Automatic and Effortful Processes in Memory

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SUMMARY

A framework for the conceptualization of a broad range of memory phenomena is proposed in this article. The framework integrates research on memory performance in young children, the elderly, and individuals under stress with research on memory performance in normal college students. One basic assumption of this viewpoint is that encoding operations vary in their attentional requirements. Operations that drain minimal energy from our limited-capacity attentional mechanism are called automatic; their occurrence does not interfere with other ongoing cognitive activity. Automatic operations function at a constant level under all circumstances. They occur without intention and do not benefit from practice. Certain automatic processes, we propose, are ones for which humans are genetically “prepared.” These processes encode the fundamental aspects of the flow of information, namely, spatial, temporal, and frequency-of-occurrence information. These automatic processes are expected to show limited developmental trends. Other automatic processes develop through practice and function to prevent the subcomponents of complex skills from overloading our limited-capacity system. Contrasted with these processes are effortful operations such as rehearsal and elaborative mnemonic activities. They require considerable capacity and so interfere with other cognitive activities also requiring capacity. They are initiated intentionally and show benefits from practice.

A second assumption of the present framework is that attentional capacity varies both within and among individuals. Depression, high arousal levels, and old age are among the variables thought to reduce attentional capacity. The conjunction of the two basic assumptions of the proposed framework yields the important prediction that the aged and individuals under stress will show a decrease in performance only on specific memory tasks, namely, on tasks requiring effortful processing.

Evidence from the literature on development, aging, depression, arousal, and normal memory is presented in evaluation of the framework, and four experiments are described. The bulk of the available data is supportive of the framework. For instance, evidence indicates that frequency processing is not influenced by intention, practice, depression, or age. The article also includes discussion of the origins of this viewpoint in other attention and memory theories.
This article explores the application to memory encoding processes of some ideas central to current cognitive theory. These ideas concern limits to attentional capacity, variations in the attentional requirements of different encoding operations, and variations in attentional capacity. On the basis of these ideas, a general framework will be proposed for ordering research and theory on memory performance across the entire life span, as well as in individuals under stress, with research and theory on memory performance in normal college students.

The idea of limits in attentional capacity is an old one in psychology (e.g., James, 1890), but the first formal model of attention seems to have been that of Broadbent (1958). Broadbent's model (as well as other early attention models) were "bottleneck" models (Kahneman, 1973); that is, they postulated a series of stages through which information passes between input and response, and they posited a particular stage of processing at which selective attention operates. Some theorists (Broadbent, 1958; Treisman, 1960) placed the bottleneck early in the information-processing sequence, prior to perceptual analysis; others (Deutsch & Deutsch, 1963; Keele, 1973; Norman, 1968) placed it late in the sequence. In both the early and late models, permanent storage of information and overt responding were assumed to require use of the attention mechanism.

More recently, the dominant view of attention has followed Kahneman's (1973) position. Kahneman proposed a capacity model of attention, by which he meant that there is a general limit on the energy available for performing mental operations. This limit does not apply to any specific stage of information processing. Rather, capacity can be allocated flexibly to different stages of processing and to different acts or objects.

Explicit in Kahneman's book was the idea that mental operations differ in the amount of attentional capacity they require. Specifically, he argued that the early stages of information processing (i.e., sensory analysis) do not require attention but that attentional demands increase as the operation moves closer to the response end of the system. In the past several years, a number of influential articles in cognitive psychology have gone further in this vein and have argued that by dint of extensive practice, some complex operations (including stages up to overt responding) can occur with only minimal attentional capacity being allocated to them (Posner & Snyder, 1975; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). Such mental operations are referred to as "automatic."

At the other end of what is really a continuum in the attention requirements of mental operations are those that require for their occurrence considerable attentional capacity. Mental operations of the latter type have been called conscious (Posner & Snyder, 1975) or controlled (Schneider & Shiffrin, 1977). In this article we use the term effortful for such processes.

The significance of the distinction between automatic and nonautomatic processing is that a number of important functional characteristics are correlated with the differences

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1 The suggestion of such a continuum is either explicit or implicit in most other models. Nonetheless the language used in various reports may sometimes suggest that a dichotomy is assumed. This is likely to have been the result of the avoidance of rather awkward circumlocutions such as "virtually automatic" and "nearly automatic."
in attention requirements. The exact list of these characteristics is not invariant among authors, but there is considerable commonality. Automatic and nonautomatic processes either have been found or are presumed to differ in their correlation with awareness and intention, in their susceptibility to inhibition, in the effects of stimulus load, in practice effects, and in other characteristics (e.g., Logan, 1978; Posner & Snyder, 1975; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

The basic idea of differences in attentional requirements and associated differences in functional properties has been used in a number of ways. For instance, LaBerge and Samuels (1974) stressed the development of automatic processing of component skills as a central aspect of learning to read. Posner and Snyder (1975) were concerned with the manner in which automatic and nonautomatic processes interact in the determination of performance in tasks requiring rapid response (e.g., matching and search tasks). Schneider and Shiffrin (1977; Shiffrin & Schneider, 1977) attempted to integrate data and theory in the areas of selective attention, short-term search, and detection. Finally, Hunt (1978) incorporated the distinction between automatic and nonautomatic processes as a basic idea in his discussion of individual differences in verbal intelligence. Our major goal differs somewhat from these other authors. They have been most concerned with understanding the moment-to-moment processing that occurs in perception and attention tasks. By contrast, our major interest is in the storage or memory encoding effects of automatic and effortful processing.

Another important idea in Kahneman’s (1973) seminal book is the idea that total attentional capacity is not permanently fixed; rather, it varies both within and among individuals. The implications of this idea for cognitive theory have not been as fully explored as has the automatic–nonautomatic distinction (but see Hunt, 1978). In the framework presented in the present article, the consequences of variation in cognitive capacity are a central concern. An outline of our framework follows next.

The Framework

The present framework for the conceptualization of memory processes rests on two basic ideas. The first of these is that there is a continuum of attentional requirements among encoding processes; processes at either end of this continuum will be referred to as automatic and effortful processes. The second idea is that there is a variable capacity limit to attention and that this limit interacts with encoding demands.

Automatic encoding of information only minimally diminishes one’s capacity to process other components of the flow of information. Such encoding insures that certain basic aspects of both internal and external events are entered into long-term memory despite other, concurrent demands upon capacity. According to the framework, among the aspects of events encoded automatically into memory are spatial location, time, frequency of occurrence, and word meaning. By contrast, effortful processes require the expenditure of attention and effort and so use a portion of the limited-capacity system. Such processes maximize the efficiency with which nonautomatically encoded information is assimilated. The effortful processes considered here in some detail are imagery, rehearsal, organization, and mnemonic techniques.

Along with a number of other authors (e.g., Bower, 1967; Tulving & Watkins, 1975; B. J. Underwood, 1969), we think it useful to conceive of to-be-remembered items as bundles of attributes (or elements), and memory traces as the aggregates of those attributes that have been encoded. Our framework adds to this general conception of memory traces the idea that when a person attends to an input, some of its attributes are automatically encoded into long-term memory whereas others require more or less effortful processing to be encoded into a permanent memory trace. Elaboration of attributes and the encoding of relations among items also require effortful processing. Notice that we assume that for an automatically encoded attribute to enter long-term memory the person must be attending to the input in...
question. For such encoding, it does not matter whether attention is incidentally or intentionally guided. If an individual is attending to an input, the encoding of frequency (and other automatic attributes) requires little or no specific further attentional processing. By contrast, the encoding of an image of the input, the elaboration of integrative attributes, and so on, do require additional attentional processing.

The second basic idea upon which this approach rests is that at any given moment, a person has limited resources available for processing information. In agreement with Hunt (1978), we accept the viewpoint presented in Kahneman’s (1973) model: capacity is not permanently fixed, but varies both within and among individuals. As Kahneman suggests, a number of organismic and environmental variables such as arousal, mood, and disease may influence capacity. It is also possible that capacity changes with age. Our assumption is that capacity limitations interact with type of memorial processing to determine the efficiency with which information requiring effortful, but not automatic, processing is stored (see also Hunt, 1978).

These basic ideas will be expanded upon in this article to develop a general framework for memory research that applies to both normal and nonnormal states and that has a life-span developmental orientation. In the first two sections of the article we will describe what we believe to be the general characteristics, origins, types, and functions of automatic and effortful processes. The assumptions made about cognitive capacity will then be discussed. Next, some explicit predictions about memorial processing that follow from our position will be described. In this section we will also consider the differences between our framework and a number of current theoretical statements with respect to the distinction between automatic and effortful processes. In the final major section, the predictions will be tested against the literature on automatic and effortful processes. The results of four experiments will also be presented.

Automatic Processes

General Characteristics

Several functional properties characterize automatic processing.

Automatic processes operate continually to encode certain attributes of whatever information is the focus of attention. Once a process is automatized, it can no longer be improved upon either by additional practice or by feedback about earlier performance. Automatic processes do not require either awareness or intention, and their operation cannot be willfully inhibited. They drain minimal amounts of energy from attentional capacity, allowing the organism to continue to operate even when extraordinarily high demands are made upon that capacity, as in moments of high stress or injury. The knowledge gained by automatic processes is accessible to consciousness and can then be used in a number of ways, which will be discussed shortly.

It should also be noted that a person can pay attention to incoming information that would otherwise be automatically encoded. One can, for example, actively pay attention to the frequency of events. Although such unnecessary effortful processing does not improve upon the encoding of the incoming information, it does reduce one’s ability to engage in other nonautomatic processing.

At least two sources for the origin of automatic processes can be considered: heredity and practice. This consideration in turn gives rise to the notion that there are two types of automatic processes. With regard to the former source, it may be that the nervous system is wired in such a way to to maximize the processing of certain types of information. By this we mean that minimal experience is required for the acquisition of some automatic processes. Speculations concerning the relative ease of passage into the automatic state find some basis in the concept of “pre-

2 Some attributes of events such as word meaning may be activated even when attention is not focused on those events, as in the case of the nonshadowed message in a dichotic listening task. However, such activation probably leaves no permanent record in memory (see, for example, Norman, 1969).
paredness” in animal learning (Seligman, 1970). Preparedness to learn a particular association reflects the survival value of the association for the species. For example, rats are prepared to associate gastric distress with novel tastes and odors but not with sights or sounds (Garcia, Ervin, & Koelling, 1966).

The operations that encode the frequencies, spatial locations, and time of events are among the processes that we suggest are automatic at least in part because of innate factors. These processes, which we believe are at one anchor point in the attentional demand continuum, allow us to cognitively orient to the routine flow of events in our environment. Because of the contribution of innate factors, these processes should be widely shared and minimally influenced by differences in age, culture, education, early experience, and intelligence. The latter are variables likely to influence effortful processes (and possibly also automatic processes acquired by virtue of practice).

The second source for the origin of automatic processes is practice. Recent discussions of skilled reading (Kolers, 1975; LaBerge & Samuels, 1974), of communication (Shatz, 1977), of detection skills (Shiffrin & Schneider, 1977), and of individual differences in intelligence (Hunt, 1978) have supposed that large amounts of practice will under some circumstances result in the development of automatic processes. It is not yet clear which factors determine how much practice is required in the case of tasks that permit automatic processing, but the amount of practice does seem to be extensive (e.g., LaBerge, 1973).

Although a variety of memory skills may, by virtue of sufficient practice, become automatic, we consider here only the process of encoding the meaning of words from their written presentations. We select this particular encoding operation because it is an important subcomponent of an important cognitive skill, reading. Furthermore, the contention that meaning activation is automatic is supported by several lines of evidence.

Because meaning extraction and reading are both learned skills, they may function differently from the automatic operations at the terminus of the continuum. In particular, the former may show substantial individual differences and may also be subject to disruption. Hunt (1978) argued that there are major individual differences to be seen in automatic processes. From our perspective, differences among normal individuals may be expected in processes that become automatic by virtue of extensive practice, since the need for practice could enable ability and motivational differences to play important roles. Minimal differences are expected on automatic processes for which humans are genetically prepared.

There is some evidence in the literature that could be interpreted as suggesting that learned automatic processes are subject to disruption. When very difficult material is being read, reading processes (including, presumably, meaning extraction) are disrupted (Hardyck & Petrinovich, 1970). Furthermore, repeated presentation of a word results in its meaning being less strongly activated (Lambert & Jakovits, 1960). There appear to be no comparable data concerning disruptions in the processing of frequency, spatial location, or temporal order information.

These considerations give rise to the suggestion that memory processes occur along a continuum from effortful to automatic, with the “learned” automatic processes sharing some but not all of the attributes of processes at the automatic terminus of the attentional demand continuum. Alternatively, learned automatic processes may share all of the characteristics of automatic processes except under stressful circumstances. These suggestions are clearly speculative and so demand careful empirical investigation.

Utility of Automatic Encoding Processes

An important assumption underlying this perspective, and many current cognitive theories, is that a cognitive system with limited resources works best when frequently used, and basic mental operations occur automatically, leaving maximal resources available for less commonly used and more sophisticated mental operations. This prevents the cognitive system from becoming
overloaded by processing demands. Reading is an example of an activity that includes many processes that must be quickly and accurately coordinated. If all the component processes required attention, then our attentional capacity would presumably be overloaded. If, however, enough of them become automatic, then the attentional demands become tolerable and skilled reading is possible (LaBerge & Samuels, 1974).

The continual and automatic operation of mechanisms that encode space, time, and frequency attributes enables the human to perform efficiently in several ways. Because the outputs of the automatic processes are accessible to consciousness, they can serve as criteria for various decisions that a person must make, often with little else in the way of valid evidence. Thus Hasher, Goldstein, and Toppino (1977) have demonstrated that frequency of occurrence plays a role in decisions about the truth or validity of plausible statements when persons have no direct access to the requisite information. For example, the extent to which one is certain that rice is grown in Florida or that the population of Greenland is 50,000 will vary with the number of occasions on which one has heard the assertion in question made. This was the case even in the extreme situation of the Hasher et al. experiment, in which the statements were presented in an explicitly ambiguous context. The effect may be even more profound in daily experience, in which opinions are often stated as matters of fact.

There are a number of phenomena that demonstrate the importance of information about frequency, relative frequency, and co-occurrence for basic cognitive functioning. The following illustrations were selected because none of them are situations in which frequency information is explicitly the focus of attention and because all require for their operation that people have a fund of frequency information. Rosch (1978) argued that the perceived world is structured so that certain sets of attributes have a high probability of co-occurring (e.g., feathers and wings). Furthermore, she proposed that natural categories develop so as to reflect those structures. Haber (1978) argued that the reading process is built upon the knowledge and use of redundancies in the visual features of graphemes, in spelling rules, in syntactic structure, in style, in cultural restrictions, and in printing conventions. Such automatically encoded information may also underlie the ability of artists to accurately depict features of their environment—for example, the proportion of right-handed persons (Coren & Porac, 1977).

Knowledge from automatically acquired information can also serve as retrieval cues. For example, one can cue oneself with the knowledge that a name one cannot recall is a common or uncommon woman's name, or that the missing keys may be a part of a collection of stuff near the door. Or, as in a familiar example, one may recreate the events of the day in temporal sequence in order to remember where some object may have been left. Relevant here are studies that have examined retention of both events and their locations. Generally, these studies have found that event and location retention are positively correlated (e.g., Mandler, Seegmiller, & Day, 1977; Schulman, 1973), supporting the proposition that automatically encoded spatial information can be used as retrieval cues.

It is also important to consider the role of automatically acquired information in reconstructive recall. In discussions of reconstruction, it is typical to consider thematic information and a few salient details as the schemes that, together with one's general knowledge, guide recall. This overlooks a major source of such data: the automatically encoded information. One's consistent processing of space, time, and frequency information can provide information for the reconstructive recall of a particular event. As an example, consider the results of a pilot study in which subjects were presented with words from exhaustive categories (e.g., the seasons) that were then randomly arranged in a long list. For some of the categories, not all of the items were presented (incomplete categories). Recall of the complete and incomplete categories showed important differences: For one, the probability of recalling all of the members of a complete category
was higher than was the probability of recalling all the members of an incomplete category. Subjects could apparently discriminate the complete from the incomplete categories, even though information about the completeness of a category could not be known for certain until all the items in the list had been presented. In recalling the incomplete categories, subjects showed little discrimination between the items that had actually been presented and the missing ones. Thus, reconstructive recall in this situation may be described as being tied to two sources of information: knowledge of which categories were presented and knowledge of the frequency with which each category instance occurred. The latter information, we believe, was encoded automatically.

**Definitional Discrepancies**

Although various theorists have recently discussed automatic processes, the definition of such a process varies slightly across the theories. Our definition incorporates the three criteria used by Posner and Snyder (1975): Automatic processes occur (a) without intention, (b) without necessarily giving rise to awareness, and (c) without interfering with other processing. The Shiffrin and Schneider (1977) model makes four additional assumptions about automatic processes: When activated, they run to completion; they are difficult to suppress once aroused; they do not on their own result in the storage of new information; and they develop (under certain circumstances) if given large amounts of practice. The first two attributes form a portion of the present definition. However, we believe it possible that the last two attributes are characteristic only of "learned" automatic processes. We do not believe that they characterize the automatic processes at the terminus of the attention continuum. These, we have proposed, are continual aspects of processing, requiring only that a person be attending to some event for them to be engaged. They may not be suppressed by conscious effort. They provide the person with new information that is subsequently available for a number of uses. Also, these processes may be part of the very early repertoire of the newborn as well as of the continuing repertoire of the elderly. Finally, the anchoring automatic processes are thought to be relatively invulnerable to differences in motivation, education, early experience, culture, and intelligence.

**Effortful Processes**

**General Characteristics**

Current models that postulate the existence of automatic processes contrast these with "conscious strategies" (Posner & Snyder, 1975) and "controlled processes" (Shiffrin & Schneider, 1977). For Posner and Snyder, nonautomatic tasks or operations require conscious attention. Shiffrin and Schneider present a more elaborate definition: a controlled process (e.g., decisions, search, rehearsal, coding) serves to regulate the flow of information into and out of the short-term store, as well as between levels. In their model there are two types of controlled processes, veiled and accessible. Accessible control processes are slow, can be perceived by the subject, and are both instituted and changed by instruction. Veiled processes occur quickly and so are not necessarily open to awareness.

In the present framework, effortful memory processes are analogous to Posner and Snyder's strategies and to Shiffrin and Schneider's accessible controlled processes. They are processes that require effort and so limit one's ability to engage simultaneously in other effortful processes. The efficiency of effortful memory operations increases with practice, and their use is voluntary, often occurring only with specific instructions. We are almost always aware of the effortful processing mechanisms we are using. In fact, the work on the development of "metamemory" skills indicates that the abilities to use and to introspect about effortful memory operations develop hand in hand (Kreutzer, Leonard, & Flavell, 1975). Finally, effortful processes are ones in which a wide range of individual differences may be seen.

Certainly, many different kinds of effortful operations are possible. We will deal in this article with only a few. These are pro-
cesses that have been extensively studied in memory research; and they include imagery, mnemonic or elaborative devices, organization and clustering, and rehearsal. Others might have been included, but the above seemed sufficiently close to the effortful end of the attention continuum to make the case.

Origins and Utility

Very little is known about the origins of effortful memory processes (Flavell, 1977). Explicit training and instructions by parents and teachers are doubtless involved to some extent. For instance, mnemonic aids like “i before e except after c” are drilled during the elementary school years and may provide examples from which children can subsequently generalize. Other learning of effortful operations may well derive from problem-solving activities on the part of the learner. By using feedback from attempts to learn, more efficient learning procedures can be developed. Modeling of adults’ attempts to remember may also play a role.

The usefulness of effortful learning processes lies in their ability to make information acquisition efficient. A substantial portion of the human learning literature has demonstrated that the appropriate use of effortful strategies such as imagery and mnemonic devices increases learning speed. Also, to a large extent, the relatively poor performance in memory tasks shown by the young (Brown, 1975a; Flavell, 1977), the aged (Botwinick, 1973), the highly aroused (Eysenck, 1976), and the depressed (Miller, 1975) may be attributed to the inefficient use of effortful learning processes.

Effortful learning mechanisms also allow for flexibility in information processing (Shiffrin & Schneider, 1977). If only automatic processes were available, behavior would be highly stereotyped (Blumenthal, 1977) and the handling of novel kinds of information would be severely hampered, as would responding to unfamiliar tasks. Presumably, with sufficient effort and time, new operations can be established to deal effectively with a once-novel situation that now occurs frequently. These operations may sometimes become automatic if practice is sufficient.

Attentional Capacity

We turn now to a brief elaboration of the concept of attentional capacity. Consistent with a capacity view of attention, we think of attention as a nonspecific resource for cognitive processing. This resource is necessary in varying amounts for the carrying out of mental operations, but its supply is limited (cf. Hunt, 1978; Kahneman, 1973; Logan, 1978).

Along with others (e.g., Kahneman, 1973), we believe that capacity has a variable rather than a permanent limitation. Thus, capacity can vary within and between persons as a function of a number of organismic and environmental states (see also Hunt, 1978). At least one empirical study (Beatty & Wagoner, 1978) offers direct support for this assumption. Also, some (e.g., Friedrich, 1974) have argued that the improved performance of children on memory tasks as they grow older is in part a function of increased attentional capacity (but see Chi, 1976; Olson, 1976). Similarly, there are indications that attentional mechanisms are at least partly responsible for deficits in cognitive performance in old age (e.g., Botwinick & Thompson, 1966). The present approach attempts to integrate such observations and hypotheses. It explores the possibility that a number of different variables may have similar effects on memory processes because they all alter cognitive capacity.

Variation in attentional capacity should have major effects on the efficiency with which effortful processes occur. Deficits in their performance should then be seen in instances of reduced cognitive capacity. Automatic processes, because of their minimal drain on capacity, should not be similarly affected by altered cognitive capacity. In what follows, evidence supporting this view is discussed. Work is reviewed on a number of states that are typically thought of as influencing cognitive capacity. Because of insufficient appropriate data, no attempt is made to present an exhaustive list of the states that might influence cognitive capacity. For instance, although fatigue and phase of the diurnal cycle may well influence atten-
tional capacity, the relevant findings are far too few to permit more than this speculation.

**Depression**

Although the clinical treatment and even the classification of depression are matters of considerable controversy (Akiskal & McKinney, 1973; Beck, 1967; Mendels, 1970), a consensus about the importance of a cognitive deficit associated with depression appears to have emerged. The experimental data on the nature of this deficit are extremely limited, but they are intriguing because (a) persons diagnosed as depressed frequently complain of a loss of memory function (Beck, 1967) and (b) the available data seem to be compatible with the hypothesis that the deficit is due to a reduction in cognitive capacity.

A review of the experimental literature suggests a loss of efficiency, which is, according to the present view, constrained by total capacity. For example, intelligence scores decline with the depth of depression (for a review, see Miller, 1975). Deficits in performance on serial learning, free recall (Henry, Weingartner, & Murphy, 1971, 1973; Russell & Beekhuis, 1976), anagram-solving tasks (Miller, 1975), and clustering in recall (Russell & Beekhuis, 1976) have also been found. The recall of depressed persons benefits less from increasing contextual constraint (approximation to English) than does the recall of controls (Levy & Maxwell, 1968), thus suggesting less use of organizational strategies.

Although the research on memory functioning in depression is not extensive, it does suggest that the memory dysfunctions associated with depression occur for tasks requiring effortful processing.

**Arousal**

The relationship between arousal and cognitive capacity appears to be a complex one, conforming to an inverted U-shaped function (Kahneman, 1973; Mandler, 1975). At low levels of arousal, capacity seems to increase with increasing levels of arousal. At high levels, a reduction in functional attentional capacity occurs.

The conclusion that underarousal is accompanied by reduced capacity is supported by the finding that the presentation of noise, an arousing stimulus, improves performance on a prolonged vigilance task, during the course of which arousal generally decreases. Furthermore, the beneficial effect of noise is greater for extroverts (whose arousal level seems to be chronically suboptimal) than for introverts (Davies, Hockey, & Taylor, 1969). (Reviews of further evidence on this point can be found in Kahneman, 1973, and in Eysenck, 1976.)

That high levels of arousal and stress may have associated with them a reduction in available cognitive capacity has long been recognized (Kahneman, 1973; Mandler, 1975). And this recognition has probably occurred more often (as Norman, 1976, suggests) outside rather than within the field of psychology. Trainers of divers, pilots, parachutists, firemen, and others have long seen the need for high levels of overlearning of emergency procedures. Their operating assumption here sounds quite similar to ours: Under high levels of stress or arousal, only automatic and unconscious processes function; the diver who must consider in detail how to get his weight belt and air tank removed is one who may not make it to the surface in an emergency. Norman sees the wisdom of the belief of trainers of emergency personnel that "automatic, non-conscious actions" are "less susceptible to disruption by levels of arousal" (Norman, 1976, p. 65).

In the psychological investigations of the cognitive deficits of high levels of arousal, current views (e.g., Eysenck, 1976; Kahneman, 1973; Mandler, 1975; Norman, 1976) all appear to be variants of Easterbrook's (1959) classic theory: Overarousal narrows attention from peripheral information toward central information. Mandler suggests a mechanism for this narrowing of attention: The activation of the autonomic nervous system characteristic of high arousal levels re-

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3 Arguments are presented at the section entitled "Role of Task Variables" in support of the contention that recall tasks generally require extensive effortful processing, whereas recognition tasks are less demanding.
results in the elicitation of internal cues that complete with task cues for processing capacity. Although the narrowing of attention may sometimes improve performance by excluding irrelevant cues, performance on tasks that require attention to a wide variety of cues will deteriorate under high levels of arousal. On the production side of cognitive processing, high arousal biases search processes toward the more readily accessible sources of stored information (Eysenck, 1976). There is some suggestion that over-arousal lowers clustering (Hörmann & Osterkamp, 1966, and Schwartz, Note 1, both as cited by Eysenck, 1976). High levels of arousal also change patterns of retrieval from semantic memory (Eysenck, 1974), and influence performance on the Stroop task (Glass & Singer, 1972).

Preschool and Grade School Children

There is substantial evidence in the developmental literature of pronounced changes in learning efficiency over the grade school years (for recent reviews see Brown, 1975a; Flavell, 1977; and Hagen, Jongeward, & Kail, 1975). As Brown (1975a) argued, memory skills requiring “deliberate strategies” (e.g., rehearsal and organization) are the ones that show the most profound changes during the grade school years. These are the skills that according to the present framework require effort and thus make demands on capacity. There is also some evidence that memory skills termed “basic” by Flavell (1977) and “non-strategic” by Brown (1975a) show limited developmental trends. Proposed as falling within this category are the encoding of space, time, and recognition information (Brown, 1975a; Flavell, 1977). These are, of course, within the category of memory processes and tasks that require little or no capacity, according to the present viewpoint.

The Elderly

Aging is also a process associated with a reduction in cognitive capacity. For example, the elderly are at a great disadvantage when the task they are performing requires divided attention (cf. Craik, 1977). Memory is one of the functions known to decline with age (Arenberg, 1976; Botwinick, 1973; Witte & Freund, 1976). The kinds of memorial processes on which the elderly show a decrement are those that require substantial capacity. In free-recall tasks, elderly subjects use organizational strategies and clustering less frequently or less efficiently than do younger adults (Craik & Masani, 1967; Denney, 1974; Hultsch, 1971, 1974). Similarly, older subjects report the use of mediational mnemonics in paired-associate tasks less frequently than do younger adults (Hulicka, Sterns, & Grossman, 1967). Particularly reduced in the elderly is the use of imagery as contrasted to verbal mnemonics (Hulicka & Grossman, 1967). Another learning process that seems decreased in frequency in elderly subjects is rehearsal (Kausler, 1970). Since all of these may be seen as effortful processes, their reduction in occurrence in old age conforms to the present viewpoint.

Little attention has been paid to processes that do not require capacity—although some evidence will be presented in this connection below. The evidence concerning recognition, a task requiring less capacity than others, is mixed. At least two studies have found that recognition performance does not decrease with age (Kapnick, cited in Botwinick, 1973; Schonfield & Robertson, 1966; but see also Erber, 1974, and Gordon & Clark, 1974).

Summary

In the previous sections we reviewed evidence concerning losses of memorial functioning under states of depression and arousal and among the elderly, and acquisition of memorial functioning among the young. We believe the parallels found are attributable to

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4 Decrement with age have been attributed on the one hand to cohort (sociocultural, generational) differences (Schaie, Labouvie, & Buech, 1973; Schaie & Labouvie-Vief, 1974) and on the other hand to maturational differences (e.g., Horn & Donaldson, 1976). The resolution of this issue is not central to the present framework, according to which the age-related decline in capacity should limit some but not all memory functions.
reduced attentional capacity characteristic of these states and populations.

Criteria for Evaluating the Framework: Characteristics of the Automatic and Effortful Processes

The presentation of our framework is now complete. The remainder of this article deals with evidence relevant to an evaluation of the framework. In considering the extent to which this evidence supports our approach, it is useful to have in mind several specific characteristics of automatic and effortful processes. To this end, we will enumerate five characteristics that we consider to be central to the framework. They will provide a description of how particular conditions are expected to differentially affect the proposed automatic and effortful encoding processes. Collectively, they will serve as a criterion of our characterization of automatic and effortful processes, as well as the means of designating particular operations as instances of each type. Thus, taken together, the five statements define a set of converging operations for validating the proposed distinction between processes at either end of the attentional demand continuum.

Intentional Versus Incidental Learning

Automatic processes should occur equally effectively under incidental and intentional learning conditions because they require little capacity. Effortful processes will usually be superior under intentional learning conditions, because they require the allocation of attentional capacity and this will not necessarily occur under incidental learning conditions. It is possible, of course, that a cover task will force their occurrence.

Instructions and Practice

Explicit instructions about how to carry out an automatic operation will not increase its efficiency, nor will practice. Because of extensive prior practice, genetic preparedness, or both, automatic operations tested in the laboratory already function at asymptote. For effortful processes, however, both instructions on how to perform them and practice at actually performing them will usually be helpful.

Interference Among Operations

Automatic processes require little or no capacity and thus allow other nonautomatic processes to occur with minimal disruption. Effortful processes take part of the attentional capacity and thus limit the efficiency of other effortful processes but not of automatic processes. The presence or absence of such interference can be measured by performance in divided attention tasks in which there is both a primary and a subsidiary task. Decrements in performance on a subsidiary task are evidence of increasing attention demands by the primary task (e.g., Logan, 1978).

States That Alter Attentional Capacity

Under conditions of stress, attentional capacity is assumed to be reduced or reallocated (cf. Kahneman, 1973). Depressions and high levels of arousal are examples of such states. In any of these, one would expect to see the demise or diminution of effortful processes. This could be expressed in either a decrease in the number of such processes that continue to occur or in a reduction in the quality, accuracy, or efficiency with which a given process occurs. There should be no such reduction in the expression of automatic operations.

Developmental Trends

Earlier, we suggested that the automatic operations that encode information about frequency, spatial location, and temporal order may be operations for which people are genetically prepared. If so, automatic operations should begin to develop earlier in

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5 It should be noted that automatic processes can interfere with other processes, both effortful and automatic, by inducing competition between two incompatible responses, as in the Stroop effect. Here we are considering interference only in terms of attentional capacity limits.

6 Whether one believes that capacity is reduced by being taken from the cognitive system and allocated elsewhere in the total physical system or is simply reduced does not affect the predictions made within the present framework.
life and reach a level of maximal efficiency sooner than effortful processing mechanisms. Attentional capacity probably also increases during development. If true, this would have a greater impact on effortful processes than on automatic processes. Attentional capacity may also decline for elderly persons. Here, too, we would expect a minimal impact on the automatically occurring processes and a more substantial impact on those requiring attentional capacity.

It is, of course, possible to advance arguments about each of these criteria taken individually. For example, if practice does not improve performance on an encoding process thought to be automatic, one could argue that this lack of impact is due not to the operation of an automatic process but instead to the subject's use of an inefficient or inappropriate (i.e., effortful) strategy. Thus it is important to reiterate here that all five criteria must be satisfied for an encoding process to be located at the far (i.e., automatic) end of the attentional demand continuum.

Role of Task Variables

Both the automatic and the effortful processes we have been describing are encoding processes. Implementation of any of the proposed tests of the presumed differences between the two types of processes requires that some kind of cognitive task be given to subjects. Most often this task is a retention test. However, retention tests differ among themselves in the amount of effortful processing each involves. Most relevant here is the difference between recall and recognition tests, because the former generally involve more effortful processing than do the latter. Supporting this contention are the data indicating that the organization of learning materials and the development of retrieval schemes play larger roles in recall than in recognition testing (see Kintsch, 1977, for a review). Also, the relatively poor performance of young children on recall as compared to recognition tests can in part be attributed to their poor retrieval strategies (e.g., Brown, 1975b; Kobasigawa, 1974).

The development of a retrieval plan for a recall test (especially one that provides minimal cues) seems to be a demanding, conscious, voluntary (i.e., effortful) process, and this is of course something to be borne in mind when interpreting experiments.

Summary

Table 1 provides a road map for the following discussion. The headings of its columns and rows summarize the predictions made concerning the variation of automatic and effortful processes as a function of four subject states or conditions: both extremes of age, depression, and arousal. Table 1 also summarizes the predictions made concerning the effects of a number of specific experimental manipulations on automatic and effortful processes. Although a very large number of experiments are potentially relevant for an evaluation of our approach, they are not of course equally distributed among the cells of Table 1. To avoid a book-length review, we limited ourselves to the major evidence most germane to our viewpoint. In doing so, we have taken care not to distort the major trends of the literature. At the end of the review of this literature we will reconsider Table 1. The entries in its cells will then serve as a summary of the evidence relevant to the present view of memory processes.

Evidence Concerning Automatic Processes

Each of the proposed automatic processes will be discussed in turn with the intention of demonstrating that each conforms to the postulated nature of an automatic process.

Frequency of Occurrence

There is a growing body of empirical support for the assertion that adults are extremely sensitive to frequency of occurrence. In the laboratory, college students can with some accuracy estimate the frequency with which words occur in a list (e.g., Hintzman, 1969). There is also evidence that the frequency processing device keeps something approaching independent statistics for sets of highly similar events. For example, subjects can give frequency estimates for verbatim repetitions of sentences in the face of repetitions of the gist of the content of those same
<table>
<thead>
<tr>
<th>Process</th>
<th>Intentional vs. incidental learning</th>
<th>Effects of instructions and practice</th>
<th>Interference between operations</th>
<th>States altering attentional capacity</th>
<th>Developmental trends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted finding</td>
<td>No difference</td>
<td>No effects</td>
<td>Automatic processes</td>
<td>Depression</td>
<td>At maximal level early in life</td>
</tr>
<tr>
<td>Frequency of occurrence</td>
<td>+ Flexer &amp; Bower (1975); Hasher &amp; Chroniak (1977)</td>
<td>+ Hasher &amp; Chroniak (1977)</td>
<td>+ Experiment 3</td>
<td>0</td>
<td>+ Hasher &amp; Chroniak (1977); Experiment 1</td>
</tr>
<tr>
<td>Spatial location</td>
<td>+ Mandler et al. (1977); von Wright et al. (1975)</td>
<td>0</td>
<td>+ Mandler et al. (1977); von Wright et al. (1975)</td>
<td>0</td>
<td>+ Acredolo et al. (1975); Finkel (1973)</td>
</tr>
<tr>
<td>Temporal information</td>
<td>+ Zimmerman &amp; Underwood (1968); Miller et al. (1978)</td>
<td>0</td>
<td>+ Zimmerman &amp; Underwood (1968)</td>
<td>0</td>
<td>+ Brown (1973); + Mathews &amp; Fozard (1970)</td>
</tr>
<tr>
<td>Activation of word meaning</td>
<td>+ Dallas &amp; Merkle (1976); Foss &amp; Jenkins (1973)</td>
<td>0</td>
<td>+ Posner &amp; Snyder (1975)</td>
<td>0</td>
<td>+ Rosinski et al. (1975); Schiller (1966); + Comalli et al. (1962)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Predicted finding</th>
<th>Intentional better than incidental</th>
<th>Both improve performance</th>
<th>Effortful processes</th>
<th>Interference</th>
<th>Decreased performance</th>
<th>Decreased performance</th>
<th>Strong developmental trends</th>
<th>Decreased performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imagery</td>
<td>0</td>
<td>+ Prestianni &amp; Zacks (1974)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+ Levin et al. (1973); Rohwer (1970)</td>
<td>+ Hulicka &amp; Grossman (1967)</td>
</tr>
<tr>
<td>Mnemonic or elaborative devices</td>
<td>+ Bugelski et al. (1968); Keppel &amp; Zavortink (1969)</td>
<td>+ Rohwer (1973)</td>
<td>0</td>
<td>+ Experiment 4</td>
<td>0</td>
<td>0</td>
<td>+ Flavell (1970); Hagen et al. (1975)</td>
<td>+ Hulicka &amp; Grossman (1967); Hulicka et al. (1967)</td>
</tr>
<tr>
<td>Rehearsal</td>
<td>+ Hagen et al. (1973); Keeney et al. (1967)</td>
<td>0</td>
<td>+ Shulman &amp; Greenberg (1971); Johnston et al. (1970)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+ Flavell et al. (1966); Hagen &amp; Kail (1973)</td>
<td>+ Kausler (1970)</td>
</tr>
</tbody>
</table>

Note: + = cited studies support our framework; − = cited studies are contrary to our viewpoint; 0 = no relevant data.
sentences (Gude & Zechmeister, 1975). They also have the ability to keep separate the frequency-of-occurrence information for words that occur at varying frequencies in two different lists (Hintzman & Block, 1971, Experiment III; Reichardt, Shaughnessy, & Zimmerman, 1973).

Judgments of frequency, however they are made and whatever the nature of their representation in memory (see Hintzman, 1976, for a critical review of this issue), are apparently made on information that is independent from other memorial attributes. For example, frequency judgments are known to be independent of temporal information: They are independent of the recency of successive repetitions of items (Hintzman & Waters, 1970; Peterson, 1967), and they are also independent of the duration of those repetitions (Hintzman, 1970; Hintzman, Summers, & Block, 1975, Experiment III). There is also evidence that frequency judgments can be made independently of whatever mediates the ability to recall an item (Howell, 1973; B. J. Underwood, 1969).

There is then considerable laboratory evidence that adults are extremely sensitive to information about frequency of occurrence. It is also clear that rank-order frequency records (which have high correlation to actual counts) are available to adults concerning the frequency of English words (Shapiro, 1969), of single letters (Attneave, 1953), and even of pairs of letters (B. J. Underwood, 1971).

That we can rank order events with as seemingly little meaning or importance to us as bigrams suggests that the processing of frequency may fall into the domain of automatic processes. There is now some evidence bearing directly upon the automaticity of frequency counting. Explicit instructions given prior to item presentation do not improve the ability of subjects to discriminate among words occurring at different frequencies; subjects given general memory instructions do as well as informed subjects (Flexser & Bower, 1975; Hasher & Chromiak, 1977, Experiment 1; Howell, 1973; Rose & Rowe, 1976, Experiment 1).

Frequency sensitivity also shows another unusual property: It does not improve with either practice at the task or with explicit feedback about the accuracy of one's previous judgments (Hasher & Chromiak, 1977, Experiment 2). There is, furthermore, the suggestion in the literature that frequency assessment has another characteristic attributed to certain automatic processes: The skill develops at an early age and shows no subsequent improvement.

**Experiment 1: Frequency Sensitivity in Young Children**

Earlier work has shown that second graders were as sensitive to differences in the experimental frequencies of occurrence of words as were college students (Hasher & Chromiak, 1977). In Experiment 1, we compared the performance of children from kindergarten and the first, second, and third grades.

**Method**

**Subjects.** The subjects were 40 children who were students at a Catholic school serving suburban Philadelphia. Five boys and five girls were randomly selected from each of the following grades: kindergarten, first, second, and third. Mean ages for the students by respective grade were 5 years, 11 months; 6 years, 8 months; 7 years, 7 months; and 8 years, 6 months. One subject was replaced because of prior familiarization with the task. Two other subjects were replaced when they failed to follow the initial directions.

**Materials.** The materials consisted of a set of 10 slides, each of which contained a colored picture of a familiar object which had been obtained from a child's game. The first and last 5 slides were included as buffers to counteract any primacy or recency effects. The main body of the list consisted of 60 slides. Forty of these were composed of items occurring 1, 2, 3, or 4 times during the list. These critical items were distributed throughout the list so that each quarter of the main body of the list contained 1 item at each of the four possible frequency levels (1-4). Twenty filler items (presented once only) were also distributed throughout the list, with 5 fillers being present in each quarter of the list. There were in addition 4 critical items that did not occur on the study trial but did occur on the test trial. These represented the zero-occurring items.

Five separate versions of the presentation list were derived so that each critical item appeared once at each possible frequency level (0-4). Finally, these versions were constructed in such a way that a repeated item never followed itself in a list. The
test list consisted of a random arrangement of the pictures.

**Procedure.** The study-test method was used with the study trial proceeding at 3 sec per slide, and the test trial proceeding at 6 sec per item. Each subject was given general memory instructions prior to presentation of the list. The subjects were asked to give an oral frequency judgment for each slide on the test trial. They guessed when uncertain.

**Results and Discussion**

A 2 (sex) × 4 (grade) × 5 (frequency) analysis of variance was performed with repeated measures on the last factor. Using mean scores (see Figure 1) as the dependent measure for this analysis, the only significant effect found was for frequency, \( F(4, 128) = 218.04, p < .001 \). A Newman-Keuls test showed frequency judgments to be significantly different at each actual frequency level \((p < .01)\). Analyses performed on measures of accuracy of responses (deviation scores and number correct) and on medians also showed frequency to be the only significant factor.

Thus on both estimates and accuracy scores, there are no developmental differences in performance on this task. Kindergartners perform on a par with third graders. If it is fair to use these data together with those from the Hasher and Chromiak (1977) study, there appears to be no developmental change in frequency sensitivity from kindergarten to college. (Further information on this issue can be found in Goldstein, Hasher, Attig, & Kosteski, Note 2.)

Thus, while there is considerable evidence that the effortful memory skills develop with age over the grade school years, no such trend has been found for frequency tagging. While children become more proficient at overt and covert rehearsing, elaborating, imaging, naming pictures, and knowledge about their own memory skills, frequency sensitivity appears to be one of those rare skills that is outside of this domain. If we assume with B. J. Underwood (1971) that frequency sensitivity underlies performance in recognition memory, then the suggestion in that literature of a lack of a developmental trend would also make sense (Brown & Campione, 1972; Brown & Scott, 1971; Corsini, Jacobus, & Leonard, 1969).

At the other end of the developmental continuum, according to the framework, frequency sensitivity should not deteriorate in old age. There is some evidence from recognition tasks that suggests the elderly maintain an ability to perform on a par with college-age subjects (e.g., Schonfield & Robertson, 1966). This indirect evidence for the maintenance of frequency sensitivity is complemented by the results of Experiment 2, which deals explicitly with frequency tagging by aged individuals.

**Experiment 2: Frequency Sensitivity in the Elderly**

Experiment 2 attempted to extend the developmental results to old age. While there is, in the gerontology literature, substantial evidence of differences in learning efficiency between younger and older adults, our prediction is that the elderly will be as sensitive to differences in frequency as are young adults. Furthermore, providing subjects with specific information about a frequency test that will follow list presentation should have no more effect on the performance of elderly subjects than it does on the young.

**Method**

**Subjects.** The 40 young people in this study were undergraduates who ranged in age from 18 to 24 years. The elderly people were attending an annual meeting of the umbrella organization of senior citizens clubs in Philadelphia. No measure of physical or mental health was taken, although the fact that this meeting was held at the time of a
city-wide transportation strike suggests that the people we tested were resourceful and energetic. The 40 elderly subjects ranged in age from 56 to 80, with an average age of 67.5 years. The elderly subjects were paid $3.00 for their participation; the college students received course credit.

Materials. The materials were familiar words taken from a pool used by Hasher and Chromiak (1977, Experiment 2). The list was 70 slots long with critical items occurring 0, 1, 2, 3, or 4 times. Two unique sets of items were used, with five forms of each (allowing for the counterbalancing of items across frequency levels). Each form was used twice in each between-subjects condition. At each age level, half the subjects were informed with respect to the subsequent frequency test; the remaining subjects were uninformed. A test sheet on which words were presented in alphabetical order was prepared for each of the two different presentation lists.

Procedure. All subjects were tested in pairs, in a quiet room away from the mainstream of traffic. Words were presented visually at a 4-sec rate. Subjects filled in their own answer sheet by recording next to each word their estimate of its occurrence frequency. Subjects who were uninformed about the frequency test were told to “pay close attention because after you see the list, your memory will be tested.” In addition to this, informed subjects were told that their memory task would be to report how many times each word occurred. Both informed and uninformed subjects were given full instructions about the frequency task after the list was presented. For the informed subjects, these instructions were partially redundant with those given prior to presentation of the list.

Results and Discussion

The patterns of performance may be seen in Figure 2. It is clear that the elderly, like college-age students, increase their estimates of occurrence as actual frequency increases, \( F(4, 304) = 340.59, p < .001 \). Furthermore, as previously found, explicit instructions that frequency estimates would be required did not result in improved performance relative to that obtained with vague memory instructions. This was true for both the elderly subjects and the college students, \( F(1, 76) = 15.68, p < .001 \). The actual judgments made by the elderly differ from those made by college students, \( F(4, 304) = 4.65, p < .01 \). While the judgments of the elderly increased as actual frequency increased, they did so at a slower rate than was the case for college students; the largest discrepancy is seen then at the higher actual frequency levels. It is important to note that both the elderly and the college students showed significant increases in mean judgments at each increase in actual frequency (Newman-Keuls tests). Thus, both age groups discriminate at all points along this experimental frequency continuum.

As a further measure of the ability of different-age subjects to discriminate among frequencies of occurrence, a sensitivity measure originally proposed by Flexser and Bower (1975) was calculated for each subject. This measure is the correlation coefficient between true frequencies and judged frequencies and so is unaffected by any differences among subjects in the criteria used to assign particular values to an event.
All but one subject, an elderly person, produced coefficients that were significant \((r > .48)\). This person's correlation value was .10, suggesting that he was not at all sensitive to frequency differences. For the 39 remaining elderly subjects the mean correlation index was .74; for the college students, it was .80. These groups did not differ significantly from each other \((t\) test at .05).

That the actual judgments differed between these two groups of subjects is troublesome, particularly in light of evidence that showed that school-age children and college students assigned similar values. However, the meaning of these differences should be evaluated in light of three observations: (a) Both college students and the elderly are able to make judgments among items occurring over a deliberately truncated frequency range, a presumably difficult task; (b) the two groups appear to be equally sensitive to frequency differences (see also Attig & Hasher, in press); and, (c) there is a well-known conservative response bias that is characteristic of the elderly (Craik, 1969). In light of these considerations, we conclude that this evidence is generally in support of the assumption that frequency processing is a skill relatively invulnerable to the changes in cognitive performance typically associated with aging.

Experiments 1 and 2 have shown that frequency tagging is minimally affected by an individual's age. Automatic processing should also be unaffected by stress states that reduce cognitive capacity. The next study suggests that there are no differences between depressed and nondepressed adults in their ability to detect differences in the frequency of occurrence of items in a list.

Experiment 3: Sensitivity to Actual and Imagined Frequency inDepressed and Nondepressed Subjects

Both adults and young children are reasonably accurate in estimating frequency of occurrence. They are not, however, perfect. One possible source of this inaccuracy is confusion between actual repetitions of an event and subjective repetitions, that is, those due to thoughts or images evoked during presentation. An explicit demonstration of this confusion source for adults (Johnson, Taylor, & Raye, 1977) has also been extended to grade school children (Johnson, Raye, Hasher, & Chromiak, 1979). The latter study found that the confusion rates for children and adults were equivalent: young children were no more likely to be influenced by subjective occurrences when judging actual frequency than were adults. This finding is further confirmation of the present assumption that automatic processes show limited developmental trends.

Experiment 3, using procedures and materials from the Johnson et al. (1979) study, looked for differences in frequency judgments, as well as for differences in susceptibility to confusion from subjective sources, in depressed and nondepressed adults.

Method

Design. Subjects were first given a self-administered test of mood state, the Beck Depression Inventory (Beck, 1967). Following that, subjects looked at and then imagined colorful pictures of common objects across a sequence of eight alternating trial types. Subjects were then asked to judge the number of times they had seen, as opposed to imagined, each picture. Each picture was seen either one, two, or three times. Subjects imagined items occurring at each of these presentation frequencies either never, once, or three times. The design was thus a \(2 \times 3 \times 3\) (presentation frequency) \(\times 3\) (imagination frequency) factorial with the last two variables occurring within subjects.

Subjects. The 16 subjects ranged in age from 19 to 40 years. They were all living in an urban working class neighborhood. They were tested individually.

Materials. Mood state was assessed by a variant of the Beck Depression Inventory (BDI). The BDI in its usual format has been shown to be useful in both clinical (Beck, 1967) and empirical work (Miller & Seligman, 1973). Some validation work has been done with college students as subjects.

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7 Finding even one subject who cannot frequency tag poses a difficulty for aspects of the present framework. Automatic processes should be functioning under all conditions of consciousness—except perhaps where brain damage has occurred. This is of course a possibility among an elderly sample.

8 The similarity in these judgments obviated the need to calculate the Flexser and Bower (1975) sensitivity measure for these age groups.
(Goe, 1975; Miller & Seligman, 1973). The reliability and validity of this instrument have been demonstrated (Beck, 1967). Because our subjects were not seeking clinical treatment, we converted the test to a paper and pencil format where the subject in an isolated portion of the experimental room indicated his or her answers in relative privacy.

Thirty-six pictures representing common objects that would be familiar to young children were selected from children's books and photographed in color for slide presentation. The 36 pictures were assigned randomly to the nine conditions produced by the factorial combination of three presentation frequencies (1, 2, 3) and three imagination frequencies (0, 1, 3). Eight study trials alternated with eight imagination trials. On study trials, nine pictures were presented, none of which were repetitions. On test trials, subjects were asked to imagine six different items. Items were assigned to both presentation and imagination positions randomly, with the restriction that no item was ever imagined prior to its initial presentation and that items from different conditions were distributed as similarly as possible throughout the sequence. This procedure was then repeated to make up a second sequence of materials. No item was used in the same condition in the two assignments. The sequence of items for testing on the frequency judgment task was arrived at by constructing two random assignments of items. Each presentation sequence was used equally often with each final test sequence, creating four sets of materials. Each set was used twice with depressed subjects and twice with nondepressed subjects.

Procedure. Subjects were informed that we were interested in the relation between mood state and memory function. The BDI was then given to the subjects, who filled it out at their own pace. The memory portion of the experiment then began. The subjects were instructed that they would see pictures on a screen and were shown two examples that were not from the experimental set. They were then told that they would be asked to remember the pictures in a special way, which consisted of imagining the slide. To encourage the subjects to make accurate images of the slides, we asked detailed questions about each example slide (e.g., did the alligator have its mouth open?). During the experiment itself, no such questions were asked.

The alternating sequence of study and imagination trials was explained. Each slide was shown for 4 sec with a .8-sec slide-change interval. On the imagination trials, the experimenter gave the name of a new picture each 5 sec. Subjects were told the nature of each trial, study or imagination, as it was about to begin.

The frequency test was given immediately after the completion of the presentation phase. Each picture seen during presentation was shown one at a time and the subjects were to make a judgment of the number of times they had seen it. The example slides were used to clarify the fact that we did not want to know how many times they had imagined the slide. The frequency judgments were un-paced. When no response was offered, a guess was solicited.

Results and Discussion

The median BDI score in this sample was 8.5. A score of 9 and above has elsewhere been used to classify college students as depressed (Goe, 1975; Miller & Seligman, 1973). Subjects were divided into two groups, depressed and nondepressed, using the median as the criterion. The mean BDI scores were 15.0 and 4.9 for the depressed and nondepressed groups, respectively.

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*We thank Marcia Johnson and Carol Raye for the use of these materials.*
Judgments of presentation frequency. As can be seen in Figure 3, the performance of the depressed and nondepressed adults was identical. Mean estimates of the frequency of occurrence increased with actual frequency of occurrence, \( F(2, 28) = 101.71, p < .01 \), and the two groups did not differ significantly in their estimates, \( F < 1 \).

Judgments as a function of imagination frequency. Figure 4 shows the mean judged frequency at each imagination frequency for the two groups of subjects. Imagination frequency obviously influenced the judgments of actual frequency, \( F(2, 28) = 20.44, p < .01 \), but did so equally for the two types of subjects, \( F < 1 \).

Three conclusions may be drawn from Experiment 3. First, depressed and nondepressed subjects can estimate the frequency with which events occur. Second, both types of subjects show a tendency to confuse internally generated with externally experienced sources of information. Third, and perhaps most important to clinicians, depressed persons are no more likely to confuse factual with imagined information than are nondepressed persons.

In summarizing the evidence on frequency processing, the following points can be made: Frequency monitoring is done accurately by college students whether or not they are informed that this is their task. It is done as accurately by second graders as by college students, and even kindergartners and the elderly do it well. Preliminary evidence suggests that it is a task that benefits minimally from training, and is one on which depressed adults can do as well as nondepressed adults. It conforms very well, we believe, to our predictions about automatic memory processes.

Spatial Location

While the data on the processing of spatial location are neither as numerous nor as clearcut as those on frequency processing, they may be interpreted as suggesting that spatial location, like frequency of occurrence, is processed automatically. Some of the positive evidence comes from the recent report of Mandler et al. (1977). In these experiments, subjects were shown a matrix of 36 locations, 16 of which contained to-be-remembered items (small toys). Recall of both the objects and their locations was tested following instructions that both would be tested (intentional learning of location) or that only the objects would have to be recalled (incidental learning of location). Neither recall of the objects nor of their locations differed between these two conditions. The data from a third condition, which controlled for the possibility that the incidental subjects may be using some kind of spatial mnemonic in trying to remember the objects, lent further support to the conclusion of Mandler et al. that "active processing does not seem to be required for spatial information to be encoded into long-term memory" (p. 15).

Other findings are concordant with those of Mandler et al. in showing that recall of spatial location does not differ between intentional and incidental conditions, and that furthermore there is no trade-off between item and location information when subjects attempt to learn both. Included among the concordant data are those of von Wright, Gebhard, and Karttunen (1975), who presented subjects with a series of four-picture arrays and asked them to recall the pictures and the quadrant in which each had been presented. Prewarning about the spatial location test did not affect performance. Similarly, Zechmeister, McKillip, Pasko, and Bespalec (1975) found that memory for location of information on a page of text was not affected by instructions that spatial location would be tested. Nor did such instructions affect item recall.

There are, however, some apparently conflicting findings. Acredolo, Pick, and Olsen (1975) found that prewarning increased the accuracy of recall of the location of an event. This result is, however, hard to interpret in that no specific cover task was used in the incidental condition, and therefore what the child was attending to at the time of the event is not known. Nonetheless, even the children in this latter group gave location judgments that indicated the incidental encoding of this attribute. Other nonconfirmatory results come from Schulman's (1973) study. He used a procedure similar to that of von
Wright et al. (1975), except that the stimuli were words instead of pictures and the list was much longer. In Schulman’s study, instructions to learn the location of each word in its presentation array resulted in poorer recognition memory of the words than when subjects had prior knowledge of only the word test. Unexpectedly, performance on the spatial location test was also marginally poorer in the intentional than in the incidental condition. Schulman suggests that the instructions to learn location may have induced his subjects to use spatial mnemonics, which is for his experimental situation (25 words in each of only four possible positions) an inefficient strategy. It seems, then, that Schulman’s data may not be contrary to the position that spatial location is encoded automatically.

Thus the experiments that have compared incidental and intentional memory for spatial location are in general supportive of our approach. The only other aspect of automatic processing that has been tested in the spatial memory literature is that regarding developmental trends. According to our framework, encoding of spatial location will occur early, and developmental trends in memory for spatial location will fall short of those for memory tasks that require effortful processing. Children do show sensitivity to the spatial location of objects and events from a very early age (see Kail & Siegel, 1977). For instance, newborn infants will turn their heads toward the source of an auditory stimulus (Wertheimer, 1961). This suggests that the processing of spatial information is basic and automatic.

However, when children of different ages have been studied, it has been consistently found that accuracy of recall of spatial information improves with increasing age (Acredolo et al., 1975; Altm & Weil, 1977; Finkel, 1973; Mandler et al., 1977; von Wright et al., 1975). The developmental improvements reported in this literature may be attributed in part to testing procedures that require a great deal of planning and effort on the part of the child. Such procedures can of course prevent one from observing a child’s knowledge. Less effortful testing procedures, such as recognition tests, would be required to evaluate this prediction of the framework. (This point was discussed above in the section entitled “Role of Task Variables.”)

In summary, memory for spatial location of objects or events is usually as accurate when subjects expect to be tested for this as when they do not. This is true for both children and adults; but accuracy of spatial location recall currently appears to increase with age.

Temporal Information

Subjects can do a number of laboratory tasks that suggest that they have temporal information about past events available in memory (cf. B. J. Underwood, 1977). For example, subjects can judge both an item’s relative recency of occurrence (Yntema & Trask, 1963) and its absolute recency of occurrence (Hinrichs & Buschke, 1968). Subjects can judge the spacing between successive repetitions of the same item (Hintzman & Block, 1973), and they can judge the spacing occurring between two different items under at least some rehearsal conditions (Proctor & Ambler, 1975). Finally, subjects can judge the duration of events (Hintzman, 1970; Hintzman et al., 1975; Treisman, 1963).

Indeed, there is evidence that suggests substantial sensitivity to temporal information. For one thing, many of the temporal judgments that subjects have been able to make were done under incidental conditions (e.g., Hintzman & Block, 1973; Proctor & Ambler, 1975). For another, subjects can under incidental instructions locate an item in its proper tenth of a long list and can assign items that occurred twice to their two proper segments in the list (Hintzman & Block, 1971). There is also some evidence that approximate temporal information is kept even for a series of unrelated words that occur within a single experimental session (Hintzman, Block, & Summers, 1973), surely a difficult task.

While there is evidence that college students do have incidentally acquired temporal markers and considerable sensitivity to
time cues, there are few studies that have explicitly examined temporal information processing in terms of any of our criteria for automatic and effortful processes (Zimmerman & Underwood, 1968). Subjects in this study were given 12 lists of words to study with the knowledge that they would have to recall each list. At the end of this study–test series, subjects first recalled as many words as possible from the 12 lists. They were then given the 12 lists and asked to arrange them in order of presentation. Subjects then indicated which of two words from a particular list appeared earlier in that list. One third of the subjects were instructed only for free recall; another third were given recall instructions and were also told that their knowledge of the position of the lists would be tested; the final third were fully informed about all three test types.

Three pieces of evidence from the Zimmerman and Underwood (1968) study point to the automaticity with which temporal information is processed. First, instructions about the temporal tests did not improve the ability of subjects to judge list position; uninformed subjects did as well as informed subjects. Second, instructions did not influence performance on the test of memory for within-list position of items; uninformed subjects did as well as informed subjects. Finally, subjects informed about the temporal test or tests did as well on item recall as subjects prepared only for item recall; automatic processes do not disrupt the processing of effortful components of memory.

One study compares duration judgments made by subjects who either were or were not aware prior to the critical duration that such a judgment would be required (Miller, Hicks, & Willette, 1978). Subjects discriminated among three durations, and forewarning apparently had no significant impact on their temporal judgments.

With respect to the developmental criterion for automatic processes, there is evidence that memory for time is functioning at least by the age of 7. Children at this age can make recency judgments that are equivalent to those of older children and young adults (e.g., Brown, 1973). Further, even children as young as kindergarten age show memory for temporal sequence—if this is tested by either recognition or reconstruction (e.g., Brown, 1975b). Some evidence does, however, contradict this early development trend (Mathews & Fozard, 1970; von Wright, 1973). Mathews and Fozard, using a series of short lists rather than the more typical continuous judgment task, reported developmental trends from ages 5 to 12 years. Also, von Wright, using the Yntema and Trask (1963) procedure, found that 5-year-olds cannot make recency judgments, 8-year-olds cannot make difficult recency judgments, and 10-year-olds do quite well.

Thus the developmental evidence here is a bit less supportive than is the case with frequency tags. It can be pointed out, however, that under some measurement procedures (e.g., Brown, 1975b), very young children can do quite well at tasks that rely on temporal information.

**Activation of Word Meaning**

There are a number of lines of evidence in the experimental literature that support the contention that word meanings are automatically activated. Even in dichotic listening tasks, in which subjects typically report hearing little of a nonshadowed input, it appears that the meanings of nonshadowed words are activated at least briefly (Corteen & Wood, 1972; Smith & Groen, 1974; G. Underwood, 1977). Underwood found that context facilitated the shadowing of target words even when the context occurred in the unattended channel, thus indicating that meaning activation does not require attention. It can also be noted that the activation of word meaning does not appear to take attentional capacity away from other processing demands, at least as these are indexed by a probe reaction time measure in a divided attention task (Posner & Snyder, 1975).

Meanings of words can of course be accessed from written as well as from aural inputs. Activation of meanings from printed words may also be an automatic process, at least for literate adults reading familiar materials. In a visual analogue of the dichotic listening task, Dallas and Merikle (1976)
measured reaction time to name one of two rows of letters. The target row always formed a word; the other row could be a nonword or a word that was either associated or not associated to the target word. The presence of an associated word in the non-attended row facilitated reaction time (cf. Willows, 1974; Willows & MacKinnon, 1973) even when subjects were told before stimulus presentation which row of letters would have to be reported. Thus attention is not required for meaning to be activated when input is visual.

Probably the most persuasive evidence that meaning is derived automatically from printed words comes from the Stroop phenomenon. Most explanations of this phenomenon argue that the difficulty in naming the ink colors comes from interfering reading responses made to the incongruent color words (Dyer, 1973; Klein, 1964; Posner & Snyder, 1975). Subjects struggle to inhibit reading the words, but cannot do so completely; thus responses to both the word and the color are activated and are in conflict. This inability to inhibit an interfering process strongly indicates that the meaning activation process is an automatic one (Posner & Snyder, 1975).

Since it takes extended practice for meaning activation from printed words to become automatic (LaBerge & Samuels, 1974), the Stroop phenomenon should increase during the early school years as children learn to read. Using a standard version of the task (Schiller, 1966) and a picture-word version (Ehri, 1976; Rosinski, Golinkoff, & Kukish, 1975) maximal interference was found for second graders. Apparently, meaning is activated automatically from printed words for children as young as second graders. Furthermore, meaning activation from written words does not seem to become less automatic in old age. If anything, Stroop interference increases beyond the age of 50 (Comalli, Wapner, & Werner, 1962).

Yet another source of evidence on the automaticity of meaning activation comes from work on the processing of ambiguous words—words that have more than one distinct meaning. When the context is compatible with two or more meanings of a word (neutral context), multiple meanings are accessed (Conrad, 1974; Foss & Jenkins, 1973; Swinney & Hakes, 1976). Subjects are generally unaware of the multiple meanings aroused by the ambiguous words, and even those who do notice some of the ambiguities do not behave differently from those who do not (Foss & Jenkins, 1973; Swinney & Hakes, 1976). These data fit in nicely with the present viewpoint.

The situation is not so clear-cut when ambiguous words are presented following a context that is compatible with only one meaning for each word. Several experiments, employing different procedures, have obtained data indicating that multiple meanings of ambiguous words are accessed even in such biased contexts (Conrad, 1974; Foss & Jenkins, 1973; Holmes, Arwas, & Garrett, 1977; Warren & Warren, 1976). These results strongly support the contention that meaning activation is automatic, so automatic in fact that even a biased prior context does not prevent the accessing of irrelevant and possibly interfering meanings of an ambiguous word. However, Schvaneveldt, Meyer, and Becker (1976) and Swinney and Hakes (1976) have recently reported results indicating that only the compatible meaning of an ambiguous word is accessed in a biased context. The reasons for the discrepancies between the two sets of data are not known.

We have described several lines of evidence that a word activates its meaning automatically. This activation occurs without attention or awareness (dichotic listening tasks and their visual analogues), and it cannot usually be inhibited (Stroop and ambiguous word effects). Printed words appear to activate their meaning automatically in children as young as second graders and continue to do so into old age (as shown by the Stroop task). The effects of stress on this automatic activation are unclear; however, if automatic activation is one component of reading, then stress induced by task difficulty is known to disrupt performance (Hardyck & Petrinovich, 1970; Kolers, 1975). Stress induced by repetition of an automatic process also appears to reduce meaning knowledge (Coman...
tic satiation", Lambert & Jakobovits, 1960). Processes that become automatic only after extensive practice may thus function somewhat differently from "prepared" automatic processes.

Evidence Concerning Effortful Processes

Because the investigation of the effortful end of the continuum has occupied a central stage in the human learning literature over the past 10 years, there is considerable knowledge about these processes. Because of the extent of this literature and the availability of secondary sources—see Paivio (1971) on imagery, Bower (1970) on mnemonics, Postman (1972) on organizational processes, Flavell (1970) and Rohwer (1973) on elaboration, and Atkinson and Shiffrin (1968) on control processes—our reviews will be relatively brief and will concentrate on those discussions in the literature that are most relevant to our model.

Imagery

It is clear that imagery is a device that can be used to facilitate learning efficiency (Paivio, 1971). These facilitative effects have been seen across a variety of the standard learning tasks, including free-recall, paired-associate, recognition, and verbal-discrimination tasks (Paivio, 1971). Explicit instruction to subjects to use imagery in their learning typically facilitates the performance of those subjects relative to that of uninstructed subjects (e.g., Prestianni & Zacks, 1974).

The literature on the development of visual representations is contradictory at both the theoretical and the empirical levels (cf. Perlmutter & Myers, 1975). However, there is evidence that in associative learning tasks, imagery is a process whose likelihood of employment increases with age through the elementary school years (Levin, Davidson, Wolff, & Citron, 1973; Rohwer, 1970). Among the elderly, there is some evidence of a decline in the utilization of imagery as a device for learning in a paired-associate task (Hulicka & Grossman, 1967). We could find no evidence about the occurrence of the process among the depressed or the highly aroused.

Thus the use of imagery in associative learning appears to be an effortful process. It speeds learning, typically requires instructions to subjects, and shows some developmental change.

Mnemonic or Elaborative Devices

Encoding devices come in many guises. Basically, these are all devices in which the to-be-learned material is linked, via practice, to some additional material. The latter may be, as in the case of elaboration, some common referent or shared meaning (a low-strength associate), or, as in the case of mnemonics, a jingle or series of images. Despite the seeming ungainliness of a memory that appears to work better under conditions of maximizing input (i.e., adding to what would otherwise be simple material), the substantial evidence of the improvement in learning under such conditions is not to be denied.

The one-is-a-bun rhyming device can result in very high levels of recall, even when many lists are learned in succession (Bugelski, Kidd, & Segman, 1968). The method of loci, which may be viewed as either a general mnemonic or as an imagery mnemonic, also has considerable impact upon the ability of a subject to learn ordinarily difficult material (e.g., Bower & Reitman, 1972). Adding sentence-like links to pairs also facilitates learning (e.g., Rohwer, 1973).

It should be noted that subjects do not spontaneously employ many of these devices. It is a rare subject in a free-recall task who reports using a rhyming device (e.g., Hasher, Riebman, & Wren, 1976). Indeed, in experiments designed to show the utility of such devices, subjects often received extensive training in them prior to the beginning of the experiment proper.

Young school-age children are particularly unlikely to use such elaborative devices (Flavell, 1970), as is also the case for the elderly (Hulicka & Grossman, 1967; Hulicka et al., 1967). College students, however, do report their use (Bugelski, 1962; Montague, Adams, & Kiess, 1966). Both children and adults have been shown to benefit from in-
structions to use verbal links between members of pairs (Rohwer, 1973).

Although elaborative and mnemonic devices clearly facilitate learning speed, either explicit instruction or substantial training is required for them to be employed in an optimal manner. Thus, the available evidence suggests that the use of elaborative and mnemonic devices requires effort.

**Organization and Clustering**

Organization is a process that imposes structure where little existed (Tulving, 1962) or that capitalizes upon a presumed preexperimental structure (Bower, Clark, Lesgold, & Winzenz, 1969). Clustering (Bousfield, Cohen, & Whitmarsh, 1958) may be considered to be a special case of organization that occurs when strong preexperimental relations exist among events in an environment. The presence of an organization among to-be-remembered items, even if it is a previous subject's organization of unrelated words (Earhard, 1967), will facilitate the learning of a naive subject. The more obvious the organization the greater is the facilitation, as seen in the level of recall of both children and adults with blocked versus randomly arranged lists of categorized words (Cofer, Bruce, & Reicher, 1966; Kobasigawa & Middleton, 1972). College students can be trained, either with explicit instructions or with experience on successive lists, to systematically organize lists of related words (Postman, Burns, & Hasher, 1970). Such training makes the subjects faster learners on successive lists of words (Postman et al., 1970).

Organization is a process in which there are considerable developmental trends (Moely, Olson, Halwes, & Flavell, 1969; Neimark, Slotnick, & Ulrich, 1971). Young children show organizational groupings that are considerably smaller than those of older children and adults (Hasher & Clifton, 1974; Neimark et al., 1971). This is thought to account in part for the considerable differences in speed of learning over the grade school to college years (e.g., Hagen et al., 1975). It should be noted that when young children are carefully taught to use the organizational patterns of college students, they can do so; and that such a change in organizational patterns yields substantial increases in their levels of recall, albeit not to the level of adults (Liberty & Ornstein, 1973).

High levels of arousal do appear to disrupt category clustering in free recall (Hörmann & Osterkamp, 1966; Schwartz, Note 1, both as cited by Eysenck, 1976). And the elderly appear to show lower levels of organization than do younger adults (Craik & Masani, 1967; Denney, 1974; Hultsch, 1971, 1974). Specific instructions to use these processes facilitates the recall of the elderly (Hultsch, 1971).

Organization, then, appears to fit our criteria for effortful processes. It aids learning efficiency; it is an activity that benefits from training; it shows life-span changes; and it is disrupted by overarousal.

**Rehearsal**

The likelihood of recalling an item on an immediate test of memory is thought to be in part a function of the number of rehearsals an item receives during the study phase (Rundus, 1971). This is especially true if the rehearsals are elaborative rather than maintenance in nature (Woodward, Bjork, & Jongeward, 1973). There is substantial evidence of rehearsal pattern differences among persons of different ages. Older children are more likely to rehearse groups of items than are younger children. The latter are more likely to rehearse whatever item has just been presented (Cuvo, 1975; Ornstein, Naus, & Liberty, 1975). The latter is of course an inefficient strategy for facilitating recall; indeed, there is some evidence that it disrupts recall. There is also evidence, however, that the rehearsal patterns of young grade school children can be changed by careful instructions and that these then succeed in boosting levels of recall (Hagen, Hargrave, & Ross, 1973; Keeney, Cannizzo, & Flavell, 1967). Furthermore, spontaneous rehearsal is known to increase with age (Hagen & Kail, 1973). Lip-reading observations of children during a delay between presentation and recall have found little activity among 5-year-olds and substantial activity among 10-year-old children.
olds (Flavell, Beach, & Chinsky, 1966). Finally, high school youths and adults have been found to be efficient rehearsalers, at least insofar as they spend available time rehearsing items they did not get correct on a prior test trial (Masur, McIntyre, & Flavell, 1973; Zacks, 1969); young children are less likely to spend their time so selectively (Masur et al., 1973). Kausler (1970) has reported that the elderly show decrements in their employment of rehearsal processes.

Rehearsal thus appears to fit our category of effortful processes. Certain types of rehearsal improve recall, and there are lifespan changes of the sort expected within our framework. In addition, rehearsal of items for short-term memory has been shown to require attentional capacity as measured by various subsidiary tasks. Furthermore, the amount of capacity required appears to increase with memory load (e.g., Johnston, Greenberg, Fisher, & Martin, 1970; Shulman & Greenberg, 1971).

Experiment 4: Rehearsal, Elaboration, Recognition, and False Recognition

A substantial literature now suggests that one component of the automatic activation of word meaning is the spread of this activation to an associate of the presented word (e.g., Schvaneveldt & Meyer, 1973; Warren, 1974). Activation of an associate can be automatic, but it can also have a strategy or set component that amplifies or enhances the activation (Shulman & Davison, 1977; Tweedy, Lapinsky, & Schvaneveldt, 1977). Other research suggests that activation of the associate has only a momentary duration (e.g., Conrad, 1974; Meyer, Schvaneveldt, & Ruddy, Note 3). Thus, if after an elapsed of a substantial amount of time (e.g., the time required to present a list of 70 or so words) any evidence is seen of the persistence of list item associates, processes other than the automatic ones that activated the associates in the first place must have been operating in that interval. One such effortful process is rehearsal. Indeed, elaborative rehearsal may be particularly likely to incorporate associates into attention-receiving item pools.

The impact of long-lasting associates, presumably via the mechanism of rehearsal, may be seen in a number of situations. One is seen in the few overt intrusions made in a free-recall test trial. Another is in the false recognition paradigm (e.g., Underwood & Freund, 1968). The latter is a task in which subjects see a series of words they are instructed to "remember." The memory test is then a multiple-alternative, forced-choice recognition task. The alternatives typically include the target plus an unrelated control, together with one or two semantically or phonemically related words. When college students fail to recognize the target, they are more likely to identify as old an associate of a target item than they are a rhyme or an unrelated word. Two covert processes are required for this pattern of results to obtain: (a) At the time an item is presented, it activates an associate (or meaning network, or implicit associative response); and (b) while subsequent items are being presented, the subject must be actively rehearsing at least some of the associates. The first of these processes is assumed to be at least partly automatic. The second is effortful. If, as we argue, depressed persons engage in less active, less effortful processing than do nondepressed persons, a different distribution of errors should be seen for the two groups. When a recognition error is made, the depressed subjects should show less of a tendency than the nondepressed to identify an associate as being an old item. It should be noted that no difference in recognition accuracy between the two groups is expected if, as Underwood (1971) has argued, recognition is based on frequency tags, the latter being an automatic process on which depressed and nondepressed should be equivalent. These two predictions were tested in Experiment 4.

Method

Materials. The presentation list consisted of 40 target words. The recognition list was a four-alternative, forced-choice test with items created in the following manner: For each target word there were three distractors, which included a high-frequency associate of the target, an item acoustically similar to the target, and a neutral word unrelated to the target.
The targets and distractors were chosen according to the following criteria: The target word was a word in the Palermo and Jenkins (1964) norms having an associate that was produced by at least 50% of the respondents. The word also had to have another word that was judged by the experimenters to be acoustically similar to the target. Where possible, these words and the neutral words were chosen from the high-frequency ranges of the Thorndike-Lorge (1944) norms and were of equal length. Finally, none of the words chosen had a negative connotative meaning, as judged by the experimenters. (Pilot research had indicated some tendency for depressed persons to select words having negative connotations. For further details, see Iavecchia and Hasher [Note 4].) After the 40 sets of 4 items had been selected, 10 additional items were chosen by the same frequency and length criteria to serve as buffer items divided equally between the beginning and the end of the presentation list.

Each of the 50 presentation words was typed in capitals on a 3 x 5 inch index card with one word per card. A single random ordering of the presentation list was then devised and this ordering was given to all subjects. The order of the 40 target words on the recognition test was different from the input order. The recognition test was presented in booklet form with each set of target and three distractors presented on a single line. The position of the correct word on each line was randomized with the constraint that the correct word occurred in each position equally often.

Procedure. The subjects first answered the questions on the BDI (see Experiment 3) and were then read instructions about the memory task. They were told that they would study a number of familiar words and then be tested on them; no specific mention was made of the type of test that would be given. Subjects turned the cards of the presentation list over at a 3-sec rate, which was paced by recorded clicks. Subjects pronounced each word as they saw it. The recognition test was given immediately after the end of the presentation list. Subjects were under no specific time limit, and they were instructed to guess when uncertain.

Subjects. A total of 214 subjects enrolled in the introductory psychology course participated. Because 9 subjects had to be eliminated for failing to follow instructions, a sample of 205 subjects remained.

Results

Classification of mood state. Subjects were ordered from lowest to highest on the basis of their BDI score. The mean score on the BDI was 8.48 as compared to a mean of 9.00 reported by Miller and Seligman (1973). Subjects were then assigned to depressed and nondepressed groups in two different ways. The first method was based on a median split. The median was 7.00. The second classification, believed to be more sensitive to real differences in mood state, was based on extreme quarters of the distribution. On this basis, nondepressed subjects were all those scoring from 0 to 4 inclusive, plus two subjects randomly selected from among those scoring 5, to make a total of 51 nondepressed subjects. Depressed subjects were all those who scored 12 or above (51 people). The highest score in this sample was 28. Results will be reported for the analysis of the extreme groups only, since little difference was seen between the analyses based on the two classification methods.

Recognition performance. The total number of errors made by the two groups was very similar (Table 2). These values were not statistically significant, $t(100) < 1$. Thus, as predicted, depressed and nondepressed persons appear not to differ in their ability to recognize old words.

False recognition performance. Also seen in Table 2 are the distributions of errors into three categories: associative, acoustic, and neutral. There is a clear suggestion in Table 2 of a difference between depressed and nondepressed subjects in the types of errors made. The interaction between subject type and error type is significant, $F(2, 100) = 9.16, \ p < .01$. Simple main effects revealed that the interaction lay entirely in the rate of associative items selected as “old.” Depressed subjects chose fewer of these than did nondepressed, $F(1, 100) = 7.56, \ p < .01$. The two groups did not differ in the rates

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Total errors</th>
<th>Associative errors</th>
<th>Acoustic errors</th>
<th>Neutral errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nondepressed</td>
<td>10.94</td>
<td>5.63</td>
<td>2.76</td>
<td>2.55</td>
</tr>
<tr>
<td>Depressed</td>
<td>10.41</td>
<td>4.22</td>
<td>3.27</td>
<td>2.92</td>
</tr>
</tbody>
</table>

Note. Subjects are classified according to extreme quartile categories. *n = 51 per group.
with which they chose either rhymes or neutral words as old items ($F_s < 1.38$).

It is clear from these results that depressed and nondepressed subjects differ from each other in a highly specialized manner. They are equivalent in their ability to recognize old items accurately, but they differ in the kinds of recognition errors they make. In particular, the depressed are less likely than the nondepressed to select as an old item a word that is a high-frequency associate of that old item. This suggests that during list presentation the depressed subjects included fewer of the activated associates in their rehearsal pools, or alternatively that they engaged in less active rehearsal than did the nondepressed subjects. As a consequence, the depressed subjects had fewer associates available at the time of the recognition test to act as a source of confusion with the target item.

The data from Experiment 4 support our view that depressed and nondepressed college students differ in their rehearsal processes. While the exact nature of this difference cannot be specified—and may be due to the number of rehearsals or to the content of the rehearsal pools—it is clear that one consequence of this difference is the lesser availability of associates at the time of the recognition test. Assume further that recognition is a task that can, at least under some circumstances, be based on frequency tags and that frequency is an encoding attribute tagged automatically; then the data also suggest that depression does not disrupt automatic processes involved in the recognition of old items, and they agree with results reported in Experiment 3.

This concludes a brief review of some of the effortful processes. These appear to differ from automatic processes in a number of ways: They require intention to be employed, they benefit from training, and they show pronounced developmental changes between early childhood, young adulthood, and old age.

Conclusions

Current evidence suggests that encoding processes may lie along a continuum from automatic to effortful in terms of the capacity they require. Processes at the ends of this continuum differ from each other on a number of important dimensions: (a) the consistency with which they are used; (b) the necessity for intention; (c) their potential for training-related improvement; (d) their susceptibility to attentional decrements; and (e) their patterns of developmental.

A summary of the data is presented in Table 1. While it is clear that not all the evidence is positive, the preponderance of it appears to be so. Where the findings are mixed (e.g., on the development of processing mechanisms for spatial location and temporal order), task-related retrieval variables may well be operating. Clearly, the empty cells of Table 1 suggest that a substantial research effort is needed before an overall evaluation of the present viewpoint can be made. In the meantime, the framework stands on a reasonably firm empirical base and it offers a rather unusual opportunity in the field of memory—the chance to integrate a broad range of adult memory phenomena with lifespan developmental differences and with changes associated with stress states.

The framework proposed and evaluated in this article is conceptually similar to a number of important recent theories in cognitive psychology. It nonetheless makes some unique contributions: The framework provides an extension of concepts from the traditional areas of attention and perception to the area of longer term encoding processes in memory. The framework also applies these concepts to a broad range of subject populations and states and shows the continuity of memory functioning across these variables. Finally, the framework specifies the existence of a small set of basic cognitive processes that encode certain attributes of information directly into long-term memory throughout the life span and in spite of any alterations in capacity from stress.

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2. Goldstein, D., Hasher, L., Attig, M. S., & Kosteski, D. The development of frequency sens...


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