of the interacting words were 3.6° apart across the fovea.

Does the interference arise between competing nodes within the lexicon or display board, or does it depend simply on the presence of another object in the field? In another condition we used a stimulus that in its visual features seemed as different as possible from a word and could not conceivably draw on lexical resources or compete, either phonologically or semantically, with reading the word: a word-sized patch of randomly placed black dots. Again we presented a word above or below fixation, with dots in the other location on half the trials. Again we found a delay of the same extent: 34 msec. A similar result was obtained with a variety of colored shapes as interfering stimuli.

The effect seemed sufficiently surprising to warrant further investigation. We ran a number of variants of the experiment to narrow down the possible interpretations. When the dots were always shown at the fovea with the word above or below them, the delay of reading was much less than in the earlier experiment (only 10 msec), despite the fact that the interfering stimulus was now spatially closer to the word. This result makes peripheral interaction an unlikely explanation. When the word was consistently at the fovea, there was no interference from dots above or below it. When there was spatial uncertainty, however, interference was inversely related to the distance separating the word from the dots but independent of the size of the patch of dots. The importance of spatial uncertainty implicates a central attentional factor, and the interfering effect of unreadable objects eliminates conflict between reading responses as an explanation. Neither peripheral interference nor interference between central nodes in the lexical display board seem apt accounts of the 30-msec delay.

Reading, Attention, and Search

If the interference is indeed attentional, precuing the location of the word should eliminate it. The following experiment tested this prediction. We also changed the nature of the irrelevant stimuli to test the generality of the phenomenon. Finally, we varied the number of distractors to determine whether the delay increases with display size. A color terminal was used to show displays comprising one 3-letter word in white uppercase letters and a variable number of shapes, each in a different color and each subtending about the same visual angle as a word. These stimuli were randomly located in any of six possible positions arranged in a clock face around the fixation point. Two conditions were compared: (1) In the precued condition, the critical display was preceded 100 msec earlier by three white dots in the position that the word would occupy; (2) in the control condition, one dot appeared in each of the six possible stimulus locations, giving the same temporal warning but no information about the location of the word. We found that (1) in the control condition, the colored shapes produced the expected delay in reading the word; (2) moreover, the delay increased with the number of irrelevant objects, averaging 14 msec per extra object; and (3) the delay was completely eliminated when a precue informed the subject where the word would appear. This clearly ties the interference to attention because the precue could have no effect on peripheral sensory interaction between the word and the colored objects. There was no time for eye movements to occur because the critical displays were masked after 150 msec (i.e., 250 msec after onset of the cue).

The findings are surprising because search for a target defined by a simple feature normally shows no effect of display size (Treisman & Gelade, 1980). In all the experiments described so far, the word differed from the irrelevant stimuli in several obvious features. Why then did we obtain an effect of display size on reading time? The paradox may be resolved by noting that the reading task involves filtering. We pointed out earlier that filtering tasks require further analysis of attended stimuli beyond their detection in order to determine the appropriate response. In search tasks, on the other hand, the detection of the target suffices to trigger a response without further analysis.

Another experiment was designed to compare filtering and search tasks in the same displays. The displays were similar to those of the uncued condition in the previous experiment, but four-letter words were used, and there was no masking. In the reading condition, subjects read the word as before. The results replicated previous studies of the filtering cost, with substantial delays of reading, increasing with the number of irrelevant colored shapes. There was also a detection condition, in which the word was replaced by a colored shape on half the trials; the subjects indicated the presence of a word by pressing a key. The number of colored shapes had very little effect on the speed of positive detection responses. The qualitative difference between filtering and search suggests that detection may require much less processing than reading. We can detect a target without attending to it and perhaps even without locating it in the display (Treisman & Gelade, 1980). Reading, on the other hand, appears to require both that the word be found and that attention be directed to its location. These extra operations take longer when additional distractors are present. The difference between reading and detection is clearly established when the vocabulary of stimuli and responses is large. Whether the same rules apply to constrained vocabularies (digits or letters) is a matter for further research.

Attention and Object Integrality

We have argued that attention selects *objects* in their spatial locations, not properties or internal nodes. Thus response conflict in the Stroop task is greater when the irrelevant stimulus evoking the competing response is perceived as part of the attended object (Kahneman & Henik, 1981). Filtering costs, on the other hand, should be reduced when the relevant and irrelevant stimuli are perceived as belonging to the same object, if we are correct in attributing the cost to competition for attention and not to competition for response. The next experiments (Treisman, Kahneman, & Burkell, 1983) used an interfering object in the shape of a colored frame. The frame could appear either around the word that was to be read or on the opposite side of fixation. Peripheral sensory interactions could only be greater when the frame was close to the word, but the reading delay was 42 msec when the frame was separated from the word and 21 msec when it surrounded the word. The result confirms the conclusion that the delay arises from competition between objects for the control of attention.

We have seen that a separated frame delayed reading more than did a frame that surrounded the word. Did the separate frame attract processing resources from the word? On such a hypothesis one would also expect the frame to be better perceived in the separate than in the combined display. In contrast, our analysis suggests that competition between the word and the frame should be less severe in the combined display. Competition is between objects; there is less of it between different parts of an object and perhaps none between its different features (Kahneman, 1973; Treisman, 1969). Consequently, the frame should be perceived more easily when it surrounds the attended word than when it is separate.

A dual-task experiment was designed to test the alternative hypotheses. The subjects were required on each trial to read the word as quickly as they could; this was the primary task. The frame was positioned either just above or just below fixation, so that one of its horizontal edges passed through the fixation point. A small gap was made in the fixated edge, to the left or to the right of fixation. The subjects' secondary task was to report the position of that gap. The exposure was followed by a field that included a thin masking stripe of random black and white squares that covered the central edge and made the gap less detectable without masking the word. The duration of exposure of the word and frame was varied continuously by a staircase method to maintain the error rate in gap location at 25%.

As before, the reading delay was greater by 17 msec when frame and word were separate than when they were together. The interesting finding was that subjects also made significantly more errors in locating the gap when the frame was separate (27%) than when it was around the attended word (16%). Thus, the frame and the word were both better perceived when they were combined in one perceptual object than when they formed two separate objects. Hoffman, Nelson, and Houck (1983) report a related finding, that it is easier to divide attention between two stimuli when they are spatially close together than when they are distant. In the present experiment, the distance between the gap and the word was constant, and we varied the belongingness or integrality of the two stimuli. Any account of filtering costs must incorporate the notion of unitary versus separate objects.

Selective Attention under Masking

In a final series of experiments, we looked at the accuracy of reading the relevant word when it was followed by a mask as a function of whether the word was presented alone or with another stimulus. If the filtering costs in the experiments so far described reflect an early perceptual interference, we should expect the presence of an irrelevant stimulus also to reduce accuracy under masking. If, on the other hand, the interference was due to some form of competition to initiate and to control responses, interference could vanish in a situation in which accuracy was stressed rather than speed.

Stimuli for this experiment were presented on a graphics display, permitting accurate control of exposure duration, and were immediately followed by a pattern mask. The subject was instructed to read an uppercase word from a display that could contain a single word, two different words, or an uppercase word and a distractor, which could be a scrambled word, a row of X's or a word in lower case. The items could appear in two positions, above and below fixation. The duration of exposure was varied for each subject, so as to maintain average accuracy (over all conditions) at 50%. The percentage of correct responses in the different conditions is shown in Table 2.4. The decrement of 10% caused by the row of *X*s was highly significant; performance in the two other distractor conditions was almost halved. In particular, selection between a word and a nonword, both in uppercase, was nearly impossible under conditions of pattern masking. To a first approximation, it appears that subjects were only able to process a single item, and that they could attempt to choose the appropriate location only when the distractor was marked by salient physical characteristics (the repeated shapes of the row of *X*s).

The results are difficult to reconcile with the ideas that lexical access is automatic and that limits to concurrent perceptual processing only concern the number of active nodes that can be checked or retrieved within the lexical memory (Shiffrin & Schneider, 1977). In particular, scrambled letters do not access a lexical node because they do not form a word. Selection should therefore be easy because only the node corresponding to the relevant word is active. Although these conditions appear optimal for late selection to operate, selective reading was apparently almost impossible. We know of few other results that provide such strong indications of the limitations of late selection.

TABLE 2.4

Percentage of Correct Responses for Each Condition in Reading One Word Followed by a Mask

No distractor	
Single word	63
Two words	62
Distractor present	
Lowercase word	38
Scrambled uppercase word	35
Row of Xs	53

Two additional experiments were run to test the possibility of semantic selection (Allport, 1977; Marcel, 1983). Subjects were asked to indicate whether or not a display contained an animal name. Reaction time was used as the measure in one of the experiments, and accuracy (with a pattern mask) in the other. The mean positive reaction time and percentage correct (adjusted for chance success) in the various conditions of the two experiments were as follows: When no distractor was shown, accuracy was 64% and reaction time 826 msec for a single word; when a distractor was shown, these values were 34% and 1098 msec for a word and 49% and 929 msec for a row of *X*s.

The conclusions of the previous experiment are confirmed. If two words can automatically register their identity or their meaning, it is hard to explain the marked interference that is observed in these studies.

Discussion and Conclusions

We have reported the following main results: (1) The impact of color words in the Stroop situation varies with the spatial allocation of attention; a color word in a rejected location has little effect on color naming. (2) The impact of a color word on color naming is reduced by the presence of words or other shapes in the field. Thus, an effect that resembles attentional competition can be observed outside the intended focus of attention. (3) The intentional reading of a word is also retarded (30 msec, approximately) by the presence of other objects in the field. This interference occurs even when the target word and the interfering objects are highly discriminable. It is an attentional effect that is completely eliminated by precuing the relevant location and is reduced when the potentially interfering stimluus and the word can be attended as a unit. (4) The ability to report a word that is followed by a pattern mask is severely impaired by the concurrent presentation of a random string of letters in another position; the results indicate that subjects attend to an object in a particular spatial position, not to a lexical entry activated by the word.

All these results are surprising within a framework that describes information processing in terms of automatic access to nodes in LTM. We repeatedly found that the impact of an item was affected by the intentional direction of attention or even by the mere presence of other objects in the field. Processing that might be expected to be automatic was thus shown to depend on attention. Another recurrent theme in these studies, which does not fit with a display-board model, is the obvious importance of spatial factors. Attention is assigned to objects, or to the locations that objects occupy, rather than to nodes in LTM.

We now sketch an alternative to the display-board metaphor, which is designed to cope with the evidence for filtering and for the role of objects in the control of attention. As will become clear, the proposed metaphor suggests a possible resolution for the old debate between proponents of early and of late selection.

Perceptual processing is equated in the display-board analogy with the temporary activation of nodes in long-term conceptual memory. Instead, we suggest that perception is mediated by the creation of new, temporary representations of objects and events, a perceptual analogue of *episodic* memory (Kahneman & Henik, 1981; Treisman & Schmidt, 1982). The analogy we propose is the information room of a police station. Messages constantly arrive, reporting incidents in the world outside. Some of these messages indicate the beginning of a new incident. Others provide updated information about an incident previously reported, such as the current location of a fleeing burglar, or his name if he has been identified. The information is used accordingly, to open a new file or to update an existing one. We think of the perceptual system as opening an object file when an object or event is first sensed. The initial entry and the identifying label for the file simply state the location and time. As information about the features of the object is received, it is entered in appropriate slots in the file. Color, size, shape, brightness, and direction of movement are specified early, but can be updated if and when they change. At some stage, the object may be identified by matching it to specifications in long-term perceptual memory. This allows retrieval and storage in the file of a name or category and of previously learned facts relating to the object and may also guide the accumulation of further sensory information.

We propose the notion of an object file as the representation that maintains the identity and continuity of an object perceived in a particular episode. The identity of the object is carried by the fact that information is entered on a particular file, rather than by a name or a particular enduring set of features. The object-file analogy resembles the notions of message center or blackboard proposed by other authors (Lindsay & Norman, 1972; Reddy, Erman, Fennell, & Neely, 1973; Rumelhart, 1976) as a device to combine information from different sources (context, sensory data, rules of syntax, etc.) in the perception of spoken or written words. In addition, however, it explicitly accounts for the segregation of the information pertaining to different objects. Marr (1976) and Fox (1977) introduced the related idea of "place tokens" or "object tokens" as a means of referencing particular local aggregates of features that were likely to be the precursors of perceived objects. Such a notion appears necessary to accommodate the phenomenological experience of a world comprised of coherent objects and events. It also has several advantages in dealing with the phenomena of attention:

1. The distinction between episodic tokens and semantic types may help to explain filtering. Within the present framework, it is natural to think of the object file as defined by salient physical properties of the object, including in particular the time and location of its initial appearance. The semantic knowledge associated with the object may become available in the file much later, and may not be the feature by which the content of the file is most easily accessed. The intention to select for special processing any object that possesses certain physical properties could become effective more quickly, and could be easier to follow, than an instruction to select objects that belong to a particular semantic category. This difference could account for the major line of evidence that favors early selection over late selection in attention: that selection by stimulus set is generally much easier and more effective than selection by response set.

2. The analogy helps explain why it is difficult to direct attention to a specific feature of an object. Our assumption is that attention affects the object file as a unit, whether by controlling the entry of information into it or by controlling the outflow of information from it. As a result, Stroop interference is especially severe when the color and the word belong to the same object because it appears impossible to attend to the color without simultaneously facilitating the response to the word. It also appears relatively easy to divide attention between different properties or parts of the same object, as illustrated by our combination of a reading task with the detection of a gap in a frame surrounding the word.

3. The analogy is compatible with research suggesting a crucial role for attention in the perception of objects (Treisman & Gelade, 1980). Whenever a task requires an object to be identified by a *conjunction* of properties, attention must be focused on each object in turn: search is serial, and each object is correctly identified only if it has been accurately localized. When attention is diverted or overloaded, illusory conjunctions may be formed that recombine the features of different physical objects (for example, an illusory yellow shirt generated from a yellow chair and a red shirt; Treisman & Schmidt, 1982). These mistakes could reflect confusions in keeping track of which features should be entered in each of several concurrently active object files.

4. The notion of object files suggests a possible compromise between early and late selection. The classic question of attention theory has always been whether attention controls the buildup of perceptual information, or merely selects among the responses associated with currently active percepts. In the terms of our analogy, the question is whether focusing attention on an object file facilitates the accumulation of information *in* it, the dissemination of information *from* it, or perhaps both. A possible alternative to the early-selection hypothesis is that attention (1) has no effect on the buildup of information in the object file, (2) affects only the output of object files, and (3) can be directed to an object file only by physical characteristics. Such a mechanism would be an early-selection device in the sense that its selective functions are controlled by elementary features. However, the effect of attention, as in late-selection theories, would be to control access to the executive devices that produce responses. A rather similar idea has been advanced by Eriksen and Schultz (1979) and by Posner, Davidson, and Snyder (1980) who suggested that one of the effects of attending to a location is to enhance the readiness to respond to any event in that location.

5. The suggestion that attention controls the dissemination of information from object files could be elaborated in several different ways. The simplest possibility is that the information is made

available (or conscious) on an all-or-none basis. A more complex arrangement would assign different levels of urgency or priority to the information sent from a particular object file; an attended object could be assigned high priority in this fashion. The most intriguing possibility is that the information in the object file (or different parts of that information) could be made selectively available to some agencies of the mind but not to others. The well-known study by Corteen and Dunn (1974), for example, suggested that shock-related words presented on the unattended ear in a dichotic shadowing situation can cause electrodermal responses although they have no access to the control of instrumental responses. The revival of interest in subliminal perception is also focused on a notion of dissociation (Allport, 1979; Dixon, 1981; but see also Merikle, 1982).

Dissociation phenomena are troubling because they raise doubts about the validity of our sense of personal identity. If my skin responds to the emotional significance of words that I have not seen, do *I* know the meaning of these words? There seems to be no good answer to this question. The solution to the dilemma may be to revise our criteria for the use of epistemic words such as *know, see,* or *understand.* In particular, the suggestion has been made by authors in the traditions of artificial intelligence (Hinton & Anderson, 1981; Minsky, 1980), philosophy (Dennett, 1978), and experimental psychology (Allport, 1980) that we should treat the mind as a collectivity of semi-independent entities, rather than as a single entity.

Perhaps we should take as our model of the mind a large organization, such as General Motors or the Central Intelligence Agency. Under what conditions can such an organization be said to know something? Certainly, the organization "knows" a fact if all its significant members act coherently on it. But there are many borderline cases. Does the CIA know a fact if one functionary in that organization knows it but has told nobody else or is believed by no one? Does an organization know a fact if the lower echelons act on it but without informing higher echelons that they do so? The evidence of dissociation phenomena suggests that it may at times be as difficult to assign epistemic states to individuals as it is to assign such states to organizations.

It now appears at least conceivable that future discussions of attention will be conducted within the framework of an organizational metaphor for the mind. The notion of modularity was introduced earlier in attention research (and in this chapter) to account for the surprising efficiency of performance in combining concurrent tasks that engage very different processors or resources. It may be equally helpful or necessary in accounting for dissociations in the availability of information. It is disconcerting, but perhaps also encouraging, that many of the questions with which we have been concerned for years—including the question of automaticity that is the focus of this chapter—will turn out, in such a framework, to be slightly out of focus. Some "attentional" limits may turn out to be failures in the dissemination of information rather than in its processing. Certain systems (e.g., autonomic control centers) may have access to detailed representations of states of affairs of which other systems (e.g., those controlling voluntary instrumental responses and/or conscious awareness) remain ignorant.

The participants in the debate about the automaticity of semantic processing and early selection have shared many presuppositions. In particular, they have shared the notion of a standard path of information processing and the idea that attention operates at one or more bottlenecks (or roadblocks) along that path to select the messages that should be processed further, or perhaps to attach to each message a single value of relevance. While we continue the debate within the old framework, we should remain alert to the possibility that it could soon become obsolete.

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