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3
ATTENTION AND COGNITIVE CONTROL[1]

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INTRODUCTION

To what extent are our conscious intentions and strategies in control of the way information is processed in our minds? This seems to be a question of importance to us both as psychologists and as human beings. Yet as Shallice (1972) has pointed out, most theorists in psychology have avoided consideration of the relationship between conscious and unconscious mental events. While psychological writers rarely deal with this distinction directly, the reader of psychological publications can hardly avoid it. On the one hand, the pages of journals are full of studies in which the "strategies" or "optional processes" of the subject are used to explain the results obtained; on the other hand, we are told that human memory is an associational machine that operates entirely without control of the subjects' strategies (Anderson & Bower, 1973). Both of these views need to be accommodated. Even the most cognitive of theorists recognizes that people are not always able to adapt their thought processes to the strategies required by the task, and Anderson and Bower (1973) explicitly recognize that their strategy-free memory system must be coupled to other strategy-dependent systems.

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In this paper we review studies designed to provide some experimental analysis of how conscious strategies interact with automatic activation processes to determine performance.

As a first step toward an understanding of conscious control of cognition (Section II) we examine in detail the characteristics of purely "automatic" processes. We are all introspectively familiar with thoughts, ideas, or feelings that seem to intrude upon us rather than occur as a result of our intentions to produce them. We propose three operational indicants of whether a process is "automatic," as we will use the term: the process occurs without intention, without giving rise to any conscious awareness, and without producing interference with other ongoing mental activity. Even with these stringent requirements it is possible to show that many complex but habitual mental processes can operate automatically and thus, in principle, be strategy independent.

Many theorists have proposed a fixed processing stage at which limited-capacity attentional effects are to be found. Sometimes the stage is early in processing and sometimes late, but the idea is that some types of operations are not capacity limited while others are. Our view is different; we see a specific mechanism of limited capacity. This mechanism can be committed flexibly to different stages, depending upon many factors. Thus, it is necessary for us to develop operational methods for distinguishing whether a given process is being performed in an "automatic" or "conscious" mode (Section III).

Many cognitive tasks may be viewed as combining automatic activation and conscious strategies. By reviewing a number of experimental results we try to see how well our distinction aids in furthering the investigation and understanding of these tasks (Section IV). In particular, we try to illustrate how a number of disparate paradigms demonstrate similar principles.

Perhaps the problems of cognitive control have been discussed in an effort to understand the nature of emotion. Signals with emotional significance seem more intrusive than other signals. Some have used this to argue that emotions have a special status in memory and thereby serve to guide our conscious cognitions. We introduce some experiments aimed at understanding the way emotional information is activated in the memory system and how that activation affects our conscious cognitions (Section V).

AUTOMATIC PATHWAY ACTIVATION

Intention

Stroop effect. There is excellent evidence that subjects cannot choose

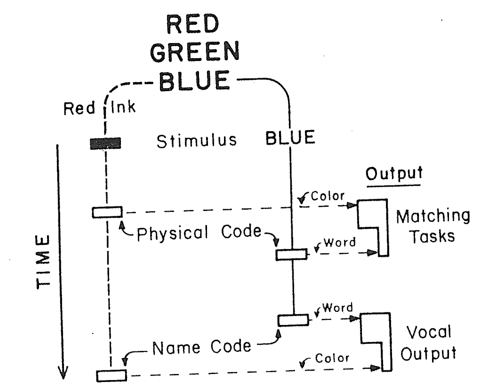


FIG. 1. A schematic explanation of the Stroop effect. Two internal look-up processes produce representations of the ink color name (dashed line) and the word name (solid line) respectively. If the task is one of physical matching, ink colors arrive at output first and interfere with word matching. If the task is one of naming, words arrive at output first and interfere with ink colors. These interference effects result from the time course of the look-up process.

The Stroop effect is based upon this difficulty (Dyer, 1973). When given the task of naming the ink color of the words in Fig. 1, one intends to avoid reading the words, but it is not possible to do so completely.

There is now a great deal of evidence that supports the kind of explanation for this effect which is outlined in Fig. 1 (Dyer, 1973; Hintzman, Carre, Eskridge, Owens, Shaff, & Sparks, 1972; Keele, 1973; Morton & Chambers, 1973; Murray, Mastronadi, & Duncan, 1972). First, the usual Stroop effect arises because of competition between vocal responses to the printed word and the ink color. Keele (1973) demonstrated the importance of output interference by showing that noncolor words, which produce a small interference over a nonword control with a vocal output, produce no such interference when a key press output is used. Second, the direction of interference depends upon the time relations involved. Words are read faster than colors can be named; thus, a color-naming response receives stronger interference from the word than the reverse. Colors can be matched physically faster than can words, so that a matching response results in greater interference from colors on words than the reverse (Murray *et al.*, 1972). Third, words often facilitate the vocal output to colors with which they share a common name (Hintzman *et al.*, 1972).

These three results suggest that color naming and reading go on in parallel and without interference until close to the output. If they result in look-up of the same name, the overall reaction time is speeded; if they produce different names and a vocal output is required, the word tends to compete with the color name and reaction time is increased. One puzzle that remains is this: why does a vocal response to color names interfere so much more than words that are not color names? After all, both have

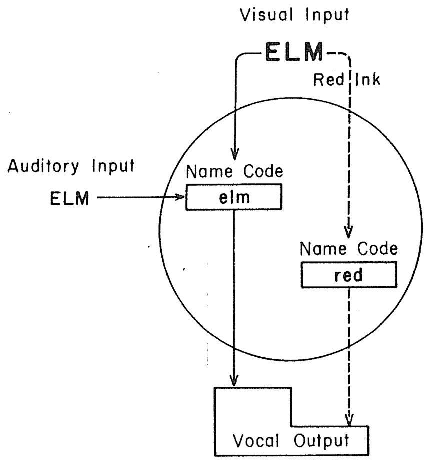


FIG. 2. Amount of interference (milliseconds) with color naming as a function of associative strength: condition: high forward, 95; medium forward, 50; low forward, 20; high backward, 0. An auditory word activates its name code. When the following visual word shares the same pathway it will arrive at output first and produce greater interference with color naming. The lower panel shows supportive data for this theory from Warren (1974).

well-learned names stored in the memory system. The answer lies in the close semantic associations existing between color names and in the fact that prior activation of an item affects the time for look-up of its name, a phenomenon to which we now turn.

Memory activation. One can use the Stroop effect to investigate the automatic activation pattern of a word in the memory system (Warren, 1972, 1974). Warren presented an auditory item or items, followed after a brief interval by a single visual word printed in colored ink. The only task set for the subject was to name the color of ink as quickly as possible. Warren's results showed clearly that the time for naming the ink color increased with the associative strength between the auditory word and the visual word. As shown in Fig. 2, only associative strength in the forward direction is important; there is no effect of backward associative strength from the visual word to the prior auditory word.

The Warren effect can be explained by a logic quite similar to the one shown in Fig. 1. An auditory word activates a pathway in the nervous system which consists of its auditory representation, its name, and a motor program for its production. When the visual word shares some of the same pathway (e.g., name and motor program) its processing rate is increased. Thus, the word name is delivered more quickly and/or more strongly to the output mechanisms, and thus produces more interference with saying the ink color name. There is no incentive in the task for the subject to activate items related to the auditory word. They are not asked to form associations nor need they be required to recall the auditory items to show the effect. Even when, as sometimes happens, subjects become aware that

they are having difficulty in processing related items, they do not seem to be able to shut off the activation process.

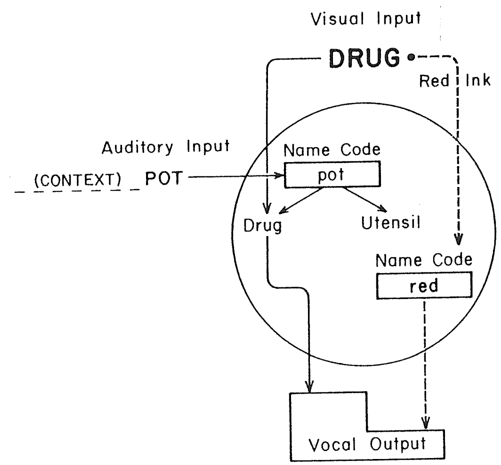
The Warren results show why interference in the Stroop effect is greatest for color names, intermediate for associated words, and least for unrelated words. This is due to a general tendency of a word to activate related items. This effect occurs without any apparent intention by the subject. The effect of automatic activation on reaction time drops sharply with delay (Warren, 1972), but the well-known tendency for related words to be reported as "old" on recognition memory tests (Underwood, 1965) suggests that at least on some occasions the effects remain present for a considerable time.

Awareness

Stroop studies. Recently Conrad (1974) showed that the subject may be quite unaware of the activation pattern created by input words. She presented to her subjects sentences that ended with an ambiguous word (e.g., pot). The word was either disambiguated by context or not. Following the oral presentation of the sentence, she showed her subjects a single visual word in colored ink. The subjects' task was to name the color of the ink. In agreement with the Warren effect, she showed that the time to name the color of ink was longer when the word was related to the sentence. This was true both for the ambiguous word itself and for words related to either one of the word's meanings. The size of the interference effect was approximately equal whether the sentence had been disambiguated by context or not. These results are illustrated in Fig. 3. Since the sentences disambiguated by context are consciously perceived in only one way, the finding that both meanings of the ambiguous word are activated is evidence that the activation pattern is not dependent on the subject's conscious percept.

The results of the Conrad experiment seem to us to be striking support for the kind of automatic activation of lexical memory proposed by Anderson and Bower (1973). They postulate that individual items of a proposition look-up related facts in parallel. Context has its effect as the activation patterns of the different lexical items are combined. The importance of context and the fact that we are rarely aware of ambiguity suggest that the equality of activation found by Conrad will change rapidly as one meaning or another comes to dominate. Her findings show that it is possible to develop psychological experiments that reveal memory processes relatively free of context and strategy effects.

Dichotic listening. The Stroop demonstrations all involve the automatic activation of a word meaning when subjects are attending to the



Amount of interference (msec) with color naming as a function of context

Context	Word itself	Appropriate category	Inappropriate category
Ambiguous	73	77	77
Unambiguous	58	61	50

FIG. 3. (Top) The ambiguous word "pot" activates its lexical pathway irrespective of its linguistic context. A following visual word related to either pathway produces greater interference with color naming than a neutral word. Lower panel shows supportive data from Conrad (1974).

channel on which it arrives. One might well argue that form and color are integral dimensions (Garner & Felfoldy, 1970), and thus the inability of the subject to ignore the word while attending to color is a very special phenomenon. Suppose instead that the subject attends to another set of items entirely. Will automatic activation still occur?

Much evidence on this comes from studies of dichotic listening. For example, Lewis (1970) has shown that when subjects are shadowing items to one ear, an item occurring on the unattended channel which has the same semantic meaning as an attended item will slow his rate of shadowing. Mackay (1973) and Lackner and Garrett (1973) have shown than an unattended lexical item may serve to disambiguate the meaning of an attended sentence. In these experiments there is a semantic relationship between the attended and unattended items; thus, the effect could depend upon having an already activated locus in memory related to the unattended item.

Recent work (Corteen & Wood, 1972; von Wright, Anderson, & Stenman, 1975) has eliminated this problem. They first condition subjects to produce a galvanic skin response (GSR) to particular words. They then show that the GSR occurs when these words are presented on an unattended channel during dichotic listening. In the von Wright data, the size of the GSR to semantic associates of the conditioned stimulus was as large when they occurred on the unattended channel as on the attended channel. These results could only occur if semantic classification of the unattended word had taken place. Thus, the dichotic listening studies suggest that very complicated processing, including even stereotyped responses such as the GSR, occur when the subject's attention is focused elsewhere.

In these studies the subjects have relatively little incentive to shift attention to the nonshadowed ear. Attempts to test awareness of unattended information have involved assessing breakdowns in shadowing, obtaining reports of unusual or obscene items, and measuring recognition memory for unattended items. Overall, it seems fair to conclude that a large amount of automatic processing still occurs when the subject's attention is focused on different items.

Parallel Processing

The Stroop method of studying automatic activation requires subjects to attend to a particular position in space, although to the ink color rather than to the word. The dichotic method has subjects attending to a particular modality, though not the channel within that modality to which the unattended item is presented. Is there evidence that unattended items activate semantically related information even when they occur to an unattended modality? The results of several experiments (Greenwald, 1970a, b; Lewis, 1970) indicate that subjects are not successful in filtering out information occurring on a modality that they are instructed to ignore when it has a close semantic relationship to the attended information. Thus, it appears that the intention to ignore a modality will not prevent it from affecting attended processing.

Recent studies have provided another technique for examining the buildup of information on an unattended modality. We know from many reaction time studies that subjects are slow to respond to information occurring on a channel that is not the expected one. This might suggest that the buildup of information about the unexpected stimulus is being delayed because the subject is actively attending elsewhere. A more careful analysis raises doubts about this view, however. Consider the results of the following experiment (Posner & Summers, unpublished). In this experiment, subjects are required to classify a single item as to whether or not it is an animal name. On half the trials the stimulus is an animal name, while on the other half it is not. In pure blocks the stimulus is always auditory or always visual, while in mixed blocks it may be either. In addition, some-

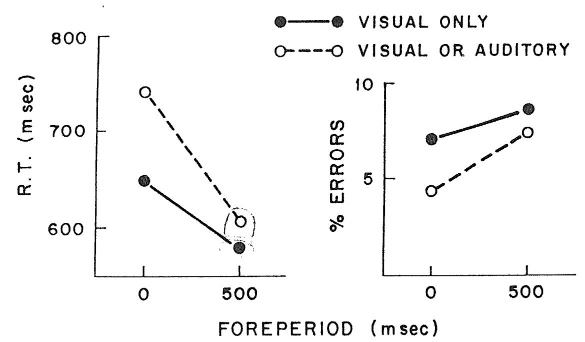


FIG. 4. Reaction time (left) and errors (right) in classifying a visual word as an animal name as a function of amount of warning (foreperiod) and whether or not the words are all visual or mixed visual and auditory. (After unpublished experiments by Posner and Summers.)

times the subject has a warning signal in advance of the stimulus, and at other times he has no warning signal.

When the word is visually presented to the subject, his reaction time is generally fast, provided that he either (1) has a warning signal, or (2) knows the channel of entry. But if neither of these obtain, his reaction time is quite long (see Fig. 4). One might imagine that the subject has his eyes closed or defocussed. However, one feature of the data argues against this interpretation. Although the reaction times under these low attention conditions are long, the accuracy is high. It is as though the buildup of information goes on regardless of whether the subject is attending or not. If he is not attending, the response time is slow, but accurate. We think this is because the quality of information builds up at the same rate with or without attention.

Suppose instead of merely making the subject uncertain about the modality on which the information will arrive, his attention is carefully directed to the wrong modality. LaBerge (1973) reported such a study. The task involved a classification response on the auditory modality (1000- versus 990-Hz tone) or on the visual modality (yellow versus orange light). In pure blocks the subject knew the modality that would be used. In mixed blocks he received the expected modality on .85 of the trials and the signal on the unexpected modality on .15 of the trials. A 1000-Hz tone or an orange light was used as a cue stimulus to rivet the subject's attention on the expected modality prior to the signal stimulus. The results for reaction time show that the method was extremely successful (see Fig. 5). In the pure blocks and when the expected modality was presented in the mixed blocks, the subjects were fast and reaction times were nearly equal. This shows that subjects were attending to the expected modality.

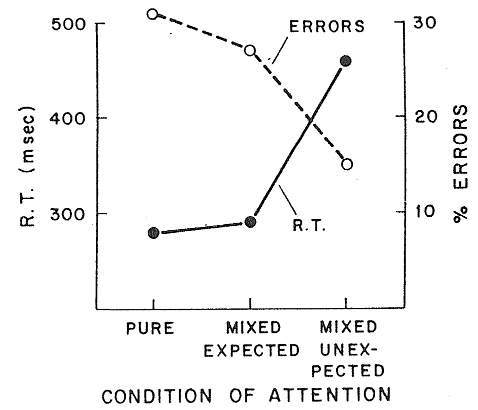


FIG. 5. Reaction time (left ordinate) and errors (right ordinate) as a function of whether signals are all in one modality (pure) or whether they are mixed and subjects are induced to focus on one modality (expected). (After LaBerge, 1973.)

When a stimulus on the unexpected modality occurred, subjects were very slow but showed the most accuracy. In this experiment, which requires fine discriminations, error rates are always high, but they are lowest in just those conditions where the subject's attention is directed to the wrong channel of entry.

One explanation of these cross modality results is that information from the unattended channel is building up in the normal way even though the subject is not attending to it. When he switches attention he is able to execute a response that is more accurate because the information quality is higher. Other interpretations are possible. Since the input remains present until the subject responds, he may take more samples once he has shifted attention. There are studies in the literature where errors occur *more* frequently to unexpected items than to expected ones. Indeed, the increase in accuracy so prominent in Fig. 5 is not found in another condition of the same study in which subjects are involved in a detection rather than a discrimination task. In studies where errors increase when an unexpected event occurs, there are usually many rapid false responses which are made as though an anticipation of the expected event.

Clearly the cross modality data by themselves are not totally convincing. However, coupled with the results of the Stroop and dichotic listening studies, there begins to build a picture of stimulus information automatically activating those internal representations that have been habitually associated with it. Note that this view, which is similar to those presented by LaBerge (1975) and Keele (1973), has the nice feature of making the automaticity of a perceptual pathway closely related to the degree of learning or experience that the subject has had to particular associations. This is the same position that has long been used in the area of motor skills (Fitts & Posner, 1967).

A VIEW OF CONSCIOUS ATTENTION

Many psychologists have identified conscious attention with the limited-capacity processing system discussed by Broadbent (1958, 1971). The idea of the unity of conscious experience compared to the diversity of input stimulation makes such an identification appealing, and we also have followed that basic idea. However, the processing system as Broadbent defined it also had a definite location in the information-processing sequence. Specifically, it stood between stimulation and access to the associative structure of long-term memory. This feature has proven unacceptable because experiments of the type outlined in Section II made it clear that access to long-term memory information is virtually unlimited. This led to efforts to identify the limited-capacity mechanism with other particular mental operations, for example, the view (Keele, 1973) that memory look-up was not limited but that response execution was. These efforts are not entirely successful. Some habitual outputs, such as are involved in the GSR (Corteen & Wood, 1972) or eye movements, may occur without involvement of the limited-capacity system, whereas memory look-up with weak retrieval cues may involve a great deal of conscious capacity.

Limited-Capacity Mechanism

Instead we identify conscious processing with a brain mechanism of limited capacity which may be directed toward different types of activity. For example, it may be directed toward a particular structure in the memory system, a particular input channel or response. If it should be so directed, it will be less available for processing other items. This lack of availability does not prevent automatic activation of the type we discussed in Section II.

Economy. One major objection to this rather intuitive view of active attention seems to be that it would lack economy. This objection has been raised in response to the idea that emotional words are suppressed from consciousness, but it applies as well to our more general view. In Broadbent's (1973) words,

> It seems to require a biologically unlikely kind of machinery. It seems to mean that the part of the brain which analyzes inputs from the environment, and which is presumably quite complicated, is preceded by another and duplicate part of the brain which carries the same function, deciding what is there in order to reject or accept items for admission to the machinery which decides what is there [p. 67].

If, however, the conscious mechanism is primarily designed not to decide what is there, but to produce integrated actions to often antagonistic

habitual responses, its function is not really duplicative. Moreover, the limited-capacity mechanism may serve an important inhibitory function. By giving priority to a particular pathway, it prevents other pathways from having access to any but their habitual response systems (Shallice, 1972). It does not seem worthwhile to debate the general issue, except to suggest that Broadbent's point need not be fatal to the view that we are putting forward.

Pathway inhibition. Another major objection to our view of automatic pathway activation is that it provides for facilitatory but no inhibitory effects within the memory system. This aspect of the theory is very likely in error (Milner, 1957). It is well known that repeated auditory presentation of a word may lead to an alteration of its perceptual quality (Warren, 1970). It is difficult to know the basis of this effect, but it has suggested to some that repetition inhibits input pathways. Eimas and Corbit (1973) have shown that repeated presentation of a phoneme leads to a shift in the phonemic boundary. It is not yet clear that this shift is due to inhibition (fatigue) of the pathway, as they argue. In any case, a successful demonstration of inhibition of a pathway resulting from repeated stimulation would not require great modification of our views, since such inhibition would be pathway specific and differ markedly from the widespread inhibition of all signals resulting from commitment of the central processor.

More serious for our views is the theoretical integration presented by Walley and Weiden (1973). They argue that selective attention results entirely from lateral inhibitory processes in the sensory–memory system. They do not distinguish between automatic pathway effects of the type discussed in Section II and effects of conscious attention. Their views are of importance, but it seems to us that they would have great difficulty in handling the abundant evidence for facilitation due to pathway activation and would also have trouble dealing with the kind of interference found by Warren (1972). Warren has shown that reaction time to name the base word of the Stroop following activation by a related item is facilitated, while the time to name the ink color is retarded. This would not lend itself easily to a lateral inhibition account. The cost benefit experimental results outlined below also seem difficult to accommodate to a lateral inhibition view, at least unaided by additional assumptions.

Cost Benefit Analysis

Theory. The views of automatic and conscious processing we have been setting forth lend themselves to a summary statement (see Fig. 6) that dictates the kind of experimental inquiry we have been following. An input item will automatically activate a specfic pathway in the nervous system. Any item that shares the same pathway will be processed more rapidly and thus be facilitated. This is needed to account for the data obtained by Warren and Conrad. However, as long as the activation pattern is confined to the memory system, there will be no cost or inhibition of the processing of items whose pathways are not activated. This produces a kind of one-way set, in which the nervous system is set to process an item, but is not set against any other item. According to this view, stimulating the memory system in this way produces facilitation but no inhibition.

Once a subject invests his conscious attention in the processing of a stimulus, the benefit obtained from pathway activation is increased, and this benefit is accompanied by a widespread cost or inhibition in the ability of *any* other signals to rise to active attention. This position follows from the limited-capacity nature of the conscious processor. New items still continue to activate input pathways in a purely automatic way, but they are not easily associated to nonhabitual responses. This results in the usual two-sided set familiar in the psychological literature. Subjects do well when the expected stimulus occurs, but are slow in responding to or miss entirely any unexpected item.

Experiments. In previous papers we have reported in detail the experimental work that has resulted from the cost benefit analysis (Posner & Snyder, 1974). The basic design is to present a single priming item which is either a signal of the same type to which the subject will respond or a neutral warning signal. By manipulating the probabilities that the prime

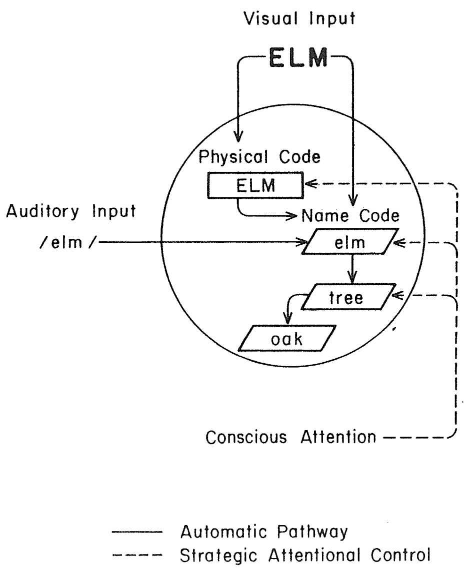


FIG. 6. A schematic diagram of the role of conscious attention in selecting levels of the automatic activation process upon which to base an output: dashed line, strategic attentional control; solid line, automatic pathway.

will be a valid cue to the stimulus item, we hoped to vary the degree of active attention that the subject commits to the prime. According to our theoretical view, when the subject commits little processing capacity to the prime, he should benefit from automatic pathway activation but show no cost. When he actively attends to the prime, he should show benefits from both automatic activation and conscious attention, and these should be accompanied by costs on those trials when the prime is not a valid cue to the target.

To calculate benefit we subtracted the reaction times when the prime matched the array from the reaction times obtained following the neutral warning signal. To calculate cost, we subtracted reaction times obtained following the neutral warning signal from those obtained when the prime mismatched the array. The error data were generally high when the reaction times were long.

The most favorable results are those obtained from "yes" reaction times when the array is a pair of letters that must be matched for physical identity and the prime is either of high validity (prime matches array on .8 of the "yes" trials) or of low validity (prime matches array on .2 of the "yes" trials). Figure 7 provides a cost benefit analysis obtained from these studies as a function of the time by which the prime led the array.

Two features of these data are of primary interest. When the prime is of low validity (upper panel, Fig. 7), there is benefit but no cost. When the prime is of high validity, the benefit begins to accrue more rapidly than does the cost. According to our view, benefit should begin to accrue rapidly after the presentation of the prime as the input pathways are activated. It should be closely time-locked to presentation of the prime. Cost is associated with the commitment of the conscious processor to the prime. This should occur more slowly and depend upon the use the subject intends to make of the prime. The lower panel of Fig. 7 confirms the striking asymmetry of cost and benefit in the condition where the prime is a valid cue. A comparison of the cost function in the upper and lower panels confirms the degree of flexibility that the experimental situation produces in the amount of cost.

The asymmetry in the time course and flexibility of cost and benefit can be demonstrated in data obtained from other studies (Comstock, 1973; Posner & Boies, 1971; Posner & Klein, 1973). In these studies the attention given to a primary letter-matching task is assessed by the degree of interference (cost) in reaction time to a secondary auditory probe. The facilitation in processing the second letter, produced by varying amounts of prior exposure to the first, increases sharply over the first 150 msec of input and levels out after 300 msec. It is very similar in form to those shown in Fig. 7 and illustrates close time-locking to the input signal. Cost func-

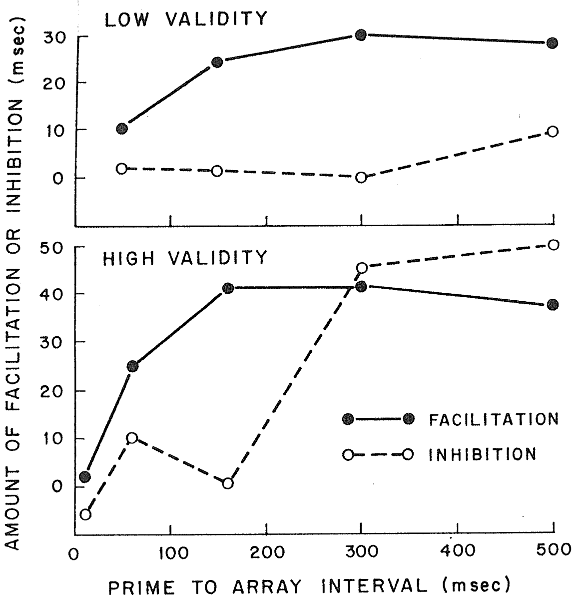


FIG. 7. Amount of facilitation (benefit) or inhibition (cost) produced by a prime stimulus in relation to a neutral control. The upper panel illustrates a low-validity prime to which subject is not supposed to pay attention; the lower panel illustrates a high-validity prime that is supposed to involve subjects' active attention. (From Posner & Snyder, 1975.)

tions are far more flexible in form. They begin quickly when the subject is given incentive to process the first letter actively. For example, Comstock (1973) turned off the first letter after 15 msec and followed it by a masking field. The cost function for the auditory probe rose sharply within the first 50 msec after first letter presentation. According to our view the subject must have been timing his attention to coincide closely with the letter onset so that he would not miss it. On the other hand, when the first letter is left in the field for two seconds, no cost in processing the probe is found until well after one second (Posner & Klein, 1973).

Strategies

Although these findings provide support for our distinction between pathway activation and conscious attention, other results of our studies (Posner & Synder, 1975) raise problems for it. A complete account of our data requires a knowledge of the strategy the subject used in this task. This task required subjects to perform a match between the two array items. We found clear evidence that subjects also tend to match the prime item against the array. This strategy serves to improve reaction time and reduce error performance on those occasions when the prime and array match, while hurting performance on those occasions when they do not match. Evidence of this strategy appears in the "no" responses. Subjects tend to be faster in rejecting a pair of letters as being identical when they are given a prime that matches neither of them. However, such strategies would not produce the temporal differences in cost and benefit shown in Fig. 7.

We found a task for which there is no evidence of any automatic pathway facilitation at all. In this task subjects are given either a digit or a neutral warning signal (+) as a prime, followed by a row of letters that might or might not contain a single digit. Their task is to indicate if a digit is present in the array. The results show that when subjects are instructed to use the prime to match deliberately against the array, they show both benefit from a matching prime and cost from a mismatch; if they are not so instructed, they show neither cost nor benefit. These results suggest that a more complete model will include an analysis of how strategies imposed by the task affect the way the attentional mechanism interacts with pathway activation. We turn to this question in the next section.

STRATEGIES AND CONSCIOUS CONTROL

A large number of tasks have been studied in recent years which require subjects to make a rapid response to a simple display. The stimuli are familiar ones that come from a particular location and have well-learned semantic associations. The experimenter provides the subject with a specific task the subject is to accomplish with these stimuli. Although subjects usually can carry out the task assigned, they often have to overcome certain automatic tendencies in order to do so. For example, if the display comes from a certain position (e.g., left of the screen) they find it most natural to respond with the key in the same relative position (e.g., left key) (Simon, 1969). If the word used in the display is an unmarked adjective (e.g., good), they find it easier to respond with a key that is also unmarked (e.g., true) (Seymour, 1973). If they are required to say whether a word is a member of a previously memorized list, they are slow to reject a word that has been used in the experimental situation before, even though they correctly rejected it previously (Atkinson & Joula, 1973). These automatic associations tend to speed certain responses and slow others. The subject often appears to overcome these tendencies with practice, but it is doubtful if he does so completely in the usual laboratory experiment. Experimenters usually do one of two things with these tendencies: (1) counterbalance and ignore them, or (2) incorporate them into the model but with a status exactly identical to a component the subject can employ or not employ at will.

In this section we try to examine a few tasks in an effort to see if a distinction between automatic activation and conscious strategies can aid in developing a more consistent account of what often appear to be conflicting results.

Digit Search

Why doesn't the digit search task we discussed at the end of the last section show any evidence of automatic pathway activation? At the time we could only report that this experiment was somehow an exception to our belief that activating a pathway speeded processing of items that shared the pathway. Indeed, we still have no complete explanation, but it seems clear that the strategy of the subject may be rather special in this task. A number of experimental studies are consistent with the view that the human memory system has relatively separate storage areas for letters and digits (Brand, 1971; Jonides & Gleitman, 1972; Posner, 1970; Sanders & Schroots, 1968). There is also some conflicting evidence (Nickerson, 1973), but suppose for the moment that there is a reasonably strong separation between the two types of stimuli in the memory system.

If a subject is asked to determine whether a digit is present in a field of letters, he need simply check to see whether there is activation in that area of memory that represents digits. Notice what happens to this strategy if the subject receives a priming digit. In this case, the priming digit and the digit that is presented in the array will both activate information in the digit area of memory. Thus, the subject will have to make a more careful analysis of the activation in order to determine if the activation pattern is from a priming digit or if it is from one that is in the array. This could very easily slow the subject down, thus counteracting any automatic effect of pathway activation. Experimenters will recognize this hypothesis as entirely *post hoc,* and our data provide no direct confirmation of it.

However, this view provides insight into some interesting discrepancies in the experimental literature. Two studies in which subjects are asked to look for a digit in a field of letters are an experiment by Jonides and Gleitman (1972) and one by Lively and Sanford (1972).

In the Jonides and Gleitman study, when subjects are asked to look for a target item of the opposite class, the array size makes absolutely no difference in the rate of their responses. There is a completely flat function relating the number of items in the array to reaction time. In what appears at first to be a virtually identical condition, Lively and Sanford

required subjects to tell whether an array, which consisted of one, two, or four letters, contained a single probe item. On some trials the probe item was a digit; on other trials it was a letter. If one examines those occasions where the probe item was a digit, there is a distinct slope about half that when the probe item is of the same class.

Why the discrepancy between these results? The reason becomes clear when we consider the way in which the subject can use his attentional processes. In the work by Jonides and Gleitman, the subject may ask himself whether there is activation in the area of memory represented by the digits. If there is, he can respond "yes," and if not, "no." In the Lively and Sanford study, activation in the digit area is sufficient basis for a "no" response, but the subject cannot respond "yes" in the absence of such stimulation. Rather, he must shift his attention to the letter area and ask if there is a match in the letter category. If shifts of attention are relatively slow, it is not a very useful strategy to keep one's attention on the digits. Thus, the slope could result from a combination of different strategies adopted to solve this task.

Lexical Decisions

A distinction between automatic activation and conscious attention is also useful in understanding the lexical decision task (Rubenstein, Lewis, & Rubenstein, 1971). These experiments have shown that when subjects are asked to judge whether a string of letters is a word, judgments occur more rapidly following a semantically related item than an unrelated item (Schvaneveldt & Meyer, 1973).

Two mechanisms might produce this effect. The first is based on the concept of automatic activation. According to this view, activation of a particular memory location spreads to nearby locations. The increase in activity in these locations makes it easier to access information stored there. The second model assumes a limited-capacity system that can read out of only one memory location at a time. Time is required to shift from one location to another, and the shifting time increases with the distance between locations. Thus, the association effect occurs because shifting to nearby locations is faster than shifting to more distant locations.

To test these two models, Schvaneveldt and Meyer (1973) presented three words in a simultaneous vertical array. The first and third word were associatively related. They examined whether improvement in the processing of the third word was reduced when the middle word was unrelated. The location-shifting model predicts that an intervening item will abolish the advantage of the association between the first and third items, while the automatic activation model does not. Their initial results conform to the automatic activation model. But the materials were presented simultaneously and there was little real control over the order in which the subject examined them.

Subsequently, work by Meyer, Schvaneveldt, and Ruddy (1973) presents evidence somewhat more favorable to the location-shifting view. In this study they found evidence that the advantage of an association between two words is reduced by an unrelated intervening item, particularly when it is a nonword and thus uses a different output, as well as input, pathway.

The evidence used to choose between automatic activation and location shifting is biased. If both are true, as we believe from our results, one will expect to find facilitation when the items are separated by an unrelated item, and the experimenter will conclude that the effects are due only to automatic activation. In order to separate the automatic from the conscious effects, one may examine what happens to a nonword or unrelated word that occurs following a priming word as compared to one following a neutral condition such as a warning signal. If the facilitation of a word by another word is accompanied by an increase in reaction time to unrelated items, one might argue for an attentional explanation. If the benefit for an associated word is not accompanied by a cost to the unrelated word, a more automatic process seems required. We would expect that attentional mechanisms would be especially important when the frequency of related words is high, and automatic activation when the frequency of related words is low.

Matching Task

A number of years ago one of us reported it was faster to respond "same" to two identical letters than it was when the letters had only their name in common (Posner & Mitchell, 1967). The reason presented for this difference was that with identical letters subjects could respond on the basis of visual information alone and thus emit their response before the letter names were available. In a number of subsequent papers, converging operations were presented that support this position (Posner, 1969, 1973; Posner, Lewis, & Conrad, 1972).

However, an astute reader of this paper will realize that there are now two different explanations for the same phenomenon. One is the levels-of-processing account I have just mentioned. The second is the view that two identical letters will share more of the same pathway than letters that agree only in name. Notice that the first account is a somewhat optional one, since the subject could choose to withhold responding in all cases until he verified the letter name; the second account rests upon an automatic facilitation of the pathway.

The best evidence favoring the second account is an experiment by Eichelman (1970) in which he required subjects to name letters as quickly as possible. Eichelman's subjects, showed an improved reaction time when the letter was repeated on successive trials. This repetition effect was greater for physically identical letters than for those having only their name in common. Eichelman proposed a pathway-activation account of these results. It is also possible to handle these results on the basis of a processing-levels explanation. The idea is that the name of a stimulus presented on a trial is stored along with the visual information. On the next trial the subject first attempts to match the new input to the item presented on the previous trial. If there is a match, he emits the same response without having to identify the new input item. For some time it seemed that this explanation would do. However, subsequently both Warren (1970) and Kirsner (1972)[3] showed that naming was facilitated by presentation of a prior item to which no response was required, and Posner and Boies (1971) reported that physical matches became relatively faster than mismatches as a function of the time by which the first of two items led the second. These results favored a pathway explanation.

The advantage due to pathway activation in the matching and naming experiments is in the range of 30–50 msec. This is about half the general advantage found for physical matches over name matches.

The advantage of physical matches over name matches may consist of two different components. One involves the specific level of information on which the subject may base his response, and the other refers to the general advantage of an activated pathway. In a naming experiment subjects appear to benefit from automatic activation primarily. In simultaneous matching tasks the level-of-processing component seems to dominate. In successive matching, both factors may be involved.

Summary

We feel that subjects can program their conscious attention to (1) receive information from a particular input channel or area of memory and (2) perform particular operations upon received information. These programs, which are under the conscious control of the subject, we have been calling strategies. Strategies cannot prevent the automatic activation processes discussed in Section II. This inability of attention to prevent the build-up of information through automatic activation is in agreement with

[3] Unlike Eichelman, Kirsner found no greater facilitation when the new item was physically identical (visual–visual) over when they shared only the name (auditory–visual). This could have resulted from slower decay of name activation with an auditory prime.

ideas that have been advocated by Keele (1973), LaBerge (1975), and Shiffrin (1975).

However, strategies do have a profound effect on what subjects perceive consciously, act upon, and report later. To claim that these effects are not perceptual seems to be a rather peculiar use of the term. Evidence shows clearly that subjects may activate memorial pathways even at the level of representation that underlies physical matching (Posner, 1969) and can thus increase the rate at which information enters the conscious processing system. Increases in the rate of information processing of this type improve both speed and accuracy. Shiffrin (1975) has presented evidence that knowledge of the source of input does not improve d' measures. On the other hand, Smith and Blaha (1969) have shown d' changes when subjects know where in the visual field a signal will occur. Our data do not resolve this conflict, but our feeling is that the main importance of a strategy that turns the subject's attention to an input channel or memory pathway is not so much to facilitate the selected item (benefit) as it is to reduce the likelihood of interruption from outside the selected domain (cost).

The act of maintaining concentration on a pathway requires effort. This is additional evidence that it does not turn off the automatic pathway effects of other stimuli. Rather, concentration serves to reduce the probability that these other stimuli will intrude upon the conscious processor. If such intrusion were completely impossible, it would not be necessary to break off this writing so frequently to respond to various real and imagined stimuli. In the study of emotions and attitudes, psychologists have addressed the question of why stimuli outside of consciousness sometimes intrude upon our thought processes. We turn now to examine this issue in the light of the distinctions discussed in this chapter.

THE PLACE OF VALUE IN A JUDGMENT OF FACT

Perhaps no place is the distinction between automatic and conscious processes more needed than in the study of the role of emotions, affects, and feelings on perception. The "new look" in perception argued that emotional responses to a word influenced our identification of that word (Erdelyi, 1974). How could identification depend on something (emotional response) that cannot arise unless the word is identified? According to our argument this confuses two senses of identification. One involves the activation of the pathway of interest (i.e., the word name and its habitual associates), and the other involves our conscious awareness of that representation. Studies reviewed in Section II (Corteen & Wood, 1972; von Wright *et al.,* 1975) suggest that the former may occur without the latter ever occurring.

If one makes a distinction between automatic and conscious processes, the problem of the role of emotions in perception may be divided into two parts. First, at what level of processing is emotional information accessed in the memory system? Are the emotional attributes of an item stored as an association to the item name, or are they attributes by which names are organized? This latter view, which has been advocated by Osgood, Suci, and Tannenbaum (1955) and more recently by Wickens (1972), holds that emotional connotations are primary semantic attributes that may be contacted prior to word identification. Second, how does the emotional response to a word, however produced, affect our awareness of that word?

The second question has been addressed by recent experimental investigations that suggest that the emotional response to a stimulus may serve to change the rehearsal pattern. Erdelyi and Applebaum (1973) show that an emotional symbol (swastika) captures the subject's attention in a way that reduces the information he is able to report from the rest of a complex display. This suggests that emotional stimuli will often demand attention. Broadbent (1973) has shown that emotional words affect the tachistoscopic recognition of words that follow them in a list. He finds that following the presentation of a nasty word, a subject reduces the range of cues he takes in from the next word. He is less likely to report the first and last letter, but more likely to report adjacent ones. This is similar to the effects found with other stressors (Broadbent, 1958, 1971) and may be related to what one finds with a heightened sense of alertness that commits the central processor to an early stage in the buildup of information (Posner, 1974). Broadbent suggests that the effects of an emotional word upon the report of the next word might also intervene between the emotional classification and the awareness of a given word. Of course, the time between classification and conscious awareness is short in tachistoscopic studies and one might expect weak effects, but the principle that emotional words can affect the conscious processor seems to have been established.

These results do not tell us whether emotion is contacted at a relatively early level in the processing of an item, or whether emotion is treated as a higher level semantic dimension. Since the material treated in this paper seems to show that even higher level semantic dimensions may be contacted rapidly and automatically, the fact that emotions affect the direction of our conscious attention does not give them any special status within the memory system.

Impression Formation

In order to attack this question, we wanted to have a paradigm in which we could vary the strength of the emotional response to an item and see how it affected the factual processing of item information. Many recent investigations of the memorial representation of affect have involved the emotional connotation or evaluation of trait-descriptive adjectives. Asch (1946) investigated the impressions people formed of others, based on a series of adjective traits describing a given person. This has led to a series of experimental investigations (Anderson, 1972) in which people have attempted to form deliberate conscious impressions of others from listening to a set of trait-descriptive adjectives. It is clear from these studies that people can form such impressions. Moreover, Anderson and Hubert (1965) and Anderson and Farkas (1973) have argued that the storage of such information is separate from the specific set of adjectives by which the information is conveyed. They argue that the memory underlying the emotion or evaluation is abstracted from the adjectives and stored separately from the adjectives themselves. The basis for this view is that if asked to recall the adjectives in a given list, the subjects show a relatively strong recency effect, but if asked to rate their overall impression of the person, the primacy effect is stronger.

Our goal was to develop a firmer notion of the memory structures that underlie the emotional classification and to compare them with those that mediate retention of the individual adjectives. In particular we sought to understand the level at which emotional information makes contact with a decision about the presence of a particular trait as a descriptor of a person. The experiments used a memory scanning task developed by Sternberg (1966).

Retrieval of Item and Value Information

In order to observe the relationship between emotion and item information, we provided subjects with three kinds of sentences. The sentences always consisted of a single proper name followed by one to four adjectives. The adjectives might be all positive in emotional tone, all negative in emotional tone, or a mixture of positive and negative emotional tones. Words were selected from norms provided by Anderson. The sequence of events is illustrated in Fig. 8. Following the sentences, subjects were given a single probe word. On half the trials, the probe matched one of the words in the sentence, and on half it did not. Subjects were to respond as rapidly as possible to the question of whether the item in the probe matched an item in the sentence.

The basic results of the experiment are quite simple. For "yes" responses reaction times did not differ for positive, negative, or neutral lists. The "no" responses can be broken down into two types, those in which the emotional tone matched the list and those in which it did not. We compared

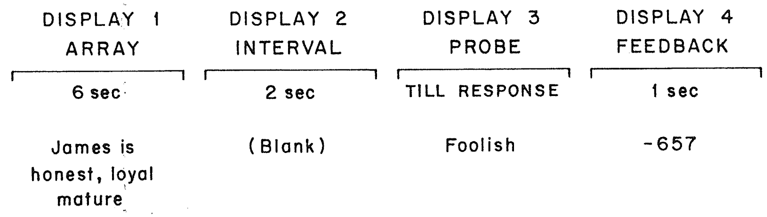


FIG. 8. Sequence of events in the studies of the role of affect on judgments about the presence of probe adjective.

the two types of "no" responses averaged across conditions where the list was positive and where it was negative (see Fig. 9). This is a particularly sensitive comparison since the probes are the same words in both conditions but follow arrays of differing emotional tone. The results show a small but significantly faster reaction time when the emotional response is opposite to that of the list than when it is identical. This is accompanied by a reduction in error when the emotional response did not match the list. While the difference in reaction times between matching and mismatching "no" responses did not change systematically as a function of size of the list, the error differences changed sharply as a function of size of the list. When the list consisted of four items, there was a much higher probability that the subject would make an error when the emotional response matched

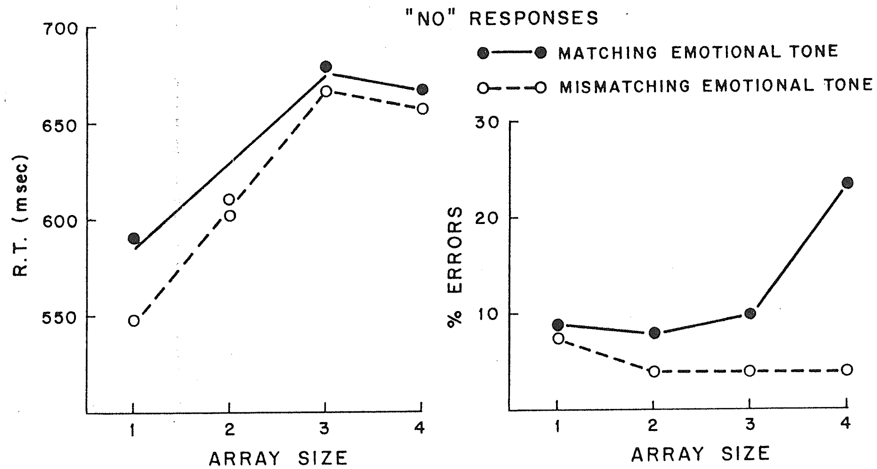


FIG. 9. Reaction time (left) and errors (right) in "no" judgments as a function of array size when the probe word either matches the array items in emotional tone (e.g., both positive) or mismatches them (e.g., array positive and probe negative).

the list than when it did not match. What do these results tell us about the relationship of the item information and the emotion?

Models

There are clear effects of the impression on the task. When the emotional tone of the probe does not match that of the list, subjects are facilitated in responding "no."

There are several possible ways this result might occur. Suppose that the emotional information was present relatively more quickly than the factual information. This might be the case if the subject consciously prepared to match on the basis of emotional tone. One would expect subjects to be able to reject the mismatching emotional tone without any required search of the factual information, and this would produce a flat slope relating mismatching "no" responses to array size. However, there is no tendency for the slope to be reduced when the probe emotion mismatches.

Another view supposes that each word consists of an item and an emotional attribute associated with it. Thus, the adjective "loyal" is associated directly with its denotative and connotative meanings. In this view, a probe word may be rejected as matching any array word more quickly if the mismatch involves both item and emotion than if it involves only item information. Lively and Sanford (1972) have adopted exactly this model for their account of what happens when a subject receives a list consisting of digits and gets a probe that is a consonant. Such a model does not fit our data, since the slope of the "no" reaction time to mismatching emotions is at least as great as for matching emotions.

In their Loyola Symposium paper Atkinson, Herrmann, and Wescourt (1974) suggest that the slope of reaction time versus array size for probes that are outside the category of the list serves as a measure of the degree of semantic analysis required prior to contact with the information representing the category of the probe. They suggest that relatively flat slopes are obtained when the subject has to process little semantic meaning of the probe, and steeper slopes are obtained as the semantic processing required in order to determine the category is increased.

The overall results of the reaction time and error data obtained from our experiment seem most consistent with the following analysis of the relation of emotional information to item information. Suppose there are two independent memory structures. One memory structure consists of the list of trait adjectives that the subject reads in the sentence. The other memory structure consists of an abstracted impression based on an integration of the values presented by the individual adjectives. The time to search the memory structure representing the traits would increase as a function of number of items in the list. On the other hand, the impression would

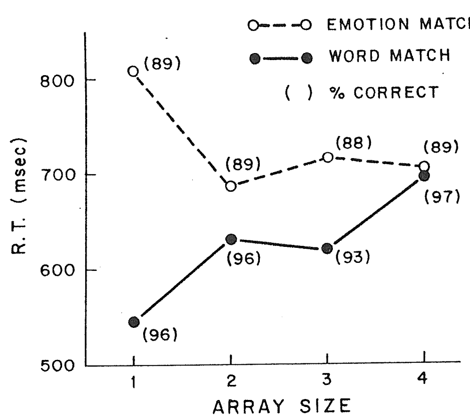


FIG. 10. Reaction time and percentage correct for "yes" responses when subjects are instructed to match the emotional tone of probe and array deliberately. Word matches are those in which the particular probe adjective was a member of the array; for emotion matches the probe word was not in the array but had the same emotional tone.

tend to get stronger as we increase the number of items on which it is based; thus, one might expect a reduction in reaction time. Since judgments based on the emotional classification alone would only be reliable for mismatching "no" responses, one would expect errors to pile up for matching "no" responses when the output of the emotional structure occurred prior to the output of the list array. This could account for the high error rate obtained with four-item arrays.

To test this idea we performed an experiment in which subjects received the same lists as described previously, but were asked to determine if the probe item had the same emotional content as in the previous list. Two types of "yes" responses are possible: first, those to probe items that were on the list, and second, those that were not identical but shared the same emotional tone. The results (see Fig. 10) support our two-process view of the matching task. The role of the number of items is to increase reaction times for those items that match, but to reduce it for those that mismatch. The two functions come together at about four-item lists.

In brief, what seems to happen is the formation of two memory structures, one consisting of a list of item names, and the other consisting of a generalized emotional response to the items. These separate memory structures appear to be oppositely affected by item length. The data seem most consistent with the view that each memory structure has an output to the binary decision. In cases where the two decisions agree, there seems to be relatively little effect on overall reaction time or errors. In cases where they disagree, however, there appears to be a lengthening of reaction time as if there were some tendency to make the conflicting response. However, the tendency seems slight unless we let the times for the output get very close together. In that case, there seems to be a very difficult decision to be made and a high probability of error.

These data agree with the view of two separate memory systems laid down by the list items (Anderson & Hubert, 1965). However, they do not agree with the view that emotional information concerning the impression is handled in any different way than other semantic dimensions in the memory system. Rather, it appears that evaluations are handled very much like other semantic dimensions. When a number of items have the same emotional content, information is integrated to produce an overall impression against which to evaluate input.

It would be of interest to examine the extent to which the conscious strategy to extract an evaluation is a necessary condition for obtaining the results we have presented. Currently we know only that subjects need no instruction to be influenced by the evaluative components, but we do not know whether they intend to extract such information either because they realize it is useful in the task or simply find it of interest. Manipulations of the probability that the evaluative information will serve as a valid cue to perform the task correctly might help us to deal with this question.

Long-Term Memory

In the psychological literature there are a number of studies that compare the retenton of specific item information with the retention of more abstracted information that stands for a set of items. Much of this literature has used dot patterns to serve as the item instances. If subjects are required to classify a set of patterns into a category, they seem to abstract from that category a prototype or central tendency that comes to stand for that category (Posner, 1969; Reed, 1972). We speculated that the abstraction of emotional information and its storage in terms of an impression would be somewhat the same as found in the previous work with patterns. To study this, we set up an experiment in which the subjects had to learn a list of ten adjectives associated with each of six proper names. Two types of test trials were given: list trials and name trials. On list trials, subjects were shown a name and four adjectives selected from those associated with that name, and they were then probed with a trait that was either from that list or not. On name trials, the subject was merely given the name that was being tested, followed after the same retention interval by a single probe adjective. On the name trials we attempted to assess the long-term memory structure that represented the set of items associated with the person's name, while on the list trials we attempted to replicate the results we obtained in the previous experiment.

The results obtained in the previous experiments were replicated on the list trials. Once again, reaction time to "no" responses that mismatched in emotional tone were faster than for "no" responses that matched in tone. On the name trials we found that the reaction time to mismatching "no" responses was 200–400 msec faster than for matching "no" responses or for "yes" responses. The memory system that came to stand for the emotional response was more available to the subject than that which represented the individual items.

Several alternative explanations of this result are possible. It could be that the subject actively attended to the emotional classification of the list, or it could be that the memory system representing the emotion resisted forgetting more than that of the individual item. Further work will be needed to separate these two accounts.

Summary

Our results, then, taken together with the recent work of Broadbent (1973) and Erdelyi and Applebaum (1973), suggest an overall account of the role of emotion at least when it arises from the evaluative aspect of words. Emotional information is stored as a high level but habitual associate to given words or constellations of words. One would expect that the presentation of an item would automatically activate associated emotional responses. These responses might feed back to affect the conscious mechanism guiding its processing of the various kinds of information associated with the input item. The complexity of this view fits with the rather diverse results that have been obtained in many experiments involving emotional items. Doubtless, what becomes conscious will be a function not only of the level of emotionality raised by the automatic process, but also by strategies used in different experiments. Thus, the presence of emotional information may lead in some contexts to perceptual vigilance, and, in other cases, to perceptual defense. Investigations of the emotional responses to items would seem to profit from the kind of methodology obtainable with trait-descriptive adjectives where a variety of different individual items may be combined to produce a single emotional trace system. Perhaps the most interesting area for study will be how well emotional material transfers from the situation in which it is learned to other tests.

OVERVIEW

Summary

This chapter discussed the distinction between automatic activation processes which are solely the result of past learning and processes which are under current conscious control. Automatic activation processes are those which may occur without intention, without any conscious awareness and without interference with other mental activity. They are distinguished from operations performed by the conscious processing system since the latter system is of limited capacity and thus its commitment to any operation reduces its availability to perform any other operation. Many current cognitive tasks were analyzed in terms of the interaction of automatic activation processes with strategies determined by task instructions. Concentration on a source of signals serves to reduce interference from outside that source. Outside signals still intrude, particularly when they are classified by the memory system as having emotional significance.

Prospects

Where are the views outlined in this paper taking us? I am afraid that it is in two directions, which may well turn out to produce a kind of research schizophrenia. The first direction is toward an understanding of the more detailed mechanisms that subserve the functions of pathway activation, levels of processing, and conscious attention (Posner, 1974). This effort leads to the creation of ever simpler tasks, toward a comparison of behavioral data with evoked potential and single-cell studies, and a closer coordination between human and animal studies. The relative stereotypy of "automatic activation" processes gives hope that a mechanistic and analytic approach may work. In contrast, they will not by themselves allow us to say much about how people will actually perform tasks.

The goal of understanding human performance requires an analysis of strategies useful in particular task environments (Newell & Simon, 1972). In part, this involves an effort to understand how strategies modify and build upon "automatic retrieval" processes. Our studies of the effects of emotion on judgment were addressed to that goal. We hope that further efforts along this line will aid us in understanding how much our prior learning biases the way we can think in a particular task environment.

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