COGNITIVE EFFORT, ENCODING VARIABILITY, AND SPACING EFFECTS:

A SEMANTIC HABITUATION MODEL

BY

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Abstract

Two experiments were conducted investigating the within-list massed practice- distributed practice effect (MP-DP effect). A model based on aspects of habituation (Hintzman, 1974), backward memory scan (Jacoby, 1978), and encoding effort (Johnston & Uhl, 1976) was proposed to account for spacing effects within an encoding variability framework (Melton, 1970; Shaughnessy, 1976). The energy model described spacing effects as a product of effortful semantic processing enjoyed by distributed repetitions. The temporal proximity of massed repetitions was seen as providing a recent, task-fulfilling trace of a target word which obviated futher processing and resulted in an impoverished memory trace at the second presentation of a target word (Jacoby, 1978). The model rested on three assumptions. They are; a) trace 'strength' is a result of total cognitive energy (effort) allocated to semantic processing (encoding) of a to-be-remembered-item (TBRI), b) at short lag (massed practice) the trace resultant from the first presentation of an item is present during encoding of the second presentation of that item, and c) processing effort on the second presentation of a repeated massed item is subjugated by task demands and recency of the first presentation of that item. These assumptions were tested in a factorial cross of spacing and encoding condition which typifies the

paradigm employed in encoding variability studies. Subjects performed orienting tasks on lists of words and were then tested for retention of the words by recognition (Experiment 1) and recall (Experiment 2). Repeated words were followed by a different orienting question on the second presentation, one-half of the time. This comprised the encoding-different condition. If the second presentation of a word involved the same orienting task, the condition was said to be an encoding-same condition. Specific predictions concerned the presence of spacing main effects, encoding main effects of some kind, and the critical spacing x encoding interaction. Results from the recognition experiment supported the energy model by showing an increase in retention for both encoding and spacing. A spacing x encoding interaction was also present. Although one encoding variable was an ineffectual manipulation, predictions concerning the ordering of condition scores based on total effortful semantic processing were upheld by the data. Recall results were less supportive of the energy model. Main effects were observed for both the spacing variable and the encoding variable. The predicted interaction was not present. Distributed items benefited as much from variable encoding as did massed items. Predictions based on total effortful semantic processing were not supported. The existence of retention measure

differences (recognition versus recall) under identical learning conditions prompted a restatement of the energy model which addressed retrieval differences and how various memory measures may access memory traces in a differential manner (Craik, 1981; Glenberg & Smith, 1981). Recognition tests are seen as removing much of the advantage of distributed learning. Recall is seen as a cue-scarce retrieval environment where varied encoding context and distributed repetition have independent, but additive, effects. Suggestions are made for future research as a replication and extension of this project as well as for more general questions posed by the within-list MP-DP effect.

Table of Contents

Cognitive Effort, Encoding Variability, and Spacing Effects: A Semantic Habituation Model

For once presented lists where some items are repeated, memory performance following distributed practice (DP) has consistently been shown to exceed memory performance following massed practice (MP). The robustness and generality of the within-list massed practice-distributed practice (MP-DP) effect is well documented (Hintzman, 1974; Underwood, 1970). The term spacing effect has often been used interchangeably with MP-DP effect in such situations. However, a distinction must be drawn between two types of spacing effect: The MP-DP effect, and the lag effect (Hintzman, 1974; Underwood, Kapelak, & Malmi, 1976).

The MP-DP effect refers to situations where repetition of a stimulus item occurs with either no intervening stimulus (MP) or with a minimum of one intervening stimulus (DP). Distributed practice is variously reported in terms of average elapsed time or average lag. Lag refers to the number of intervening stimuli between successive presentations of the same stimulus item. The lag effect refers to the relationship between a measure of retrieval and the number of interpolated stimuli; thus, retrieval is reported as a function of lag. A lag of zero is functionally equivalent to MP, while lag reported as a number of interpolated stimuli represents a breakdown of DP. Memory scores from lag studies typically yield a negatively accelerated increasing function with retention increasing as lag increases. Such functions asymptote at about 10-15 items, or 15-20 seconds. While similarities exist among these concepts, the lag effect is not as general as the MP-DP effect (Hintzman, 1974). Under certain experimental conditions the two terminologies may be equated. In the following discussion the term spacing effect will be used to refer to those situations whereby the two effects are considered equivalent.

The finding that DP produces higher retention than MP, when holding number of repetitions constant, has received much attention. In his review of the spacing effect Hintzman (1974) considered several possible explanations for the superiority of retention under DP conditions. The explanations may be grouped as to whether the mechanism thought responsible for the spacing effect is of a voluntary or an involuntary nature. Voluntary mechanisms included the attenuation of attention hypothesis and several of a class of encoding variability hypotheses. Involuntary mechanisms included an habituation model and consolidation theory. Despite Hintzman's precaution that little evidence supported a voluntary mechanism explanation, and his desire to see involuntary process explanations considered by cognitive psychologists, the major thrust of research investigating spacing effects has remained focused on voluntary processes in general, and on encoding variability in particular.

Consideration of spacing effects under variable encoding models involves attempts to produce situations whereby MP items and DP items evidence statistically indistinguishable memory scores. This attenuation of spacing effects must be brought about by enhanced memory for MP items due to some specific experimental manipulation. This situation is desired both because it may provide parameters to the spacing effect and may elucidate some critical factor which gives rise to the effect. Generally, researchers have attempted to manipulate encoding of stimulus, number of repetitions of stimulus, and lag or MP-DP. The majority of research in this area has not shown satisfactorily attenuated spacing effects, and has led to conclusions that enhanced recall under DP conditions is not due to variable encoding.

Recently, Jacoby (1978; Cuddy & Jacoby, 1982) has offered an explanation of spacing effects based on intra-list forgetting and reconstruction of encoding solutions. This paper will combine Jacoby's construction hypothesis mechanics with the work of Johnston and Uhl (1976) on encoding effort. Johnston and Uhl (1976) proposed an effort model which combined habituation notions and attentional resources to provide a processing account of spacing effects. Discussion of encoding variability, construction, habituation, and effort shall center on the relative contributions of each to an energy account of processing activities involved in producing spacing effects. The first section is a review of encoding variability studies. Section two is devoted to some theoretical implications for memory traces and processing tasks. The third section develops Jacoby's (1978) reconstruction hypothesis and habituation/effort theory (Hintzman, 1974; Johnston & Uhl, 1976). Similarities among the perspectives will be emphasized. The last section is devoted to development of an energy model which incorporates various aspects of the aforementioned perspectives. Central to the thesis are the ideas that; a) trace 'strength' is a result of total cognitive energy (effort) allocated to semantic processing (encoding) of an item, b) at short lag (and MP) the trace resultant from the first presentation (P1) of an item is present during encoding of the second presentation (P2) of that item, and c) processing effort on the second presentation (P2) of a repeated item is subjugated by task demands and recency of P1 (first presentation) during acquisition of to-be-remembered-items (TBRIs).

Encoding Variability

The encoding variability explanation of spacing effects (Melton, 1970) has dominated spacing effect literature, but has produced few satisfactory results (Bird, Nicholson, & Ringer, 1978; Maskarinec & Thompson, 1976; Shaughnessy, 1976). The logic of encoding variability is that, as the intervals between successive presentations of a TBRI increase, the greater the likelihood of encoding that TBRI in a different manner. This differential encoding may include temporal, semantic, or other contextual elements. The result of differential encoding was thought to produce either; a) more independent traces of a TBRI which summate, thus raising its probability of recall, or b) more paths or cues to one trace which again would increase the probability of recall for a given item. The introduction of two different encoding tasks in a MP situation should induce subjects to encode differentially, thereby resulting in attenuation of spacing effects by the elevation of memory performance on MP items to the level observed for DP items.

Control over variation in encoding is brought about by the use of semantic orienting tasks. The orienting task (Craik & Tulving, 1975; Jacoby, Craik, & Begg, 1978) is used to drive subjects' cognitive systems to encode items in a particular manner. Semantic orienting tasks include; yes/no judgments, providing definitions, constructing sentences, producing free associates, describing similarities among or differences between two words (relational processing), and a variety of rating scales using either a Likert-type scale or a bipolar scale. Much debate has centered on the degree of control an orienting task exerts over a subject's encoding (Coltheart, 1977; Jacoby, Craik, & Begg, 1978; Postman, Thompkins, & Gray, 1978). Although variation in encoding among subjects is largely uncontrollable (not the least of which may be accounted for by what 'activation' of a concept means between subjects), it is generally agreed that semantic orienting tasks ensure that a particular type of processing or trace attribute is present in subjects' memory trace, irrespective of any incidental elaboration on the part of subjects (Elias & Perfetti, 1973; McMurray & McIntyre, 1981).

To illustrate the effect on a memory trace of a semantic orienting task consider the situation whereby a subject is presented a simple orienting task to be performed on a given TBRI. The trace resultant from this task will be a multicomponent bundle of attributes (Tulving & Watkins, 1975; Underwood, 1969). Craik and his associates (Craik & Lockhart, 1972; Craik & Tulving, 1975; Jacoby & Craik, 1979) refer to a memory trace as a record of the perceptual/cognitive analyses performed at the registration of an item. Rose (1984) maintains that a trace consists of some element of the nature of the stimulus, the processing operations carried out on that stimulus, and a variety of contextual elements (cf. Glenberg, 1979; Glenberg & Smith, 1981). The trace resultant from performing orienting task A, for example, results in a minimum of three separable components; a) some general featural element of semantic access, b) some processing pathway specific to the cognitive operations required to fulfill the orienting activity, and c) some primary attribute that is a direct result of the processing path and is associated to the TBRI.

The investigation of spacing effects within an encoding variability framework involves variants of a basic paradigm employing a minimum of two variables; a) spacing and b) encoding condition. Spacing may be simple massed versus distributed presentation or may consist of several lag intervals. Encoding conditions can minimally be described by an encoding-same condition and an encoding-different condition where either one or two orienting tasks are presented at successive presentations of TBRIs. The dependent measure is some form of retention test. Results from studies testing the above logic are largely ambiguous, and not generally favourable to an encoding variability explanation of spacing effects (Bird et al, 1978; Hintzman, 1974; Maskarinec & Thompson, 1976; Shaughnessy, 1976). The reasons appear to be twofold; a) type of experimental materials used, and b) organizational and list factors resultant from the orienting tasks employed.

A large portion of the literature concerned with encoding variability has used homographs as TBRIs (Davis, Lockhart, & Thompson, 1972; Gartman & Johnson, 1972; Johnston, Coots, & Flickinger, 1972; Thios, 1972; Winograd & Raines, 1972). This early research followed the logic that biasing subsequent massed presentations of a homograph (e.g., RING as in wedding; and RING as in bell) should provide sufficient differential encoding so as to attenuate spacing effects. In virtually all of these experiments spacing effects were found for same-encoding conditions, and the spacing effect was not attenuated on the basis of MP equivalence on differentially encoded items. The use of homographs has since been deemed an inappropriate test of encoding variability explanations of the spacing effect (Maskarinec & Thompson, 1976; Rose, 1980, 1984). Eliciting two different semantic senses of a word is nominally identical to presenting two different words. The expectation that variable semantic senses should summate on the basis of orthographic similarity is spurious (cf. Reder, Anderson, & Bjork, 1974).

Consideration of organizational and list factors centers on a predilection on the part of some researchers to use rating scales in variable encoding studies. A series of similar experiments, which all failed to find effects of variable encoding, employed rating scales as orienting tasks (Bird et al, 1978; Shaughnessy, 1976; Young & Bellezza, 1982). All of these studies were a variation of the same basic paradigm. Variables manipulated were same versus different semantic encoding tasks and MP versus DP. The semantic orienting tasks used in all three experiments were rating scales on such dimensions as; pleasantness, imageability, size, active/passive, etc. Same-encoding conditions consisted of applying the same rating scale to a target item each time it was presented. Variable encoding conditions required a change in rating scale from one presentation of a TBRI to its next presentation. Results from these experiments were either equivocal or showed a superiority for same task encoding.

The use of within-list rating scales produces a potentially biasing factor which may cause data to be artefactual. Shaughnessy (1976) and Rose (1984) point out that applying a rating scale to a series of items requires the adoption of some standard by which to rate ensuing items. That standard may be in the form of comparison to other list items. Thus the use of a rating scale may produce intra-list, inter-item associations. Also, the rating task itself may become a mediator for recall of TBRIs. The repetition of a TBRI in the same encoding conditions of these experiments may serve to strengthen inter-item associations and/or list mediators. Any beneficial effects of variable encoding may be obfuscated if the strengthening of inter-item associations is a more salient cue for recall than the aspects of a trace resultant from variable encoding. Presumably the variably encoded items did not enjoy the same effects of list mediators as did the homogeneous task items. A lack of attention paid to orienting tasks, possible interactions between tasks, or between task and list, seems to characterize research pertaining to the additivity of differential semantic processing.

The inescapeable conclusion of the above discussion is that spacing effects cannot be overcome by variable encoding manipulations when identical tasks are used under massed and distributed conditions. Similar conclusions have been drawn on the basis of variable encoding studies (Bird et al, 1978; Maskarinec & Thompson, 1976; Shaughnessy, 1976). While variable encoding, as conceptualized by Melton (1970), may be deemed an inadequate account of spacing effects, the variable encoding methodology may serve as an effective instrument in the investigation of effort, or habituation, models. The issue of task overlap and specific effects of orienting tasks must first be addressed.

Trace Implications of Additive Processing

The term task overlap (Glenberg & Smith, 1981) refers to the number of processes two (or more) tasks share, and or the number of common attributes evoked. In consideration of task overlap and task selection vis-a-vis effort, discussion will be confined to tasks that represent the semantic domain of processing (Craik & Lockhart, 1972). Although highly effortful 'nonsemantic' tasks are available they do not lead to high levels of recall. While pure nonsemantic processing is probably a misnomer, orienting tasks which stress semantic aspects of word concepts are thought to lead to higher levels of retention because they are 'natural' units of remembrance (Postman et al, 1977). The statement that effórt leads to high retention has considerable evidence (Auble & Franks, 1978; Johnston & Uhl, 1976). However, McMurray and McIntyre (1981) illustrated that within the semantic domain of processing, there exists an ordinal depth, as defined by progressively more difficult semantic tasks. Using a procedure previously employed by Seamon and Virostek (1978) to independently establish depth across domains (shallow physical to deep semantic), McMurray and McIntyre established depth within the semantic domain with cognitive effort the predictor of both depth and retentiveness.

McMurray and McIntyre (1981) had subjects practice nine semantic orienting tasks and then judge the relative difficulty of each task. The resultant rank order of task difficulty was thought to be an indicant of amount of cognitive effort. This ordinal scale was used to predict the rank order of recall scores by groups of subjects who performed one of the tasks in an incidental learning study. Recall protocols supported the predictions derived from the ordinal depth rankings. Although McMurray and McIntyre termed the rank ordering of tasks a semantic continuum, the concept implied may be misleading. McMurray and McIntyre did "confirm the hypothesis that within a single domain greater depth of processing, as defined by tasks involving progressively deeper cognitive analyses, is associated with higher levels of retention (1981, p211)." What has not been shown is whether the deepest semantic analysis incorporates all the attributes (or retrievability) of less deep semantic analyses. Can performance of two shallow semantic analyses summate to produce higher recall than a single deep analysis or a repeated and redundant deep analysis? In the true sense of depth of processing, additional analyses at a shallower depth cannot enhance recall.

Klein and Saltz (1976) conducted an incidental learning experiment quite similar to those of Shaughnessy (1976), Bird et al (1976), and Young and Bellezza (1982) with the exception that all presentations of TBRIs were massed. The experiment involved the use of rating scales and, as such, is subject to the previous criticisms of said tasks. What makes the Klein and Saltz (1976) study interesting is that the rating tasks were pretested for orthogonality. Prior to the experiment, Klein and Saltz had an independent group of subjects rate the similarity between several bipolar rating scales. Resultant correlations yielded a scale of orthogonality between dimensions which were either high, medium, or low. In the ensuing experiment, Klein and Saltz had subjects perform either one or two rating tasks on a given TBRI. All subjects performed all tasks on the list and there were five different tasks. (The use of five tasks on a list of twenty-four items may have decreased inter-item associations when compared with using two tasks on a forty item list. While this may be seen as enhancing the design of the study, it does not preclude criticism on the basis of task factors.) Basic comparison conditions were recall scores for items which received one orienting task versus those which received two orienting tasks. Additionally, the strength of the correlation between tasks in the two task conditions was of primary interest. Results showed that recall for the two task condition exceeded recall for the one task condition. Further, there was a systematic increase in recall among the two task conditions as orthogonality between dimensions increased. Thus Klein and Saltz showed beneficial effects of differential encoding in a MP situation.

Glenberg and Smith (1981) also used rating scales in an incidental study with additional controls. They provided subjects with a standard to use when applying rating scales to decrease inter-item associations. To further enhance the distinctiveness of differentially encoded words one half of each repetition pair was presented in a different modality (visual and aural). Thus, their same-encoded items consisted of performing the same task in the same modality while different-encoded items received two different tasks in two different modalities. Glenberg and Smith conducted both a recall and a recognition experiment.

The recall experiment yielded main effects of spacing and encoding but no interaction. The recognition study revealed both main effects and the desired spacing x encoding interaction. Given that recognition rates were very high for both differentially encoded conditions, Glenberg and Smith replicated the recognition study and imposed further controls to rule out a ceiling effect. They increased the distractor to target ratio and instituted a 24-hour retention interval. Overall performance was depressed but data patterns were identical. Despite appealing to an explanation apart from encoding variability, the methodology and manipulations employed were similar. This study shall be considered further in the discussion section.

Construction, Habituation, and Effort

It is generally accepted that some deficient registration of a TBRI at P2 is the locus of the spacing effect (Hintzman, 1974; Jacoby, 1978). This assumption derives from lack of evidence for disruption of consolidation of P1 (Bjork & Allen, 1970; Hintzman, Block, & Summers, 1973) and the observation that spacing effects are probably due to some set of deleterious circumstances under MP conditions rather than some advantage enjoyed under DP conditions (Underwood, 1970). Given the assumption of deficient registration at P2, any theory attempting to account for spacing effects must use MP conditions as a starting point.

Jacoby (1978) and Cuddy and Jacoby (1982) posit two processes that operate during the acquisition phase of an incidental learning study. The first is a backward scan through recent episodic memory. The second is a construction process which fulfills task demands of an experiment, whether they be simply the registration of a

TBRI in an undirected acquisition task or the answering of a specific orienting question. The result of construction is the formation of a memory trace. At P1 (new word) it is supposed that only construction takes place. At P2 the recognition of a repeated item initiates the scanning process. This process performs a quick backward scan through recent memory and attempts to locate the trace resultant from processing at P1. Under MP conditions, or at short lag, the scan will be successful and the results of the previous perceptual/cognitive analyses performed on the TBRI may be accessed and used to fulfill current task demands. As lag increases, the scanning process is unable to contact the P1 trace and the results of the initial construction process cannot be brought to bear on the current problem (i.e., satisfying P2 encoding, or task, requirements). When the scan is unsuccessful, reconstruction of an 'encoding solution' results (Jacoby, 1978).

Jacoby (1978) offers the following example of how a P1 trace can fulfill P2 demands. Suppose you are asked to find the sum of three numbers. After you have added the three numbers and responded with the sum, you are immediately presented the same three numbers and the same task of adding them. The type of processing performed on the second presentation will be the recall of the previous solution.

Thus the second presentation of a TBRI in a massed practice situation is tantamount to maintenance rehearsal of the results of the analyses performed at P1 (Cuddy & Jacoby, 1982). In Jacoby's words, "...the processing of a first presentation of a word makes available an appropriate encoding and thereby trivializes the processing associated with the second presentation of the word (1978, p650)." In terms of the arithmetic analogy above, repetition of an identical problem at long lag requires reperforming the addition operations. The act of reconstructing the solution to the problem at long lags enhances retention to a greater degree than does recall of a previous solution at short lags (Jacoby, 1978).

The reconstruction hypothesis of Jacoby (1978) and Cuddy and Jacoby (1982) share many features with an habituation model as conceptualized by Hintzman. The purpose of the following discussion is to attempt to clarify the reconstruction hypothesis vis-a-vis habituation, and to delineate the relative contributions of voluntary and involuntary processes by incorporating the concepts of encoding effort (Johnston & Uhl, 1976) and encoding variability (Melton, 1970). At the outset it was mentioned that Hintzman (1974) categorized competing explanations of spacing effects as to whether the mechanism thought responsible was of a voluntary or involuntary nature. Of all the proferred explanations, Hintzman chose an habituation model as holding the most promise. "The habituation hypothesis I put at the top of the list partly as an act of perverse defiance of the Zeitgeist with its current emphasis on control-process explanations, and partly because it seems to have at least as much chance of being correct as any of the other hypotheses under consideration (Hintzman, 1974, p97)."

The assertion by Jacoby (1978), with respect to the immediate repetition of a word and the processing performed at P2 (recall), that, "a full repetition of the processing activity may be difficult, if not impossible, to accomplish without some delay...(p649)" appears to imply some involuntary process governing the effect prior presentation (P1) has on P2 processing. Hintzman's (1974) explanation of an habituation model also considers the locus of spacing effects to lie at P2. Under such a model an internal representation of the TBRI, which has achieved some level of activation, becomes adapted, leading to a decrease in the probability of establishing a new trace or a decrease in any additional strength P2 may add to P1 in a MP situation. For P2 to enhance retention of a TBRI it must be presented after recovery of the system from P1 (as specified by some temporal gradient). Hintzman warns that this type of habituation cannot be equated to animal behaviour studies which view habituation as a product of the neural refractory period. Unfortunately, for a purist's conception of habituation, the recovery period must be set at about fifteen seconds to account for observed spacing effects. This interval is suspiciously like the extent of short-term, or primary memory, the buffer through which Jacoby's backward scanning process operates.

Jacoby (1978) agrees that the locus of spacing effects are at registration of P2 and that it is impossible to ignore the highly primed, or adapted, solution of P1 encoding when encountering P2 in a MP situation. He states: "Although I agree with claims of the habituation hypothesis, what is habituation? That is, what processes are involved in habituation?....Perhaps a habituated stimulus is one for which an encoding can be remembered rather than constructed (1978, p660)." While it is agreed that the process governing the effects of P1 on P2 are of an involuntary nature, the classification of these processes remains unclear. Hintzman (1974) argues for nonvolitional hard-wired habituation with a recovery period while Jacoby (1978) argues for nonvolitional control processes. The extent to which Jacoby's reconstruction hypothesis can be considered an habituation model becomes moot. Both perspectives adhere to the notion that, at short lag, the trace of a previous encoding (P1) is available at P2, and that contact with P1 subjugates encoding processes at P2. Predictions for an MP-DP study are identical despite the fact that habituation views contact with the P1 trace at P2 as a product of some energy of activation persisting forward through time from P1 (temporal gradient of recovery) while reconstruction views contact with the P1 trace as a product of a search process operating backward through time and initialized at P2 (backward scan). For purposes of this paper the concept of adaptation to an activated stimulus, coupled with the mechanics of backward scanning and construction, form a solid theoretical base for an energy, or effort, explanation of spacing effects.

Energy of activation and encoding effort are inextricably intertwined with the temporal gradient of recovery, or time of adaptation. Alternately, the ability of a P1 trace to aid P2 processing is bounded by the extent of primary memory and dependent upon the non-erasure of P1 from working memory. Thus, when P2 closely follows P1, construction does not occur and recall of P1 substitutes for additional processing at P2. The construction process is more beneficial to the enhancement of a trace or the retentive ability of a TBRI than is the recall process (Cuddy & Jacoby, 1982; Rose, 1984). The basis for this statement derives from measures of encoding effort.

Johnston and Uhl (1976) proposed a model which incorporated aspects of a voluntary attention theory and an habituation theory, called effort theory, to account for spacing effects. The voluntary attention aspects will be largely ignored here as they pertain to particular aspects of methodology which do not contribute to the present model. Johnston and Uhl asserted that "[a]ccording to effort theory, memory for an item is positively correlated with the total volume of processing accorded the item (1976, p153)." In accordance with habituation, effort theory maintains that initial presentation of an item (P1) receives some base level of activation (in a semantic sense). Given the immediate presence of P2, P2 alone cannot raise that level of activation, but can only serve to prolong that same level of activation. This prolongation of activation does not enhance memory (Craik & Tulving, 1975; Lockhart, Craik, & Jacoby, 1976). As the interval between P1 and P2 increases, activation of P1 lessens, and energy or effort to reactivate (or partially reactivate) a concept at P2 increases from zero (MP) toward base level (DP). Thus the total effort required to activate a TBRI at both P1 and P2 varies with the P1-P2 interval, and this total effort is responsible for the memorability of the TBRI.

Johnston and Uhl (1976) tested effort theory as an account of spacing effects using a dual-task paradigm.

Spaced and massed items were presented in a continuous recognition task. Subsidiary tone signals were interspersed throughout the list. Reaction-time (RT) to the tone was used as a measure of cognitive effort being allocated to the TBRI at the time of the tone. Longer RT implied greater processing effort (see Kerr, 1973, for a review). Reaction times were correlated to free recall scores on a subsequent memory test. Results revealed that RT systematically decreased for massed repetitions and increased for spaced repetitions. Combined with the observation of DP superiority in recall protocols, Johnston and Uhl made a strong case for processing effort as the prime determinant of recallability. The spacing effect in continuous recognition tasks has also been observed by several other experimenters (Hintzman, 1969; Okada, 1972; Rose, 1984) although these studies did not use dual-task paradigms.

Rose (1984) operationalized Jacoby's (1978; Cuddy & Jacoby, 1982) forgetting of P1 (failure of scanning process) in terms of time taken to process P2, and used specific orienting questions for each TBRI in a spacing paradigm. He reasoned that processing time for repetitions should increase as the the P1-P2 interval increases, and that this increase would be a measure of the accessibility of the P1 trace at P2. In addition, the increase in processing time should be positively correlated to memory for those repetitions. Manipulated variables included spacing and same versus different encoding conditions. Orienting tasks were specific questions (yes/no) regarding some attribute of the stimulus item. Dependent variables of interest were processing time for repetitions and recognition hit rates derived from judgment of frequency measures (Proctor, 1977). In a second experiment a free recall task was introduced prior to frequency judgments.

In both experiments processing time for differentially encoded items was significantly slower than processing time for same encoding items at all lags. There was, however, a significant decrease in RT from P1 to P2 for same encoded items at a lag of 40 items. This facilitory effect was not observed by Hintzman (1969), Johnston and Uhl (1976), or Okada (1971). None of these latter studies manipulated encoding.

Recognition scores from both the initial study and the replication yielded identical patterns of results: Spacing effects were observed for the same encoding condition, but were not present for the different encoding condition. These results gave rise to the <u>critical</u> encoding X spacing interaction (Bird et al, 1978; Rose, 1980; Shaughnessy, 1976). Further, the interaction was brought about by MP item equivalence (to DP) on differentially encoded items.

Free recall scores from the second experiment yielded a similar pattern of results with the exception that the encoding X spacing interaction was borderline ($p<.06$).

While Rose (1984) satisfactorily attenuated spacing effects within a variable encoding framework, and observed identical results in both recognition and recall (cf. Glenberg & Smith, 1981), the rationale followed was strictly that of reconstruction (Jacoby, 1978). That is, accessibility to P1 is determined by task overlap. This differs substantially from the current proposal that accessibility is guaranteed at short lag and additional processing effort accounts for both increased processing time and increased retentiveness. Rose (1984) does agree that increased processing time implies increased effort, but, under a strict reconstruction view, inaccessibility is guided by P1 being an inappropriate trace for facilitation of P2 encoding.

<u>An Energy Model</u>

Effort theory, as a semantic habituation model, and construction, as a task-fulfilling cognitive strategy, may be seen to converge to provide an explanation for classic spacing effects where TBRIs are presented context-free, and encoding is left totally under subjects' control. A slight modification to the reconstruction process allows for the interpretation of incidental learning studies where orienting tasks are employed. The problems proposed by task selection in variable encoding studies are intertwined with the proposed semantic habituation/reconstruction model and the hypothetical composition of a memory trace. All are integral to the thesis of this paper. The following discussion will clarify the effects of P1 processing on P2 processing in a massed practice situation.

Cuddy and Jacoby (1982) maintain that repetition can produce a strength-like effect on memory but "[a]ny strengthening effect will be limited to those operations that are actually repeated" at time of P2 processing (p464). They suggest that a readily accessible P1 trace leads to "the 'dropping out' of some encoding operations and, thereby, a more impoverished trace (p464)." The extension of this argument forms the basis of the present model to account for variable encoding tasks in a MP situation. While Cuddy and Jacoby hint at the possibility of the P1 trace _partially_ fulfilling P2 encoding requirements, they never state explicitly the possibility that recall of the P1 trace may not fully satisfy the processing requirements at P2. When the P1 trace does not contain sufficient attributes to satisfy P2 processing, some additional processing, or construction, must take place and must involve effort (i.e., cognitive energy). Given the assumption of this paper that memorability of an item is a function of the amount of effortful processing performed, then any additional processing performed at P2 must improve retention beyond that of a once-presented TBRI (using same task at P1).

The sum total of energy required to establish a trace may be called cognitive effort. Immediately upon establishment of the trace, the trace may variously be said to be activated (Johnston & Uhl, 1976), adapted (Hintzman, 1974) or readily accessible (Jacoby, 1978). When the same encoding task is presented at P2, in a variable encoding study under MP conditions, the result is the situation described earlier; i.e., no further processing need take place save the recall of an highly accessible (activated) trace which completely fulfills the task-specific demands of the experiment. When a different encoding task is required at P2, a portion (or all) of the P1 trace may be used to aid P2 processing. If, however, the P2 task is sufficiently different from the P1 task, then some additional processing will be needed beyond that which can be supplied through contact with the recent trace of P1. In terms of effort theory, a different task at P2 should raise the level of activation of the P1 trace and require some additional quantum of cognitive energy, thus increasing the effort put into formation of the trace and contribute to its retentive ability (Johnston & Uhl, 1976).

The degree to which P2 encoding can elevate the activation energy of P1 requires careful consideration of task selection and delineation of which aspects of a P1 trace that may be used to aid processing at P2. Consider first the effects of the above example in a DP situation. When either the same encoding task or a different encoding task is presented at P2, the backward scanning process will fail to contact the P1 trace and construction will occur (Cuddy & Jacoby, 1982). Effort will be applied to all three components previously conceptualized as the minimum attributes of a trace (semantic access, processing path, and primary attribute). Thus, more energy is necessarily given over to processing in a DP situation than in a MP situation. Suppose that two tasks can be found which share no aspect of either processing operation or primary attribute evoked for a given TBRI. Under MP conditions , then, the only factor from the P1 trace which may aid P2 processing is the factor which has been called semantic access, that is, some basal definition of a concept which allows a starting point for further processing. Under such an assumption the effects of spacing of repetitions would be due solely to the additional effort (activation energy) required for semantic access in DP. Conversely, spacing effects are due to the inability to reactivate the general featural elements of a TBRI at P2 in a massed situation.

The view that processing effort is solely responsible for memorability affords some additional predictions concerning the interactive effects of spacing and variable encoding on memory. First, the energy model predicts, in common with encoding variability theory, that differentially encoded items will enjoy superiority in memory over same-task encoded items under MP conditions. This result has been reliably observed under conditions of strict attention to task factors (Klein & Saltz, 1976; Rose, 1980, 1984).

Second, the energy model predicts no differences in retention for DP items regardless of encoding conditions. This prediction derives from the combination of two assumptions; a) at long lag construction takes place due to failure to contact the P1 trace, and b) total effort is responsible for memorability. Some support may be claimed for this prediction from the results of Bird et al (1978, experiment II), Rose (1984), and Shaughnessy (1976, experiment II), although it should be noted that this measure was not a measure of interest and was not reported post hoc in any of the experiments. As such, no statistical validity can be attached to it and support is claimed on the basis of visual inspection. A potential rider to this prediction is required for the possible situation whereby spaced items receiving two 'shallow' semantic tasks were compared with spaced items receiving two 'deep' semantic tasks (cf. McMurray & McIntyre, 1981). It is surprising, however, that with the previous reliance on encoding variability as the determinant mechanism for spacing effects, predictions were not made concerning the ordering of memory scores for DP items which had been encoded differentially versus those which had been encoded with the same task. Given the assumption that differential encoding enhances memory for MP items, an encoding variability perspective should predict that differentially encoded DP items should show enhanced memory performance over DP same-encoded items.

The third prediction afforded by the present model is that if one systematically varies encoding task overlap (similarity) under MP, encoding effort will systematically vary, and will be reflected by a systematic increase in retention with decreasing similarity among experimental MP conditions. Although this type of result can be seen in the relevant literature, it has not been tested, nor alluded to, as a significant aspect of the investigation of spacing effects.

When testing spacing effects the assumption is that one is concerned with the summation of memory traces, or more precisely, the summation of encoding processes and their relation to memory. The following experiments varied encoding task overlap across spacing intervals and measured concomitant memory in recognition and recall. Measures of RT latency were also recorded for the recognition experiment.

Experiment I

The manipulation of task overlap in Experiment I was derived from definition of the minimum components of a memory trace resultant from a semantic orienting task; general semantic activation, procedural or processing requirements, and a specific primary attribute (endpoint of orienting task). The manipulation of the first factor, semantic activation, is tantamount to using homographic materials, and although almost every word has more than one semantic sense (Reder et al, 1974) care was taken that that only one specific sense of a word was used (including the use of transitive verbs). The remaining two components (processing path and primary attribute) were combined factorially to induce variation in encoding. The results of the factorial combination are that on the second presentation of a TBRI one may encounter one of four situations: Processing operation same, primary attribute same (OsAs); processing operation same, primary attribute different (OsAd); processing operation different, primary attribute same (OdAs); or, processing operation different, primary attribute different (OdAd). Two types of processing tasks were used, one involving generation of a specific attribute of a TBRI (e.g., KING: What does he wear on his head?), the other involving a basic comparison or checking operation (e.g., KING: Does he wear a crown?).

In terms of a network model such as Anderson's (1976) ACT model, the components of the trace may be seen as the activated semantic and lexical aspects of the word and their association to the attribute evoked. Subsequent to nonvolitional spreading activation from the primary node (TBRI), the orienting activity will focus cognitive energy in a direction specific to the fulfillment of the task. Thus, what has here been called the primary attribute will enjoy a prepotent activation and connection to the TBRI. In repetition conditions, dependent on the second task, the trace was either strengthened in terms of pathway or attribute, or the trace was elaborated by virtue of differential operations or attributes. Retrieval depended on the intersection of activation between the TBRI and the experimental context (i.e., the result of the orienting activity).

The predictions of the energy model may take on heuristic value when contrasted with traditional models. A pure memory trace strength model where strength increases with frequency or strength is added only with repeated operations would predict DP superiority in memory and decreasing memory performance within DP conditions as encoding variation increases. A strict variable encoding model would predict no effect of spacing and a systematic increase in memory performance as encoding variation increases. Within the proposed paradigm, the energy model predicts overall DP superiority and that differential encoding will enhance retention of MP items only. Essentially these predictions mean that spacing effects will be partially attenuated on the basis of MP variably encoded item superiority over the MP same encoding condition, and that differential encoding will not benefit DP items. The prediction that DP same and variably encoded items will evidence statistically equivalent recognition scores implies acceptance of the null hypothesis. While no critical statement can be made if this result obtains, the a priori prediction of statistical equivalence can only enhance the energy model.

The status, or worth, of reaction-time measures in this paradigm is unclear. The measures of processing time reported earlier all came from the acquisition phase of incidental learning studies or from continuous recognition paradigms. In this study the RT data was measured. at time of memory test. Hintzman (1969) measured recognition RTs in a continuous recognition task in which the P1-P2 interval was varied (1, 2, 4, 8, or 16 items) but the P2-P3 interval was held constant (16 items). Results showed P2 RT latencies increased with increased spacing. The P3 RT latencies, however, decreased as a function of the P1-P2 interval with P1-P2 massed items being the slowest to be recognized. In a similar study, Okada (1971) varied both the P1-P2 lag and the P2-P3 lag. He found that RT increased for both P2 and P3 as lag increased. Okada suggested a trace strength interpretation of his results, but given that his maximum lag was six items, his results may be indicative of a backward scan process through primary memory or, in habituation terms, contact with a decaying activation of a previous trace.

The Hintzman results appeal to the intuitive logic that things better remembered are more quickly remembered. Johnston and Uhl (1976) invoked encoding specificity logic and presented a paradoxical relation between time to recall and ability to recall. Encoding specificity (Tulving, 1983; Tulving & Thomson, 1973) essentially maintains that the conditions at time of study must be reinstated at time of test for successful memory performance. This led Johnston and Uhl (1976) to propose that repeated words which are slow to be recognized during the continuous recognition task will be the ones that are more likely to be variably encoded and more likely to be recalled in a free recall task. Their pattern of data, though, showed that hit latencies were fastest for spaced repetitions and were positively correlated with recall scores (1976, experiment II).

The Johnston and Uhl study did not manipulate encoding and their results may be accounted for within a trace strength model. While additional effort was applied to spaced TBRIs it was in the form of repeated processing, not elaborative processing. Repetition at long lags, without experimenter induced variation, is seen as resulting in a more convergent set of attributes rather that a divergent set of attributes as proposed by encoding variability (Rose, 1980). Still, the paradox poses an interesting question for the ordering of RTs without violating the effort model. If it is true that encoding conditions must be reinstated at retrieval, and if total effort is responsible for memorability, then effort lent to a repeated operation should speed retrieval (trace strength) and effort lent to a different operation should slow retrieval (trace elaboration). For example, the DP conditions of same process, same attribute (OsAs) and different process, different attribute (OdAd) may show equivalent effects of retention but differences in time required for retrieval due to the additional number of trace attributes which must be reinstated at retrieval. Predictions based on the above logic are that RTs will systematically increase for both MP and DP items as variation in processing increases.

Method

Subjects

Subjects were 24 undergraduate psychology students, participating in partial fulfillment of a course requirement. No other incentive was employed.

Materials

Materials were chosen from the Paivio, Yuille, and Madigan (1968) norms. All words chosen had a minimum frequency count of 15 occurences per million words of text and were scored medium to high on concreteness, imagery, and meaningfulness. The required 208 words were randomly assigned to one of three categories; a) 84 experimental items, b) 84 items comprising the "New" response condition on the recognition test, and c) 40 filler items to serve as a partial counterbalance for affirmative responses in the incidental learning phase of the experiment. Experimental words are listed by category in Appendix A.

Design

The design consisted of a 2 (spacing: MP, DP) X 2 (process: same, different) X 2 (attribute: same, different) factorial, and a once-presented condition (1P), for a total of nine experimental cells. All factors were within-subjects. The following notation is used throughout the paper:

O: Denotes processing operation performed. If O is followed by subscript s, then the processing operation performed on a repeated item was the same on both presentations. If O is followed by subscript d, then the processing operation performed on a repeated item was different on each presentation of the item.

A: Denotes the primary attribute resultant from processing operations. If A is followed by subscript s, then the primary attribute evoked on successive presentations of a target item were the same irrespective of processing operations performed. If A is followed by subscript d, then the primary attribute evoked on successive presentations of an item were different irrespective of processing operations performed.

1P: Denotes a once-presented item.

The eight factorial conditions are formed by the four combinations of same versus different processing operations and same versus different attribute evoked, for both massed practice (MP) and distributed practice (DP) conditions.

List Construction. Orienting questions were constructed for the 84 experimental items such that any experimental item could be assigned to any experimental condition (see Appendix B). This involved the construction of four questions per item (two Generate questions and two Compare questions). Additionally, one of each of the Generate and Compare questions had to elicit or evoke the same primary attribute. This latter stipulation was necessary to construct the Operation-different, Attribute-same conditions. To ensure that subject variability was at a minimum for generated responses which had to conform with their Comparison pairs, a pretest was performed on the Generate items of Operation-different, Attribute-same question pairs. The 84 experimental items and their Generate OdAs orienting questions were given to 20 subjects. Subjects were asked to amswer the questions about the words with the first response that came to mind. The response could be a single word or a short phrase. Analysis of pretest results showed that 55 of the 84 experimental items had a consistent response 95 per cent of the time or greater. The proviso that the 16 items required to complete the MPOdAs and DPOdAs conditions be drawn from those 55 was placed on the construction of the list. After the 16 items were chosen, all remaining experimental items were randomly assigned to the remaining conditions. The two operations, comparison and generation, were used equally often throughout the list and appeared equally often as the first operation performed for those conditions in which both operations were required. Table 1 shows an example of each of the four process operation X attribute conditions. When all target items were

Table 1 - Following Page
Cognitive Effort

assigned to conditions, and incidental tasks constructed, items were assigned randomly to a presentation list position with the following constraints:

1. One half of 1P items appeared in first half of list.

2. One half of all MP condition items appeared in first half of list.

3. No more than three MP items occurred in succession.

4. One half of complete DP pairs appeared in first half of list.

5. Lag for DP pairs was set at 20 items.

6. No more than a total of seven DP and/or 1P items occurred in succession.

Table 1

Example of the processing x attribute combinations for the target word KING.

OsAs:	KING:	Does he wear a crown?
	KING:	does he wear a crown?
OdAs:	KING:	Does he wear a crown?
	KING:	What does he wear on his head?
OsAd:	KING:	What does he wear on his head?
	KING:	Where does he sit?
OdAd:	KING:	Does he wear a crown?
	KING:	Where does he sit?

At this point filler items were added to the list. The filler items served two purposes; a) to act as primacy and recency buffers for the total list, and b) as a partial counterbalance to those experimental items requiring a "yes" response for the comparison task. Of the 40 filler items, 20 were once-presented. The remaining 20 items were divided equally between MP and DP pairs. All MP and DP filler pairs were necessarily incongruous such that the correct response for filler items was "no," (e.g., Does a lion have feathers?). Ten of the 1P fillers also required the "no" response, while the buffers were a mix of both task and response. The acquisition list thus consisted of a total of 208 presentations (64 MP and DP items, 20 1P items, 20 1P fillers, and 20 MP and DP fillers). Four lists were constructed in this manner and each list was learned by six subjects. List was introduced to the data analysis as a grouping factor.

Test List. The test list consisted of the 84 experimental items plus 84 distractors. Items were assigned randomly to a recognition test list position subject to the constraint that no more than four consecutive items were "Old" or "New." Filler items from the learning phase did not appear in the test list.

Procedure

Subjects were seated in a small room with the experimenter. The incidental phase of the study was explained as a reaction-time study in concept identification. The subject was unaware of the follow-up recognition test. To lend authenticity to the deception a microphone was placed between the experimenter and the subject. Subjects were told that the questions read by the experimenter and the responses given by the subject would be recorded and that the time between offset of the question and onset of the response would be measured through a voice key interface to a computer. No such measures were recorded and subjects were made aware of the deception at the close of the experimental session.

Subjects were instructed that a long list of questions was to be read to them and that they should answer each question as quickly and accurately as possible. Each question would involve a major concept (e.g., lion) which would be accented by the experimenter during reading of the question. The subject was told that questions could be of two types; a) Yes/No questions (comparison), and b) fill-in-the-blank questions (generation). The subject was also told that some concepts and/or questions might be repeated.

After all instructions were understood by the subject, the experimenter read the list at as fast a pace as the subject could comfortably respond. At an average of 8-10 seconds per item, this phase of the experiment lasted about 30 minutes.

Upon completion of the incidental tasks, the subject was informed of the recognition test. The subject was taken to another room and seated in front of a TV monitor. The subject was told that words would be shown on the screen and that some of the words were the concepts from the list of questions they had answered (Old) and some were New words. The subject was instructed to respond via a response panel with buttons labelled Old and New, as to whether they had heard the word on the screen during the incidental phase of the experiment. The subject was also instructed to respond as quickly and accurately as possible. At a rate of 5 sec/item the recognition test phase lasted 14 minutes. Dependent measures were percent correct recognition and reaction time. Materials were delivered and measures recorded by an Apple II plus microcomputer.

Results and Discussion

Recognition Data. All results are reported at an alpha level of .05 unless otherwise noted. Tables 2 and 3 show the overall recognition rates and the hit rates by condition, respectively. A 2 x 2 x 2 x 4 mixed analysis of variance was performed on the factorial conditions with list number as a grouping variable. The only significant effect which included list was the list x operation x attribute interaction $F(1,20) = 6.62$ $MSe = 3.93$. Excluding the list factor, the analysis revealed three effects. The main effects of spacing $F(1,23) = 6.49$ $MSe = 0.0085$ and attribute $F(1,23) = 12.67$ $MSe = 0.0083$ were significant. The spacing x attribute interaction was the only other significant effect $F(1,23) = 6.15$ $MSe = 0.0043$. A t-test comparing the MPOsAs condition with the 1P condition was not significant ($t = 0.22$, alpha = .2)

Table 2 and Table 3
Following Pages

The results conform well to the predictions derived from the energy model. Proportion correct recognition yielded scores of .889 and .924 for MP and DP items, respectively. The overall spacing effect was expected. Some effect of encoding was also expected and is seen in the attribute main effect with scores of .883 for attribute-same items versus .930 for attribute-different items. The operation manipulation appeared ineffectual as it was only involved in one interaction with the grouping variable.

Table 2

Hit and False Alarm Proportions in Experiment 1

Hits	Misses	Correct Rejections	False Alarms
.891	.109	.832	.168

Table 3

Hit Rate Proportions by Condition in Experiment 1

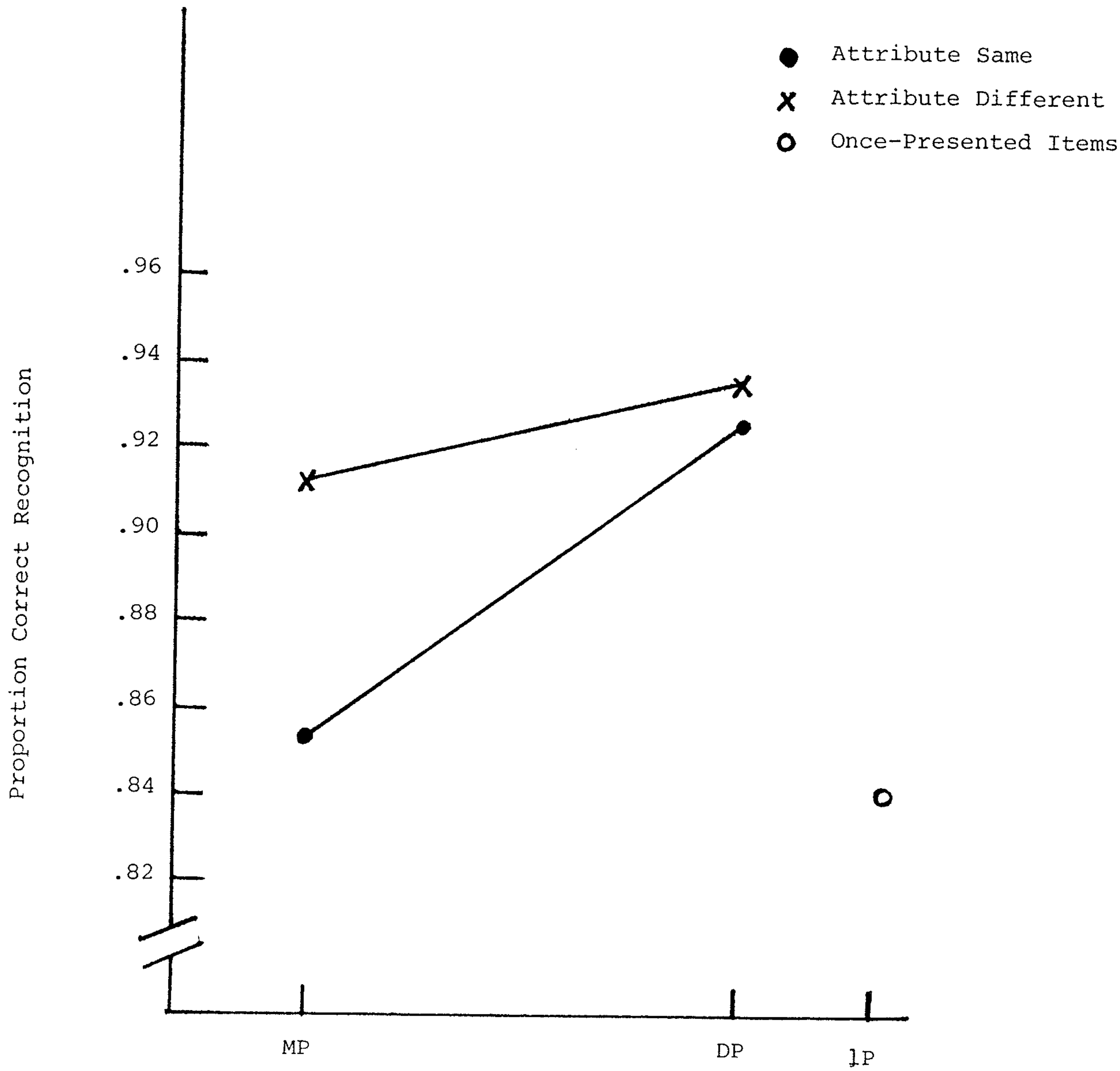
	OsAs	OdAs	OsAd	OdAd
1P	.840	----	----	----
MP	.854	.854	.932	.917
DP	.906	.917	.906	.963

The spacing x attribute interaction is of primary interest. From Figure 1 it may be seen that the change in attribute from the first presentation to the second presentation of a TBRI enhanced memory only for massed practice items. This situation constitutes the critical spacing x encoding interaction as predicted from an encoding variability perspective. These results mirror those of Glenberg and Smith (1981). A post hoc Scheffe showed that both DP conditions and the MPAd condition differed from the MPAs condition. Further, none of DPAs, DPAd, and MPAd differed from each other. The energy model made the prediction of a systematic increase among MP conditions as variation in encoding increased. Given the ineffectiveness of the operation manipulation, the results partially support the contention that MP items receiving variable encoding are better remembered than MP items receiving a redundant encoding.

Figure 1 - Following Page

The attenuation of spacing effects seen here was apparently due to the attribute manipulation. The possibility exists that the interaction may have been

Figure 1


Attribute Same
Attribute Different
Once-Presented Items
Proportion Correct Recognition
.96
.94
.92
.90
.88
.86
.84
.82
MP
DP
1P

brought about by a ceiling effect, namely, the suppression of DP items due to the high level of recognition. Both Rose (1984) and Glenberg and Smith (1981) observed similar results among distributed conditions at very high levels of recognition. Glenberg and Smith replicated their experiment with additional manipulations to control for ceiling effects. They increased the distractor to target ratio from 1:1 to 2:1 and used a 24 hour retention interval. Overall performance was depressed relative to the initial experiment but the patterns of data were identical.

Reaction Time Data. Analysis of variance on reaction-time latencies for correct responses on the recognition test yielded little of interest. The only significant effect was the main effect of spacing with scores of 1043 msec and 994 msec for MP and DP items, $F(1,23) = 11.75$ $MSe = 10,180$. While DP items were expected to be faster overall, specific predictions rested on systematic variation in RT with systematic variation in encoding. The best interpretation of these results conforms to the popular wisdom that things better remembered are more quickly remembered. These systematic variations were not observed as there was no main effect of encoding nor a significant interaction. The specific predictions were based on an assumption that all of the encoding context would be reinstated at time of test. If only a portion of the encoding context must be reinstated to effect a decision concerning the presence or absence of a target in the list, then only those strongest traces (i.e., DP items) would show beneficial effects with respect to reaction times. It may be the case that those items which received distributed presentations will show speeded judgments due to the extra semantic activation they enjoy.

Experiment II

Since the majority of past researches on spacing effects have used free recall (FR) as the dependent measure, it was desirable to replicate Experiment I with a free recall task. Experiment II tested the predictions of the effort model using FR as the dependent measure. The use of free recall requires one to limit the size of the acquisition list. To this end only the most divergent processing combinations (OsAs and OdAd) were used. The encoding same (S) condition required the same encoding question on both presentations and the encoding different (D) condition required a different processing operation and a different primary attribute on the second presentation of a TBRI. Predictions are the same as for Experiment I, namely, overall DP superiority and enhanced retention for differentially encoded items under MP only.

Previous studies have failed to find the critical spacing x encoding interaction in recall. As mentioned earlier this lack of result may have been a joint product of experimental materials and the types of orienting tasks employed. Rose (1984) did find the spacing x encoding interaction, but it was not brought about by elevation of MP variably encoded condition scores. Glenberg and Smith (1981) obtained main effects for both spacing and encoding but not the interaction. Despite the lack of this interaction, both Rose and Glenberg and Smith showed facilitative effects of variable encoding in a MP situation. Encoding effects were invariably absent in earlier researches. Given the predictive value of the energy model with respect to recognition memory performance, it is expected that the model will correctly predict the existence of both main effects and the interaction in free recall memory.

Method

Subjects

Subjects were 24 undergraduate students from the same pool used in Experiment I. No subject served in both experiments.

Materials

A subset of words were chosen from those used in Experiment I. Fifty words were randomly chosen from the 'experimental' items from Experiment I and assigned to the following categories; a) 34 experimental items, and b) 16 filler items to serve as a counterbalance for the affirmative response in learning and to act as primacy and recency buffers.

Design

The design consisted of a 2 (spacing: MP, DP) X 2 (encoding, S, D) factorial, and a once-presented (1P) condition for a total of five experimental cells. All factors were within subjects.

List Construction. Of the 34 experimental items 10 were assigned to the 1P condition. The remaining 24 words were randomly assigned to one of the four factorial cells. Once all cells were filled, orienting questions were constructed which satisfied condition requirements. The two operations, comparison and generation were used equally often throughout the list and appeared equally often as the first operation for those conditions in which both tasks were required. When all TBRIs were assigned to conditions and orienting tasks constructed, TBRIs were randomly assigned to a presentation list position subject to the same constraints as in Experiment I. Filler items were also added in the same manner. The 16 filler items were broken down as follows: 8 1P items (4-no, 4-yes) and 4 MP and 4 DP items all using the comparison operation and all requiring the 'No' response. Primacy and recency buffers were a mixture of task and response but did not include any experimental items. The acquisition list thus consisted of a total of 84 presentations (24 MP and DP items, 10 1P items, 8 1P fillers, and 8 MP and DP fillers). Again, four such lists were constructed and list was introduced as a grouping variable in the data analysis.

Procedure

The procedure was identical to that of Experiment I for the learning phase. After completion of the learning phase subjects were given an unexpected free recall task. Subjects were handed a sheet of paper with spaces for 50 words and asked to recall as many of the central concepts they heard as they could.

Results and Discussion

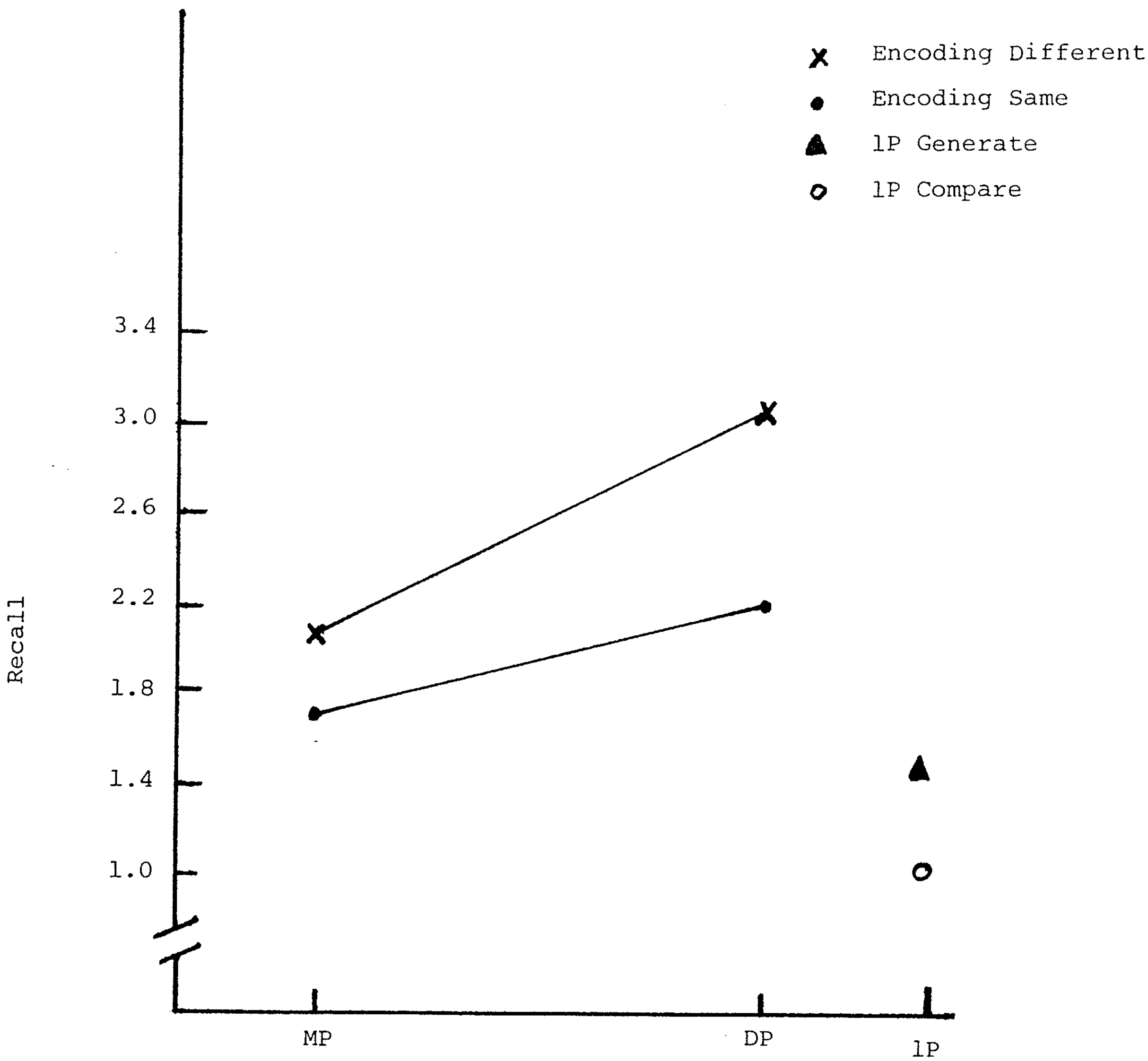
Figure 2 shows the results of the free recall test. A 2 x 2 x 4 mixed analysis of variance was performed on the factorial conditions with list as a grouping variable. List did not interact with any effects. The analysis revealed that both main effects were significant but that the interaction was not. The main effect of spacing $F(1,23) = 5.80$ $MSe = 2.33$ yielded scores of 1.88 for MP items and 2.63 for DP items. The main effect of encoding $F(1,23) = 9.49$ $MSe = 0.86$ yielded scores of 1.96 for same-encoded items and 2.54 for differentially encoded items.

Figure 2 - Following Page

The two control conditions were compared to the MP same encoding condition. The once presented Generate items did not differ from the MPS condition (alpha equal to .2, two tailed). The 1P Comparison items however, did differ from the MPS condition and the 1P generate condition (t(23 = 2.39, t23 = 1.49, alpha = .2). The result suggested a generation effect with subject generated attributes producing higher levels of recall than simple verification. This difference should not affect interpretation of repetition condition results as task was completely counterbalanced within all conditions.

The results disconfirm the energy model in that variable encoding had a greater beneficial effect for distributed practice items than for massed practice items. While

Figure 2



Note: Maximum possible score for each cell is 6.

variable encoding enhanced recall of MP items about to the level of DP same-encoded items, greater gains were evident for DP items pushing the interaction (although nonsignificant) in a direction opposite from that predicted.

If, however, a ceiling effect is present in Experiment 1, then the likely case is that the recognition results should parallel those of recall from Experiment 2. If this is the case, then only the main effects of spacing and encoding would be present, and the lack of the elusive spacing x encoding interaction would not pose a problem for reconciliation of the differential effects of variable encoding between recognition and recall. The results of Rose (1984) may also suffer from a ceiling effect. If Rose's DP variably encoded items were in fact suppressed by a ceiling effect then the true pattern of data would reveal both main effects but not the interaction. Only Glenberg and Smith (1981) have observed a reliable interaction free from the rival explanation of a ceiling effect. Their data, however, still showed an encoding advantage within DP conditions.

A point that must be considered concerns the differential effects of variable encoding in recognition and recall. Support for the energy model is claimed on the basis of results from Experiment I while the results of Experiment II tend to disconfirm the model. Differences between the two patterns of data may be isolated to the DP variably encoded items showing superiority over DP same-encoded items in recall but not in recognition. Given the identicality of the manipulations, materials, and instructions to subjects, it appears that an encoding-only interpretation of spacing effects is insufficient. In the interests of theoretical parsimony it is more desirable to incorporate aspects of retrieval into any attempt at explanation of spacing effects rather than to posit two types of spacing effect under recall and recognition.

By making an amendment to the energy model the present differences between recall and recognition may be accounted for and easily testable predictions may be generated. The amendment to the model concerns how that energy must be used for successful retrieval of the TBRI within its encoding context. The first assumption of the energy model was that the retrievability of an item is a function of the total volume of cognitive energy accorded that item. The statement that effort is solely responsible for retention of TBRIs was derived by equating the effects of elaboration with the effects of strengthening or repeating processing. Here, elaboration is seen as the case when two different attributes have been presented with a given word and have an arbitrary theoretical strength of one learning trial.

Strengthening is seen as the repetition of identical processing under distributed conditions and the attribute would have an arbitrary theoretical strength of two learning trials. The effects of elaboration and strength were equated on the basis of effort. Under the energy model both an elaborated and a streghtened set of attributes were considered to add equal retentive value to a TBRI on condition that full processing occurred at each presentation. This reasoning led to predictions concerning the equivalence of DP condition scores.

The results of Experiment 1 support the original analysis and total effort reliably predicted the observed pattern of data. Under recall conditions, however, the degree of elaboration appears to have an effect independent of the total volume of processing accorded an item. Generally, successful retrieval involves a sufficient overlap between cues present at retrieval and the products of the encoding process (Craik, 1981; Tulving & Watkins, 1975). Given that the acquisition procedures were identical between the two experiments, observed data pattern differences appear to be a product of retrieval tasks. As Craik (1981) states, the processes may be very similar in recall and recognition but the information utilized from the trace may be very different.

Consider the basic difference between recognition and recall in a simple incidental task requiring the answering of one orienting question for each TBRI. All TBRIs are presented once. In the recognition task a nominal copy of the TBRI is presented which activates the concept in semantic memory. The subject must then retrieve the conditions at time of acquisition (i.e., the encoding question) and make some decision as to whether the presented word is old or new. Thus the reinstitution of the encoding context becomes the means by which the target is judged. In a recall task the subject must generate both the TBRI and the conditions at acquisition, compare them and then make a response decision. The recall task is harder not only because the retrieval cue is entirely contextual but also because more information must be retrieved before a decision can be made.

Consider first the results of Experiment I, particularly the spacing x attribute interaction. Presentation of a nominal copy of a TBRI activates the representation of that word in semantic memory. Thus recognition subsumes the lending of cognitive effort to generation of the TBRI. At this point successful memory performance depends upon the retrieval of the encoding context. That is, some encoded attribute or characteristic of the encoding task must be retrieved to act as a decision criterion. Maintaining the idea that the effects of strength and elaboration are equal, the conditions of MPAd, DPAs, and DPAd all have an equal opportunity to be recognized by virtue of having either two different attributes associated with them or, in the case of DPAs, a repeated but strengthened attribute. The MPAs condition will show poorer performance because it has minimal strength and minimal elaboration associated with it.

In the situation of free recall (Experiment II) both the TBRI and some portion of the encoding context must be retrieved for successful memory performance. However, due to the necessity for recall of at least two items (TBRI and one attribute) the number of retrieval paths as well as the sum of energy at encoding jointly determine the probability of recall. Thus to account for the results of Experiment II, the difference between condition DPD and DPS is seen as the product of an extra retrieval path present for DPD, and the difference between condition DPD and condition MPD is a product of the extra energy of activation at P2 for DPD.

Having observed a virtually identical pattern of results as the present study, Glenberg and Smith (1981) proposed differential retrieval effects for recognition and recall under identical encoding conditions. Their explanation is derived from Glenberg's (1979) component levels theory. Glenberg and Smith proposed several components which are present in a trace as a result of encoding conditions and which interact with memory tasks in a differential manner. The two components to be considered here are called contextual components and descriptive components.

Contextual components are dependent upon some general context present at the encoding of a word. This context is assumed to drift or change over time such that DP items will naturally show more contextual variability than MP items. This context is said to be unaffected by specific encoding tasks. Descriptive components are the encoded characteristics of the word stimuli. The specific descriptive components of a trace are dependent on both the encoding task and the context at the time of presentation. Descriptive components will vary as a function of the specific orienting task and as a function of drift in context. Thus, even under same encoding conditions DP items will have greater variability in descriptive components due to the drift in context over time.

Under free recall conditions the only retrieval cue is the test context such that a spacing effect is predicted for both same encoded and different encoded items. Under recognition conditions the retrieval cue is said to be descriptive. Descriptive components may be encoded, at test, from nominal copies of target words. For same-encoded items a spacing effect is predicted due to the variability in descriptive components brought about by contextual drift for DP items. The different encoded items, however, are both rich in descriptive components and the spacing effect will be attenuated in recognition.

Despite ignoring the effects of descriptive components in recall, this formulation of differential interactions between encoding and retrieval is a useful heuristic for providing a more complete account of spacing effects. However, resolution of the differential effects of variable effort encoding in recognition and recall rests not on an explanation of why variably encoded MP items show enhanced performance but rather why these encoding effects are differential for DP items. Another problem this explanation encounters is that the contextual component remains relatively undefined. One assumes that it is some constellation of uncontrollable factors such as mood, arousal, time tagging, effects of preceding items, etc. The assertion that the contextual component is unaffected by encoding tasks and has some natural drift over time resulting in a richer descriptive component implies some elaborate form of encoding variability.

Under the present model, that factor which applies only to DP items, is a function of time, and contributes to retrievability, has been called the effect of an extra semantic activation. If that is substituted for Glenberg's and Smith's context factor, then the descriptive components are the attributes from the current manipulation.

General Discusion

Several questions arise as to what constitutes the spacing effect and what contributions the present experiments can make to literature concerning spacing effects. First, what can properly be considered attenuation of spacing effects? Second, what direction should replication and extension of this project take and, finally, what are some of the more general questions which require investigation.

Attenuation of spacing effects is typically described as the erasure of MP item performance deficits, relative to DP items, due to some experimental manipulation. Statistical support is reported in terms of a spacing x encoding interaction. As stated earlier, the existence of differences among distributed learning conditions has seldom been observed although it should have been predicted from an encoding variability perspective. With the exception of Glenberg and Smith (1981) data have shown either no difference among DP conditions or an advantage for DP same encoded items in recall. The majority of these studies used rating scales as encoding tasks (cf. Rose, 1984). The present study made the assumption that no differences would be present among DP conditions but a difference was observed in free recall.

The situation from Experiment I may be described as attenuation of spacing effects due to the experimental manipulation being beneficial only for MP items. Nowhere in the encoding variability literature is it stated that to discover the basis of spacing effects one must institute a manipulation that benefits MP items but does <u>not</u> benefit DP items. Still, support for any such theory is derived from the existence of the spacing x encoding interaction when it is due solely to elevation of MP item performance. The logical assertion that the performance of different encoding tasks should enhance MP items while simultaneously depressing DP items has been ignored within the encoding variability literature. Without accounting for concomitant memory performance among DP conditions the attenuation of spacing effects based on MP variably encoded item equivalence to DP items remains a statistical attenuation and does not provide support for the manipulation being performed as the <u>basis</u> for spacing effects, but merely a way to overcome them.

In order to avoid these logical problems, the mechanism proposed to attenuate spacing effects must involve a manipulation which naturally occurs during distributed practice and will not enhance distributed practice performance when reinstituted in the form of an experimental manipulation. The energy model supposed that the mechanism underlying DP superiority was encoding effort. The model gave rise to the prediction of differential effects of variable encoding between MP and DP and this prediction was supported by the recognition experiment. Under these conditions the spacing x encoding interaction is interpretable in full.

If the desire in the investigation of spacing effects is to overcome the advantage of distributed pactice, then this has been accomplished in both recognition and recall (Rose, 1984; Glenberg & Smith, 1981). If, on the other hand, the underlying basis for the effect is the subject of study, then one must decide what constitutes evidence in favour of one explanation over another. Barring ceiling effects, when the spacing x encoding interaction is present as well as both main effects, the manipulation employed is seen as having differential effects between MP items and DP items. Explanation of why such a manipulation does not have a beneficial effect for DP items must be an integral part of the mechanism proposed to underly such effects. When the spacing x encoding interaction is not present, spacing effects are said not to be attenuated despite variably encoded MP items showing scores equivalent to DP same encoded items. Thus, while spacing effects are overcome, at least to this extent, the manipulation used is not seen as underlying the effect. Additionally, Rose (1984), Klein and Saltz (1976), Glenberg and Smith (1981), and the present study have all shown clear beneficial effects of variable encoding for MP items. Without the spacing x attribute interaction (particularly in recall) these results are not construed as being supportive of any theory of spacing effects.

The purpose of this thesis was to test an encoding effort model of the within-list MP-DP effect. Based on notions of encoding variability, encoding effort, habituation, and reconstruction, a model was proposed that incorporated various aspects of these perspectives and rested on three assumptions. The assumptions were that; a) memorability for an item is a product of the total volume of effortful semantic processing accorded that item, b) under MP conditions the trace resultant from P1 is present at P2, and c) the amount of effortful processing performed at P2 is subjugated by the degree of similarity between tasks at P1 and P2. Support for the latter two assumptions was obtained in both experiments. The first assumption was supported by one experiment and denied by the other. A restatement of the first assumption must qualify the effects of total effort with respect to retrieval task demands. For example, memorability for an item is a product of the total effortful semantic processing accorded that item which is consonant with the retrieval environment. When the retrieval environment is cue-scarce (recall) both the volume of effort expended and the number of retrieval routes to a TBRI jointly determine retention. When the retrieval environment is cue-explicit (recognition and cued recall) only the effort involved in encoding which is not reinstituted by the test (nominal copies of TBRIs and cues) determines retention.

Further assumptions made about the role of elaboration in recall suggests a series of experiments involving recognition, recall, and cued recall. A simple way to test these assumptions would be to conduct a spacing experiment where three repetitions are used and either zero, two, or three tasks are different for each of the repetitions for a given TBRI. Three tasks, X, Y, and Z are presented with massed and distributed items. Within a recognition test situation, conditions MPXYZ (three different tasks), DPXYZ, and DPXXX (three identical tasks) should all be statistically indistinguishable. Under recall, however, one would expect condition DPXYZ to exceed performance levels for both DPXXX and MPXYZ. The use of three, two or one tasks on each of three presentations allows a clear test of the differential effects of variable encoding among DP conditions. If additional attributes are beneficial in DP only under conditions of free recall, then one would expect no differences in recognition rates among conditions DPXXX, DPXXY, and DPXYZ, but a systematic increase in free recall scores as the number of available retrieval paths combined with the total cognitive effort of processing to determine recallability.

Another simple test would be to conduct a cued recall test similar to that of Experiment II. Cued recall may be seen as the corollary to recognition memory in that the acquisition context is supplied and only the TBRI need be recalled. The negation of an energy requirement for one half of the decision pair (attribute) should result in a pattern of data that shows no effect of encoding but only a main effect of spacing. Providing the descriptive component of the trace would leave the energy of semantic activation as the only operative component in retrieval of the TBRI.

Encoding effort is still seen as the underlying basis for spacing effects assuming that the product of that effort is usable at retrieval. Clearly, a complete account of spacing effects must include both study and test procedures.

In conclusion, three topic areas should be noted for further study along the lines of this project. They are; a) measures of encoding effort and orienting task manipulations, b) encoding/retrieval interactions, and c) voluntary versus involuntary mechanisms.

In this thesis an assumption was made that systematically varying task overlap would lead to systematic variation in encoding effort. No measure of encoding effort was used. The RT data of Rose (1984) was used as rationale for the current manipulation as the tasks were very similar to those Rose used. It would be desirable to further investigate measures of encoding effort. However, the RT latency method does not lend itself to many other orienting tasks such as constructing sentences, providing definitions, or relational processing. These longer tasks also severely inhibit acquisition list length for recognition studies.

The manipulation of operation and attribute in Experiment I stem from a desire to factorially combine the endpoint of a processing task with two types of task. Reservations were expressed from some quarters (correctly, in retrospect) that the operation-different attribute-same manipulation did not constitute a manipulation of encoding. Indeed the answering of KING: Does he wear a crown? immediately after KING: What does he wear on his head? was probably guided by a simple top-down process rather than going through effortful semantic processing. In terms of a network model of semantic memory, the highly primed nature of KING, CROWN, and the relation between them, apparently relegated this manipulation to the status of the MPOsAs condition. Hence, in these experiments, attribute was far more relevant than operation per se, although the use of free associates or consistency judgments are certainly worth investigating as operationally different processes.

The second topic, encoding-retrieval interactions, is certainly not new but begs to be explored within the domain of spacing paradigms. Apart from the posteriori explanation of encoding-retrieval interactions offered earlier, and the accompanying mini-experiments, a replication of Experiment I is in order employing some controls that ensure the results are not a product of a ceiling effect (cf. Glenberg & Smith, 1981).

The clear implication of differential results for recall and recognition under identical encoding conditions is that the traces resultant from encoding are accessed differentially or that different information is utilized from the trace. Conditions under which these differential results do not obtain may enhance understanding of spacing effects. Additionally, the suggestion from the introduction that a single 'deep' analysis may be more beneficial than two 'shallow' analyses may be interesting to test.

The final area to be discussed is the situation with respect to voluntary versus involuntary mechanisms as the source of the spacing effect. Initially, the extra activation enjoyed under DP conditions was seen as the prime determinant in spacing effects. The inability to apply effort to an already activated trace is considered an involuntary mechanism. Providing support for involuntary mechanism explanations requires that performance be unaffected by instructional variables (Hintzman, 1974; Shaughnessy, 1976). Experimental manipulation, however, may affect such involuntary mechanisms. In the investigation of habituation or effort models an attempt must be made to specify the nature of the temporal gradient of recovery and its relationship to task demands. Hintzman (1974) set the temporal gradient of recovery at about 15 seconds to account for spacing effects. That is in effect saying that whatever the true gradient of recovery, at least 15 seconds must pass before statistically significant gains in memory can be measured. Full recovery is almost certainly not complete after 15 seconds. Both Rose (1984) and Johnston and Uhl (1976) noted that although DP items invariably took longer to process than MP items, DP repetitions did show a slight decrease in RT from the first presentation.

The institution of very different orienting questions was used as a means to overcome the habituated or primed trace in a MP situation. Further investigation of habituation models should attempt to somehow disrupt the activated nature of the P1 trace such that MP same-encoded items show the same performance levels as DP same-encoded items. Alternatively, subjugation of recovery from the temporal gradient, thereby depressing DP performance, may also help elucidate some factor contributing to the within-list MP-DP effect. If either of these situations may be attained then the question of whether contact between the P1 trace and the P2 encoding operations is a product of forward persisting energy (Hintzman, 1976) or backward memory scan (Jacoby, 1978) may be resolved.

REFERENCES

Anderson, J. R. (1976). *Language, memory and thought*. Hillsdale, NJ: Wiley.

Auble, P. M., & Franks, J. F. (1978). The effects of effort toward comprehension on recall. *Memory & Cognition, 6*, 20-25.

Bird, C. P., Nicholson, A. J., & Ringer, S. (1978). Resistance of the spacing effect to variations in encoding. *American Journal of Psychology, 91*, 713-721.

Bjork, R. A., & Allen, T. W. (1970). The spacing effect: Consolidation or differential encoding? *Journal of Verbal Learning and Verbal Behavior, 9*, 567-572.

Coltheart, V. (1977). Recognition errors after incidental learning as a function of different levels of processing. *Journal of Experimental Psychology: Human Learning and Memory, 3*, 437-444.

Craik, F. I. M. (1981). Encoding and retrieval effects in human memory: A partial review. In J. Long & A. Baddeley (Eds.), *Attention and performance IX*. Hillsdale, NJ.: Erlbaum.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 11, 671-684.

Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. Journal of Experimental Psychology: General, 104, 268-294.

Cuddy, L. J., & Jacoby, L. L. (1982). When forgetting helps memory: An analysis of repetition effects. Journal of Verbal Learning and Verbal Behavior, 21, 451-467.

Davis, J. C., Lockhart, R. S., & Thomson, D. M. (1972). Repetition and context effects in recognition memory. Journal of Experimental Psychology, 92, 96-102.

Elias, C. S., & Perfetti, C. A. (1973). Encoding task and recognition memory: The importance of semantic encoding. Journal of Experimental Psychology, 99, 151-156.

Gartman, L. M., & Johnson, N. F. (1972). Massed versus distributed repetition of homographs: A test of the differential-encoding hypothesis. Journal of Verbal Learning and Verbal Behavior, 11, 801-808.

Glenberg, A. M. (1977). Influences of retrieval processes on the spacing effect in free recall. Journal of Experimental Psychology: Human Learning and Memory, 3, 282-294.

Glenberg, A. (1979). Component-levels theory of the effects of spacing of repetitions on recall and recognition. Memory & Cognition, 7, 95-112

Glenberg, A. M., & Smith, S. M. (1981). Spacing repetitions and solving problems are not the same. Journal of Verbal Learning and Verbal Behavior, 20, 110-119.

Hintzman, D, L. (1969). Effects of recency, frequency, and the spacing of repetitions. Journal of Experimental Psychology, 79, 192-194.

Hintzman, D. L. (1974). Theoretical implications of the spacing effect. In R. L. Solso (Ed.), Theories of cognitive psychology: The Loyola symposium. Potomac, Md.: Erlbaum.

Hintzman, D. L., Block, R. A., & Summers, J. J. (1973). Modality tags and memory for repetitions: Locus of the spacing effect. Journal of Verbal Learning and Verbal Behavior, 12, 229-238.

Jacoby, L. L. (1978). On interpreting the effects of repetition: Solving a problem versus remembering a solution. Journal of Verbal Learning and Verbal Behavior, 17, 649-667.

Jacoby, L. L., & Craik, F. I. M. (1979). Effects of elaboration of processing at encoding and retrieval: Trace distinctiveness and recovery of initial context. In L. S. Cermak, and F. I. M. Craik (Eds.), Levels of processing in human memory. Hillsdale, NJ.: Erlbaum.

Jacoby, L. L., Craik, F. I. M., & Begg, I. (1979). Effects of decision difficulty on recognition and recall. Journal of Verbal Learning and Verbal Behavior, 18, 585-600.

Johnston, W. A., Coots, J. H., & Flickinger, R. G. (1972). Controlled semantic encoding and the effect of repetition lag on free recall. Journal of Verbal Learning and Verbal Behavior, 11, 784-788.

Johnston, W. A., & Uhl, C. N. (1976). The contributions of encoding effort and variability to the spacing effect on free recall. Journal of Experimental Psychology: Human Learning and Memory, 2, 153-160.

Kerr, B. (1973). Processing demands during mental operations. Memory & Cognition, 1, 401-412.

Klein, K., & Saltz, E. (1976). Specifying the mechanisms in a levels-of-processing approach to memory. Journal of Experimental Psychology: Human Learning and Memory, 6, 671-679.

Lockhart, R. S., Craik, F. I. M., & Jacoby, L. L. (1976). Depth of processing in recognition and recall: Some aspects of a general memory system. In J. Brown (Ed.), Recall and recognition. London: Wiley.

Maskarinec, A. S., & Thompson, C. P. (1976). The within-list distributed practice effect: Tests of the varied context and varied encoding hypotheses. Memory & Cognition, 4, 741-746.

McMurray, D. W., & McIntyre, J. S. (1981). Depth of processing: Is there a semantic continuum? Australian Journal of Psychology, 33, 197-213.

Melton, A. W. (1970). The situation with respect to the spacing of repetitions and memory. Journal of Verbal Learning and Verbal Behavior, 9, 596-606.

Okada, R. (1971). Decision latencies in short-term memory. Journal of Experimental Psychology, 90, 27-32.

Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 nouns. Journal of Experimental Psychology Monographs, 76, (1, Pt. 2).

Postman, L., Thompkins, B. A., & Gray, W. D. (1978). The interpretation of encoding effects in retention. Journal of Verbal Learning and Verbal Behavior, 17, 681-705.

Proctor, R. W. (1977). The relationship of frequency judgments to recognition: Facilitation of recognition and comparison to recognition-confidence judgments. Journal of Experimental Psychology: Human Learning and Memory, 3, 679-689.

Reder, L. M., Anderson, J. R., & Bjork, R. A. (1974). A semantic interpretation of encoding specificity. Journal of Experimental Psychology, 102, 648-656.

Rose, R. J. (1980). Encoding variability, levels of processing, and the effects of spacing of repetitions upon judgments of frequency. Memory & Cognition, 8, 84-93.

Rose, R. J. (1984). Processing time for repetitions and the spacing effect. Canadian Journal of Psychology, 83, 537-550.

Seamon, J. G., & Virostek, S. (1978). Memory performance and subject-defined depth of processing. Memory & Cognition, 6, 283-287.

Shaughnessy, J. J. (1976). Persistence of the spacing effect in free recall under varying incidental learning conditions. Memory & Cognition, 4, 369-377.

Thios, S. J. (1972). Memory for words in repeated sentences. Journal of Verbal Learning and Verbal Behavior, 11, 789-793.

Tulving, E. (1983). Elements of episodic memory. New York: Oxford Press.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. Psychological Review, 80, 352-373.

Tulving, E., & Watkins, M. J. (1975). Structure of memory traces. Psychological Review, 82, 261-275.

Underwood, B. J. (1969). Attributes of memory. Psychological Review, 76, 559-573.

Underwood, B. J. (1970). A breakdown of the total-time law in free-recall learning. Journal of Verbal Learning and Verbal Behavior, 9, 573-580.

Underwood, B. J., Kapelak, S. M., & Malmi, R. A. (1976). The spacing effect: Additions to the theoretical and empirical puzzles. Memory & Cognition, 4, 391-400.

Winograd, E., & Raines, S. R. (1972). Semantic and temporal variation in recognition memory. Journal of Verbal Learning and Verbal Behavior, 11, 114-119.

Young, D. R., & Belleza, F. S. (1982). Encoding variability, memory organization, and the repetition effect. Journal of Experimental Psychology: Learning, Memory, amd Cognition, 8, 545-559.

Table 1

Example of the processing x attribute combinations for the target word KING.

OsAs:	KING:	Does he wear a crown?
	KING:	does he wear a crown?
OdAs:	KING:	Does he wear a crown?
	KING:	What does he wear on his head?
OsAd:	KING:	What does he wear on his head?
	KING:	Where does he sit?
OdAd:	KING:	Does he wear a crown?
	KING:	Where does he sit?

Table 2

Hit and False Alarm Proportions in Experiment 1

Hits	Misses	Correct Rejections	False Alarms
.891	.109	.832	.168

Table 3

Hit Rate Proportions by Condition in Experiment 1

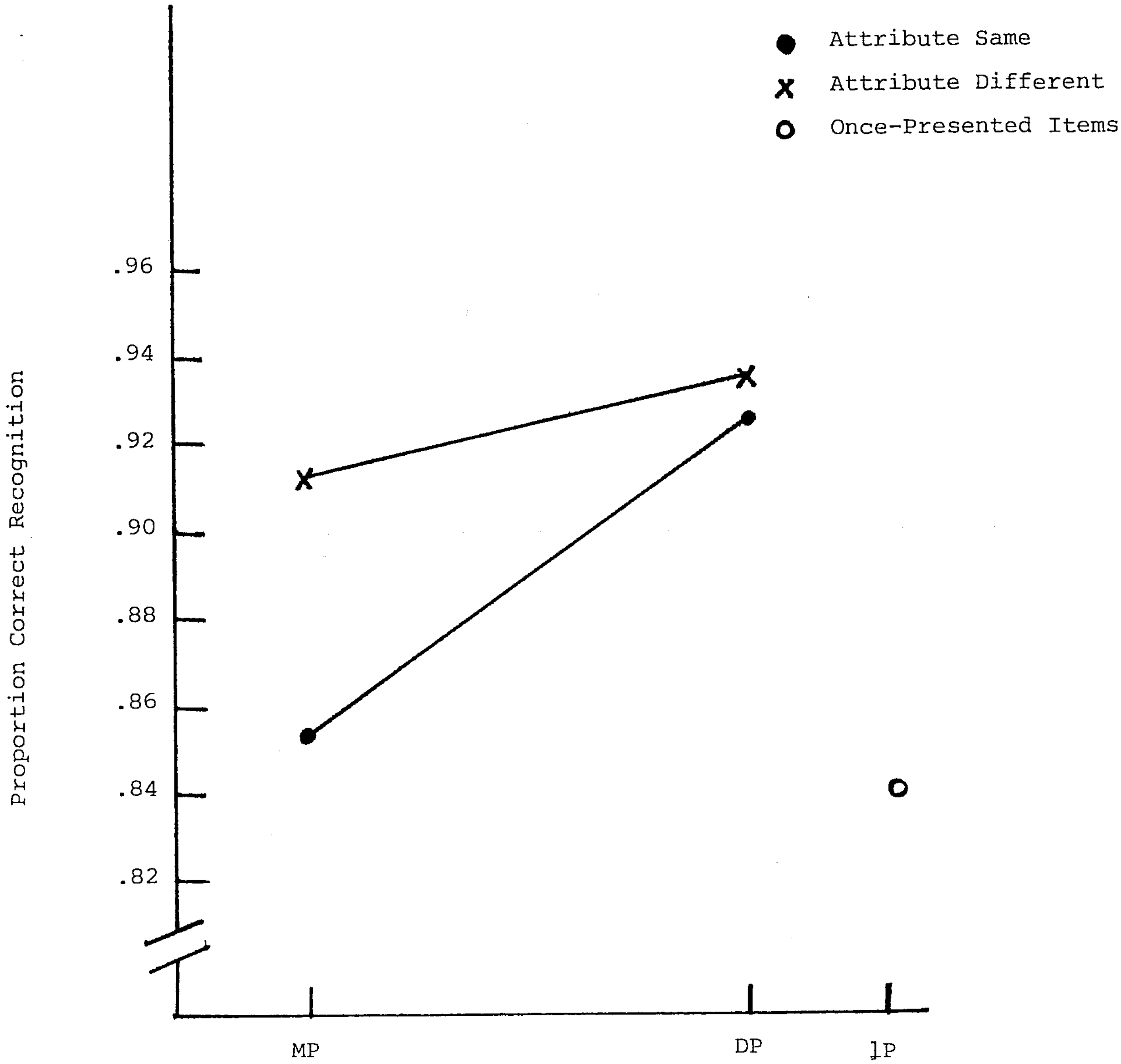
	OsAs	OdAs	OsAd	OdAd
1P	.840	----	----	----
MP	.854	.854	.932	.917
DP	.906	.917	.906	.963

Figure Captions

Figure 1. Spacing x attribute interaction from Experiment I.

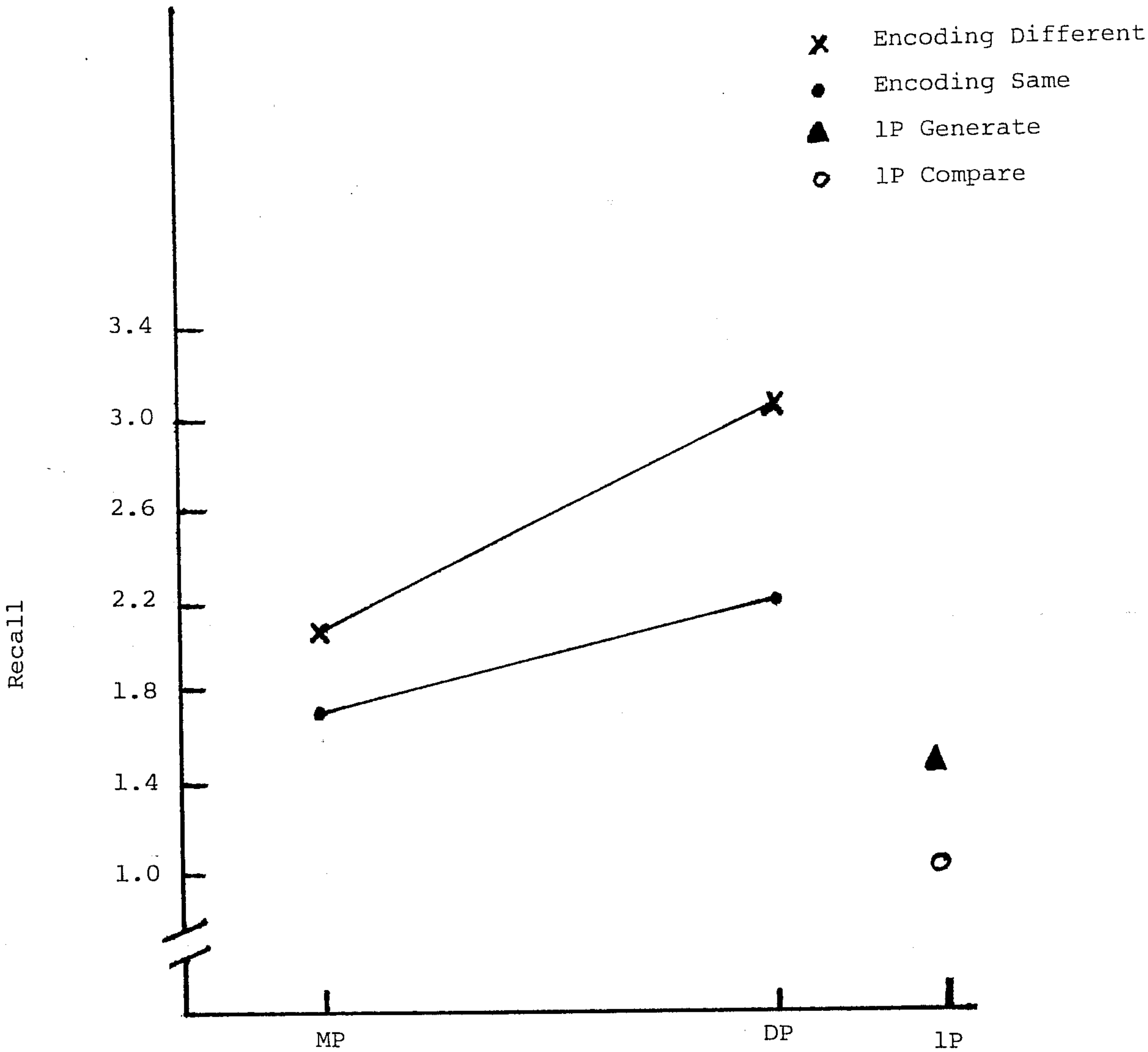
Figure 2. Mean recall for Experiment II.

Figure 1



Attribute Same
Attribute Different
Once-Presented Items
Proportion Correct Recognition
.96
.94
.92
.90
.88
.86
.84
.82
MP
DP
1P

Figure 2



Note: Maximum possible score for each cell is 6.

Appendix A

Experimental Materials

Acquisition Words

ADMIRAL	APPLE	ARROW	AUTHOR	AUTOMOBILE
BARREL	BEAVER	BIRD	BOOK	BOTTLE
BRAIN	BREEZE	BULLET	BUTTER	CAMP
CATERPILLAR	CAVE	CATTLE	CELL	CHAIR
CHIN	CIRCLE	COAST	COLLEGE	DAWN
DEVIL	DIAMOND	DISEASE	DOOR	DOVE
DREAM	DRESS	FLAG	FLOOD	FORK
FOX	FROG	GARDEN	GEESE	GIFT
GOLD	GOLF	GRASS	HARP	HORSE
HOTEL	HOUND	JUDGE	KING	LAKE
LAWN	LEMON	LETTER	MARRIAGE	MAST
MONEY	MONK	MONTH	MOSS	MOUNTAIN
MULE	PALACE	PAPER	PENCIL	PICTURE
PIPE	PRIEST	PRISON	RAILROAD	RATTLE
RIVER	SHADOW	SNAKE	SOIL	SQUARE
SULPHER	STAR	SUGAR	TABLE	THIEF
TOAST	TRUMPET	WHEAT	WINTER	

Acquisition List Filler Items

ANGLE	ANKLE	ARTIST	BAR	BOULDER
CABIN	CANDY	CASH	CODE	COIN
DEATH	DOCTOR	FACTORY	FIRE	FOAM
GIRL	HOSPITAL	HOSTAGE	INK	JOURNAL
KETTLE	LENGTH	MARKET	MEADOW	MEAT
OCEAN	OVEN	OXYGEN	POET	POLE
QUEEN	SALAD	SHIP	SHORE	SKIN

STORM	SUNSET	THORN	WINDOW	

Recognition Test "NO" Response Words

AGONY	ALCOHOL	AMBASSADOR	ANSWER	ARMY
BARON	BEGGAR	BLOOD	BLOSSOM	BOARD
BOSS	BOWL	BOY	BRONZE	BUILDING
BUTCHER	CANE	CAT	CHIEF	CHRISTMAS
CITY	CLAW	CLOCK	COFFEE	COLONY
CONTRACT	CORN	CORNER	COTTON	CRADLE
CRIME	DOLL	DOLLAR	DUST	EARTH
ELEPHANT	ENGINE	FISHERMAN	FOREHEAD	FOREST
FUR	GALLERY	GEM	GHOST	HAMMER
HEAVEN	HOOF	HOUSE	IRON	JELLY
LAW	MACHINE	METAL	MOOD	MURDER
NEPHEW	NURSERY	OATS	OFFICER	PAINTER
PARTY	PEPPER	PIANO	PLAIN	POTATO
PRAIRIE	PROFESSOR	PUPIL	RESTAURANT	ROCK
SEAT	SHOES	SKY	SLAVE	STREET
SWAMP	TICKET	TOBACCO	TOWER	TRUCK
VALLEY	VICTIM	WEAPON	WINE	

Appendix B

Orienting Questions for Experimental Words and Filler Words.

(N.B. experimental items are divided into the 55 which satisfied all conditions and the remaining 29 words.)

Experimental:

APPLE

Is a ripe one red?

What colour is a ripe one?

Does it grow on trees?

What is the center of it called?

ARROW

Is it shot from a bow?

What is it shot from?

Is it sharp?

What is on the shaft?

AUTHOR

Do they write?

What do they do?

Do they use typewriters?

Who sells their product?

BARREL

Is it made of wood?

What is it made of?

Does it roll?

What shape is it?

BEAVER

Does it build dams?

What does it build?

Is it on a nickel?

What shape is it's tail?

BOOK

Are they found in libraries?

Where do you find them?

Do they have covers?

What do you do with them?

BOTTLE

Is it made of glass?

What is it made of?

Does it hold liquids?

How do you open it?

CATERPILLAR

Does it turn into a butterfly?

What does it turn into?

Does it have legs?

What is it's nest called?

CATTLE

Do they form a herd?

What is a group of them called?

Do they live on the range?

What are the male ones called?

CELL

Does it have a nucleus?

What is the center of it called?

Is it alive?

How does it grow?

CHAIR

Do you sit on it?

What do you do on it?

Are some of them rockers?

What is the name for a comfortable one?

CHIN

Is it on your face?

Where is it?

Do some have clefts in them?

Who shaves there?

CIRCLE

Is it round?

What shape is it?

Is it symmetrical?

What is a piece of one called?

COAST

Is Los Angeles on the west one?

Which one is Vancouver on?

Is it where water meets land?

Who lives there?

COLLEGE

Does it have a dean?

Who is the head of it?

Does it have classrooms?

Who goes there?

DAWN

Is it when the sun rises?

What happens then?

Do roosters crow then?

What direction does it start in?

DEVIL

Is he evil?

What does he represent?

Does he have a forked tail?

Where does he come from?

DOOR

Does it have a knob?

What is the handle called?

Do some have locks?

How do you open them?

DOVE

Is it a symbol for peace?

What is it a symbol for?

Are they white?

What colour are they?

DREAM

Are some of them nightmares?

What are the scary ones called?

Do they happen when you sleep?

When do they occur?

DRESS

Do you wear it?

What do you do with it?

Is it all one piece?

Where do you keep it?

FOX

Is it sly?

What character trait does it have?

Are they carniverous?

Who hunts them?

GARDEN

Do they have weeds?

What don't you want to grow in them?

Does it contain vegetables?

Who looks after it?

GEESE

Do they fly in a vee?

What formation do they fly in?

Do they live in the north?

What are they covered with?

GOLF

Do you play it with clubs?

What do you hit the ball with?

Is par a good score?

Who is famous for it?

GRASS

Is it green?

What colour is it?

Does it grow in a playground?

What eats it?

HARP

Are its sounds made with strings?

What makes its sounds?

Is it played with the fingers?

Where can you hear one?

HOUND

Is it used for hunting?

What sport are they used for?

Does it have a tail?

What is its keenest sense?

JUDGE

Does he work in court?

Where does he work?

Does he use a gavel?

What is his job?

KING

Does he wear a crown?

What does he wear on his head?

Does he hold a sceptre?

Where does he sit?

LAKE

Do fish live in it?

What lives in it?

Do streams empty into it?

What is it made of?

LEMON

Is it sour?

How does it taste?

Is it yellow?

What do you do with it?

LETTER

Do you put them in envelopes?

What do you put them in?

Do you put a stamp on them?

Who delivers them?

MARRIAGE

Is it done in a church?

Where do you do it?

Does it involve making vows?

What is the woman called?

MAST

Does it hold sails up?

What is used for?

Is it tall?

Who uses them?

MONTH

Is April one of them?

What is the fourth one called?

Are there twelve of them?

How long is it?

MOUNTAIN

Does it have a peak?

What is the top of it called?

Do some of them have snow on them?

What is the biggest one called?

MULE

Is it stubborn?

What character trait does it have?

Are they used as pack animals?

What is it similar to?

PALACE

Do they have moats around them?

What is the trench around them called?

Do royalty live there?

What are they made of?

PAPER

Do you write on it?

What do you do with it?

Does it burn?

What is it made from?

PENCIL

Does it have an eraser?

What's on the other end?

Are some coloured?

When do you sharpen it?

PICTURE

Do you take it with a camera?

How do you take one?

Does it come from film?

Who takes them?

PIPE

Do you smoke it?

What do you do with it?

Does it have a stem?

How do you start it?

PRIEST

Is he Catholic?

What religion is he?

Does he preach?

When does he work?

PRISON

Is it used to house criminals?

Who lives there?

Do guards work there?

Who's in charge there?

RAILROAD

Do trains travel on it?

What travels on it?

Is it made of steel?

Who drives on it?

RATTLE

Is it a toy for a baby?

Who plays with it?

Does it make a noise?

What does it do?

RIVER

Is a bridge built over it?

What do you build over it?

Does it have banks?

What travels on it?

SHADOW

Do you see them during the day?

When do you see them?

Can they vary in size?

How are they caused?

SQUARE

Does it have four sides?

How many sides does it have?

Is it symmetrical?

How many corners does it have?

STAR

Do you see them a night?

When do you see them?

Are they far away?

Who studies them?

SUGAR

Is it sweet?

How does it taste?

Does it cause cavities?

What do you put it on?

THIEF

Does he steal?

What does he do?

Is he dishonest?

Who catches him?

TOAST

Is it made from bread?

What is it made with?

Do you put jam on it?

When do you eat it?

WINTER

Does it snow then?

What falls during it?

Is it cold?

When does it end?

ADMIRAL

Is he in charge of a fleet?

What is he in charge of?

What colour is his uniform?

Whom does he work for?

AUTOMOBILE

Does it run on gas?

What makes it run?

Does it have tires?

Where do you use it?

BIRD

Do they live in nests?

Where do they live?

Do they lay eggs?

How do they travel?

BRAIN

Is it made up of neurons?

What is it made of?

Does it control your body?

What colour is it?

BREEZE

Is it a mild wind?

What is a strong one called?

Is it soothing on a hot day?

Where isn't there one?

BULLET

Is it made of lead?

What is it made of?

Does it travel fast?

What is it fired from?

BUTTER

Is it made from milk?

What is it made from?

Is it soft?

What colour is it?

CAMP

Do you use tents in it?

What do you sleep in?

Is it in a park?

When do you go to one?

CAVE

Do bears live in them?

What lives in them?

Do bats live in them?

Where do you find them?

DIAMOND

Is it used on rings?

What jewellery is it found on?

Is it hard?

What are its sides called?

DISEASE

Are they caused by viruses?

What causes them?

Are some of them fatal?

What is a common one?

FLAG

Is it made of cloth?

What is it made of?

Is it flown during holidays?

What does it represent?

FLOOD

Is it contained by a dike?

What will contain it?

Is it caused by rain?

When does it occur?

FORK

Does it have tines?

What are the prongs called?

Is it used to pick up food?

When do you use it?

FROG

Does it jump?

How does it move?

Does it croak?

What does it est?

GIFT

Do you give it to a friend?

Who do you give it to?

Is it the thought that counts?

When do you give them?

GOLD

Do you find it in a mine?

Where is it found?

Is it valuable?

Where is it stored?

HORSE

Does it eat hay?

What does it eat?

Is the female called a mare?

Who rides them in a race?

HOTEL

Do you use them on vacation?

When do you stay there?

Do they have bellhops?

Who cleans the rooms?

LAWN

Do you have to mow it?

What do you do to maintain it?

Can you bowl on it?

How do you nourish it?

MONEY

Do you buy things with it?

What is it used for?

Is some of it silver?

Where do you save it?

MONK

Does he wear a robe?

What does he wear?

Was Rasputin one?

Who do they worship?

MOSS

Does it grow on trees?

Where does it grow?

Do you find it on antlers?

What does it feel like?

SNAKE

Does it have scales?

What is it covered with?

Are some of them constrictors?

How does it move?

SOIL

Do plants grow in it?

What grows in it?

Do worms live in it?

Who tills it?

SULPHER

Is it used to make matches?

What is it used to make?

Is it an element?

What does it smell like?

TABLE

Do you eat at it?

What do you do at it?

Is it flat?

How many legs does it have?

TRUMPET

Is it made of brass?

What is it made of?

Is it used for jazz music?

How do you play it?

WHEAT

Does it grow in a field?

Where does it grow?

Is it ground in a mill?

How is it harvested?

Acquisition List Filler and Buffer Words

CASH: Where do you save it?

DEATH: What can cause it?

GIRL: What's a name for one?

INK: What colour is it?

MEAT: How do you cook it?

FIRE: Is it cold?

JOURNAL: Is it a tool?

MEADOW: Is it full of trees?

POET: Does he do manual labour?

SHORE: Is it the same as the horizon?

ARTIST: Do they paint houses?

CABIN: Does it have a basement?

CANDY: Does it taste bad?

COIN: Are they triangular?

CODE: Is it the same a a password?

FACTORY: Do children work there?

HOSTAGE: Are they free?

KETTLE: Is it made of plastic?

MARKET: Is everything free there?

NAIL: Do you put them in with a screwdriver?

FOAM

Is it hard?

Is it a type of food?

HOSPITAL

Do lawyers work there?

Is it for healthy people?

OCEAN

Is it small?

Is it orange?

POLE

Is it made of stone?

Are they short?

QUEEN

Is she poor?

Does she live in a hut?

SALAD

Is it served in a cup?

Is it served after the main course?

STORM

Is it calm?

Does it happen indoors?

SUNSET

Is it just before morning?

Is it like an eclipse?

THORN

Is it soft?

Do you eat it?

WINDOW

Is it unbreakable?

Do closets have them?

ANGLE

Is it curved?

Does it have five sides?

ANKLE

Is it on your arm?

Do you have three of them?

BAR

Do you sleep there?

Is it for animals?

BOULDER

Is it made of wood?

Is it flat?

DOCTOR

Do they injure people?

Is it the same as a nurse?

LENGTH

Is it in kilograms?

Does it measure speed?

OVEN

Does it keep things cold?

Is it a musical instrument?

OXYGEN

Is it poison?

Is it a mineral?

SKIN

Is it made of calcium?

Is it on the inside of your body?

SHIP

Does it have tires?

Does it travel on land?