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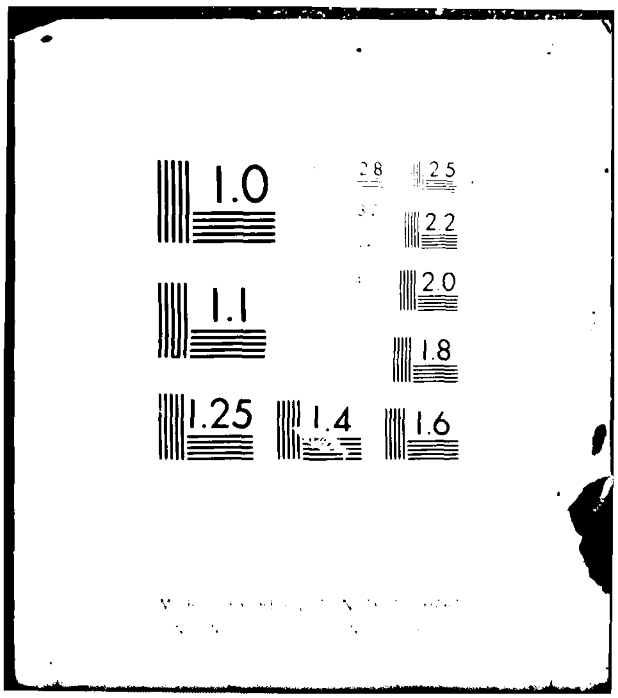
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THE USE OF DUAL TASK PARADIGMS IN MEMORY RESEARCH: A METHODOLOGICAL ASSESSMENT AND AN EVALUATION OF EFFORT AS A MEASURE OF LEVELS OF PROCESSING

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REPORT HARL-ONR-8105

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Abstract

Results from dual task experiments have often been used to make inferences concerning memorial processes. However, many dual task experiments are based on invalid methodological assumptions. Three major assumptions which are implicitly assumed by current dual task memory research are shown to be inappropriate. Criteria which should be met in dual task experiments that draw inferences from secondary task decrements are discussed. A dual task experiment meeting the proposed criteria was conducted. Contrary to previous dual task research, the present experiment demonstrates that a carefully controlled dual task experiment shows that primary task effort is neither monotonically related to levels of processing, nor does it produce better memory for verbal stimuli. It is concluded that researchers must carefully consider the assumptions inherent in any dual task experiment when designing such experiments.

The Use of Dual Task Paradigms in Memory Research: A Methodological Assessment and Evaluation of Effort as a Measure of Levels of Processing

There has been an increase in recent years in the use of dual task methodology to investigate memorial processes (e.g., see Britton, Meyer, Simpson, Holdredge, & Curry, 1979; Britton, Piha, Davis, & Wehausen, 1978; Eysenck & Eysenck, 1979; Griffith, 1976; Johnston & Heinz, 1978; Tyler, Hertel, McCallum, & Ellis, 1979; to name but a few). However, many dual task studies have incorporated methodological assumptions of which the validity is quite questionable. The purpose of the current paper is to examine these common assumptions and to provide an illustration of the potential problems that may arise when these assumptions are accepted. In addition, this methodological note is supplemented with an experiment which demonstrates that contrasting results are obtained, depending on whether the stated assumptions are or are not accepted. The experiment demonstrates that a carefully controlled dual task experiment does not support the hypothesis that effort and levels of processing are related (Eysenck & Eysenck, 1979; Tyler et al., 1979).

Researchers using dual task methodology often make three implicit assumptions: 1) Processing capacity is an undifferentiated pool of attentional resources that can be allocated in a continuous quantity as required by task demands (Kahneman, 1973); 2) There are no subject strategies that could affect the results, e.g., trading off primary task performance to increase secondary task performance; 3) There are no qualitative or quantitative performance changes with practice. Current attention research indicates that all three of these assumptions are incorrect and that there are serious problems associated with interpretations of data based on these assumptions.

The first assumption (i.e., undifferentiated capacity) implies that pairing several information processing tasks (as primary tasks) with a secondary or subsidiary task allows one to determine the processing capacity requirements of each task by examining performance on the secondary task. The logic is simply that as more resources are consumed by the primary task, fewer resources are available to the secondary task. Therefore, the most demanding primary task will be associated with the poorest secondary task performance.

Unfortunately dual task interactions are much more complex than assumption 1 suggests. Several dual task studies fail to support an undifferentiated capacity model. For example, Kahneman's (1973) model predicts that two different secondary tasks that are equivalent in their information processing demands should interfere equally with the same primary task. In fact, this is often not the case (e.g., Kinsbourne & Hicks, 1978; McLeod, 1978). In these cases, it appears that the structure of the secondary task (e.g., what modality is required for input or output) determines the degree of interference with the primary task. Wickens (1980) has termed this type of effect _structural alteration_.

A second unsupported prediction of the undifferentiated capacity assumption is that increasing the resource demand (or difficulty) of either the primary or secondary task should leave fewer resources for the remaining task and reduce its performance level. Again, some results are inconsistent with this prediction, i.e., increasing the difficulty of one task (and ensuring that performance remains constant on this task) does not always lead to decreased performance on the other task. Wickens (1980) has used the term <u>difficulty insensitivity</u> to describe results such as these. (See Isreal, Wickens, & Donchin, 1979; Kantowitz & Knight, 1976; Wickens & Kessel, 1980.)

These studies, and several others reviewed by Navon and Gopher (1979) and Wickens (1980), cannot be accommodated within an undifferentiated capacity model of attention. As a result, several investigators (Isreal, Wickens, & Donchin, 1979; Kantowitz & Knight, 1976; Navon & Gopher, 1979; Sanders, 1979; Wickens, 1979, 1980; Wickens & Kessel, 1980) have proposed that the construct of attentional resources should be modeled as multiple resource pools, each possessing limited resources which can be allocated to several concurrent processes (see Wickens, 1980). Under this multiple capacity or multiple resource view, tasks which use the same structures (or a large portion thereof) will reveal performance decrements when time-shared, and further decrements when the resource demand of one or both are increased. In contrast, a demand for fewer common structures will result in highly efficient time-sharing and show difficulty insensitivity when task parameters are manipulated. Therefore, if secondary task performance is to reflect primary task resource demands, <u>both tasks must demand resources from the same structures</u>.

The rejection of assumption 1 indicates that dual task studies must meet a criterion in regard to resource trade-offs. Studies must provide evidence that the two tasks tap a common pool. Researchers must demonstrate that performance improvements on one task result in deficits in the other.

The second assumption (asserting the unimportance of strategic trade-offs) is also inconsistent with the attention literature. Subjects have the ability to trade-off performance on one task to improve performance on another task (see Gopher & North, 1977; North & Gopher, 1976; Wickens & Gopher, 1977).

The rejection of the second assumption necessitates that dual task research meet a second criterion, that of <u>maintenance of equivalent single and dual primary task performance</u>. In order for secondary task performance to measure primary task effort, subjects must never deprive the primary task of the needed resources. If one is to make statements concerning a memorial process from secondary task performance, then primary task performance must be equivalent to its single task level when time-shared with the secondary task. Without a sensitive measure of primary task performance and <u>some</u> indication that primary task performance was held at a relatively constant level, little can meaningfully be inferred about secondary task performance.

The third assumption (that task performance does not change either qualitatively or quantitatively with practice) is appropriate only in certain situations. One must be concerned with practice and the possible automatization of tasks (see Schneider & Shiffrin, 1977). Schneider and

Shiffrin (Shiffrin & Schneider, 1977) resolved many of the conflicts in visual search, memory scanning, and selective attention paradigms by showing that some researchers were examining what Schneider and Shiffrin refer to as control processing effects (effortful processing), while others were examining automatic processing effects. Control processing occurs when subjects search for novel, perceptual threshold, or inconsistent targets, and/or are poorly trained. Automatic processing develops as subjects receive training at consistently responding to target stimuli. In contrast to control processing, automatic processing is not limited by short-term memory and does not require subject effort.

Using this automatic/control processing distinction, it is difficult to interpret a dual task experiment in which one secondary task is used throughout the experiment and this task can become automatic (e.g., simple reaction time to an easily discriminable light or tone). Under these conditions, different results and interpretations will arise depending upon whether or not sessions are averaged, the number and duration of experimental sessions, and where in the time course of the experiment comparisons are made (see Schneider & Fisk, Note 1).

On the other hand, if the secondary task is always a control process, then this third assumption may be reasonable. Schneider and Shiffrin (1977;see also Schneider, Dumais, & Shiffrin, in press) found that control process performance was stable throughout several months of practice.

The rejection of the third assumption necessitates that dual task experiments meet a third criterion, that the <u>secondary task load must be constant throughout the experiment</u>.

Based on these considerations, memory experiments utilizing a dual task paradigm should meet the following criteria: 1) There should be resource trade-off with the secondary task sensitive to the resource demands of the primary task; 2) There should be maintenance of single and dual primary task performance; and 3) The secondary task must require the same amount of control processing resources throughout the experiment and not become automatized.

To supplement the above discussion, an experiment was conducted that illustrates the differences in results obtained when the above criteria are or are not met. The general theme of our experiment was similar to two recently published papers which investigated the utility of a processing resource index for "levels of processing" (Eysenck & Eysenck, 1979) and the hypothesis that cognitive effort is directly related to long term memory modification (Tyler et al., 1979).

Both Eysenck and Eysenck (1979) and Tyler et al. (1979) used a levels of processing paradigm. The original levels approach to human memory (Craik & Lockhart, 1972) contended that verbal stimuli could be classified along a continuum ranging from structural to semantic, where the location of the stimulus on the continuum determined the stimulus's memorability. Thus, greater "depth" of stimulus processing (the closer the processing was to the semantic end of the continuum) resulted in a greater probability of the stimulus being remembered. To avoid circularity, an independent measure of processing depth is required (Baddeley, 1978; Nelson, 1977). Eysenck and Eysenck (1979) and Tyler et al. (1979) suggested that expended processing capacity could be used as an independent empirical index related to depth of processing.

To investigate processing resources expended on various tasks, these researchers used the dual task methodology based on the assumptions above. They paired several orienting tasks that required deep (semantic) or shallow (structural) processing with a simple probe reaction time (RT) task. The orienting tasks were considered primary and the probe RT task was always the secondary task. These researchers accepted (either explicitly or implicitly) the three assumptions discussed earlier.

Eysenck and Eysenck (experiment 2) asked subjects to perform four different primary tasks. Subjects were to determine if a word possessed: 1) one given letter; 2) two given letters; 3) one attribute (e.g., edible); or 4) two attributes (e.g., edible and solid). Tasks 1 and 2 represent shallow (or structural) processing while tasks 3 and 4 represent deep (or semantic) processing. The one letter/attribute conditions were considered to be less difficult than the two letter/attribute conditions. The secondary task was a simple RT to an intensity change of an easily discriminable light or tone. Eysenck and Eysenck found that secondary RTs were longer when subjects performed the semantic tasks than when they performed the structural tasks. This result indicated to them that depth of processing affected the amount of expended processing capacity required to perform a given task and they claim that semantic processing tasks require greater amounts of processing resources to perform than structural processing tasks (Eysenck & Eysenck, 1979, p. 481).

Tyler et al. employed a similar methodology (experiments 2 and 4) in which they asked subjects to perform either an anagram (nonsemantic) task or a sentence completion (semantic) task. The semantic and nonsemantic tasks had two levels of difficulty determined by the ease with which a word fit into a sentence (semantic task) or by the difficulty of letter rearrangement (nonsemantic task). The secondary task was a simple reaction timed response to a tone. Tyler et al. found that, within a level of processing, the more difficult tasks (high effort condition) led to better recall performance than the easy (low effort) tasks. They also reported a levels of processing effect for recall performance. The subjects' secondary task performance (i.e., probe RTs) were longer during the high effort conditions than during the low effort conditions. Thus, Tyler et al. concluded that their secondary task manipulation provided an independent criterion for measuring effort. However, there was no levels of processing effect for the secondary task performance, suggesting to Tyler et al. (p. 616) that secondary task performance provides an independent measure of effort which measures something separate from levels of processing and that greater effort (as measured by secondary task performance) will lead to better memory for verbal material.

Both Eysenck and Eysenck and Tyler et al. accepted the three assumptions discussed earlier. They clearly accepted the assumption that processing capacity is an undifferentiated pool of attentional resources (see the introduction to both of their papers). Acceptance of this assumption affected their choice of a secondary task. Their secondary task, we argue, did not tap resources in common with their primary tasks. Since only a simple RT was required for their secondary tasks, one can see that this type of task relied almost exclusively on processing resources associated with "simple" encoding and responding, little or no decision making was required. (Their primary tasks clearly required central processing decision making.)

Regarding single and dual task performance trade-off (assumption 2), Tyler et al. provided no information regarding primary task performance. Eysenck and Eysenck provided limited information on single/dual primary task performance (see their Table 4, p. 480) that suggested that primary task performance was not maintained.[1]

Finally, in regard to assumption 3, neither Eysenck and Eysenck nor Tyler et al. provide data regarding improvement of secondary task performance with practice. (Although Eysenck & Eysenck's experiment did contain single task trials both at the start and end of the dual task trials, there is no indication that RT performance was stable from beginning to end. Averaging the beginning and end RT trials (see Eysenck & Eysenck, p. 480) may have generated spurious performance estimates.)

The present experiment was designed not assuming the three assumptions, but rather meeting the criteria above. To provide an empirical test of the validity of our concern with acceptance of the assumptions, the present experiment was designed to parallel the experiments of Eysenck and Eysenck and Tyler et al. as closely as possible. Our experiment, like the Eysenck and Eysenck and Tyler et al. experiments, required subjects to perform orienting tasks that varied both in "levels of processing" (i.e., either a structural or semantic task) and in difficulty. As a secondary task, subjects made a four-choice reaction timed response to a visually presented probe stimulus.

Our primary task was an incidental learning task that required subjects to decide whether auditorially presented words began with specified letters or were members of some specified categories. The subjects were required to hold a critical word or words (defined by the structural or semantic orienting task) in memory until a subsequently presented word met the particular orienting task requirement at which time the previous critical word was to be replaced in memory by the new word. At the end of each word list the subjects recalled the last critical word (or words) held in memory. For example, if the orienting task required subjects to report the last word in the list beginning with the letter G and subjects heard; GOAT, DOLLAR, LION, GIRL, SKIRT, they would hold the word GOAT in memory until the word GIRL occurred. Since GIRL was the last "critical" word presented in the word list, the subjects would recall GIRL at list's end. The subjects heard several such lists after which they were given a suprise recognition test for all of the critical (or to be held in memory) words.[2]

The secondary task was chosen because it would continue to require the same processing resources throughout the experiment. For the secondary task, subjects were required to make a four choice reaction timed response to a visually presented stimulus. The stimulus to response mapping was incompatible, with the response mappings changing occasionally during the experimental session. This manipulation insured that the secondary task would continue to require resources (not become automatic). A pilot experiment, testing only the secondary task, showed that by changing the stimulus to response mappings every 50 responses (and re-using a given mapping after every 300 responses) there was no change in reaction time over a 1.5 hour experimental session ($t(11)=.29$).

Our primary and secondary tasks were chosen because they were similar to those used by Eysenck and Eysenck and Tyler et al. <u>and</u> they fulfilled the three criteria presented above. Specifically, the primary and secondary tasks were thought to demand a large portion of the same resource structure. Previous results show that spatial compatibility (in a reaction time task) interacts with verbal memory loading (Crowder, 1967) and that spatial compatibility interacts with short term memory task demands (Logan, 1980; see also Wickens, 1980). In addition, it has been shown that there is little or no peripheral interference between our primary and secondary tasks, i.e., they do not compete for common input and output channels (Wickens, 1980). To evaluate the second criterion, the single and dual task levels were established to verify maintenance of primary task performance levels. To meet the third criterion, a resource consumptive control process was chosen to provide a consistent secondary task load.

The following experiment provides an example of the way a dual task memory experiment may be conducted to eliminate potential problems associated with acceptance of the assumptions outlined in the introduction. We will contrast the results of the present experiment with the results of Eysenck and Eysenck and Tyler et al.

Method

<u>Primary tasks</u>. Four orienting tasks were employed as primary tasks in an incidental learning paradigm similar to that used by Craik and Watkins (1973). For each orienting condition, subjects were to listen to a list of words and hold in memory one or two "critical" words (with "critical" being defined by the orienting task). There were multiple critical words in each list; therefore, the subject held a particular critical word in memory until another critical word occurred at which point the subject was to replace the old critical item with the new. At the end of the list the subject recalled the last critical word(s).

There were two graphic (or structural) conditions and two semantic conditions. Each member of the pair differed in resource demands -- one "easy" and one "difficult", i.e., a one or two attribute decision requirement, respectively. The first graphic task (Orient 1) required subjects to recall the last list item that began with a specific letter. Similarly, "Orient 2" required the recall of the last words beginning with two such letters. Thus, for example, subjects in Orient 1 recalled the last word beginning with R and in Orient 2 subjects would recall the last word beginning with C and the last word beginning with G. Analogously, in the semantic orienting conditions subjects were asked to recall either the last word from one specified semantic category (such as birds) in Orient 3 or from two such categories (such as sports and fruits) in Orient 4.

Secondary task. To measure processing resources expended by the primary task, a four-choice probe reaction time (RT) task with variable stimulus-response compatibility was employed. The display for the reaction time task consisted of four white "plus" signs arranged to form a square around a central fixation dot. The subjects sat approximately 75 centimeters away from the CRT. The distance from the focus dot to the center of each display element was approximately 1.5 degrees visual angle. On approximately one-half of the word presentations one plus changed to a red asterisk. The probe onset (i.e., a white plus changing to a red asterisk) and word presentation were synchronized in the dual task trials such that probe onset was .5 sec after the start of word presentation.

The subject was required to respond to the probe by pressing one of four buttons. The subject's response box contained four buttons arranged in a square. Four incompatible button-to-display mappings were used to increase the processing resources required by the RT task and prohibit automatization. As opposed to responding to the actual position of the red asterisk, subjects were required to perform either a row reversal, a left column reversal, a right column reversal, or a top row reversal in order to correctly convert the display position of the red asterisk to the proper button response. For example, in the row reversal condition, if the asterisk was in the upper left the subject pushed the upper right button. A pilot study had indicated that these four button-to-display mappings were of equal difficulty. For each orienting condition the subjects responded with a different stimulus-response mapping. Different button mappings were used throughout the experiment to preclude reduced latencies with practice.

Test of incidental learning. Four recognition tests were given following completion of all orienting tasks. A separate recognition test was constructed for each orienting condition in order to separate false alarms across the four orienting conditions. Each recognition test consisted of 40 items which included all the 18 to-be-rehearsed (i.e., critical) words for that given orienting task plus 22 distractors. The distractors were unrehearsed (non-critical) words. The critical and distractor words came from seperate word lists and were equated for production frequency (as measured by Battig and Montague (1969)). The subjects' task was to circle all words they recognized as having been critical words. Target and distractor words (in a given test) satisfied the same category or first letter search criterion. Therefore, subjects could not perform the recognition task simply on the basis of whether or not a word satisfied the orienting task search criterion.

Procedure. Subjects were run individually in this incidental learning task. Subjects were seated at a table with the CRT and button box in front and the tape recorder speaker to their left. Before the beginning of data collection, the first button mapping was described and subjects completed 10 single task practice trials with this button mapping. The practice was followed by 10 more single task trials in which the data were stored. The particular orienting condition was then explained. The subjects were told which type of word(s) were the critical words for the upcoming word list.

Because the orienting task was considered primary, emphasis was always placed on performing this task over the RT task. The word lists and RT tasks were then paired for three dual task blocks. This was followed by another 10 single task RT trials. This entire sequence -- explanation and practice of a new button-to-display mapping, single task RT, three word lists (dual task), single task RT -- was then repeated for the three remaining orienting conditions.

Orienting conditions and button mappings were manipulated within subjects. However, to control for transfer effects between button mappings and orienting task order, both factors were completely counterbalanced. Therefore, each subject represented a unique sequence of orienting conditions, button mappings, and recognition list order.

Following the orienting task sequences, subjects were given a two-minute *arithmetic* distractor task. They were then given the recognition tests described above.

Materials. Three word lists were constructed for each orienting condition. List length varied (11 or 25 words) to control for subjects anticipating list termination. Words were selected from the category norms of Battig and Montague (1969) and were all one or two syllable nouns. The lists were equated across orienting conditions for word frequency, number of words to be rehearsed, and time required to hold critical items in memory. The longer lists contained seven to eight critical words while the shorter list contained three to four. All list entries were unique such that 61 different words were presented during each orienting condition and 244 different words were presented during the experiment. The presentation rate of one word every three seconds was constant for the four orienting conditions.

Equipment. Word stimuli for the orienting tasks were recorded and presented by a tape recorder. The probe RT task and all timing of the experiment was controlled by a PDP 11/34 computer. The stimuli for the RT task (white pluses and red asterisks) were presented on an Intelligent Systems Corporation 8001G color terminal. The computer collected and stored subjects' reaction times to the probe.

Subjects. Sixteen students from the University of Illinois introductory psychology pool participated in the experiment. Their participation partially fulfilled a course requirement. All subjects reported English as their native language and normal or corrected to normal vision.

Results

Primary task performance. The end of list recall of critical items for the structural and semantic "easy" conditions (one critical word, orient 1 & 3) was 100 percent. The "difficult" conditions (two critical words, orient 2 & 4) showed a slight deficit: 94 and 98 percent, respectively. The primary task performance did not differ from the expected single task level. It is also important to note that the reduced performance in the difficult conditions did not facilitate the subjects' performance in the secondary task (see below).

Secondary task reaction times. Secondary task RTs are presented in Figure 1 along with single task RT performance. (Error rates from the RT task averaged 3.75% and 5.75% for single and dual task trials, respectively. The error rates were positively correlated with reaction time which indicates no speed/accuracy trade-off problems that would interfere with interpretation of the RT data.)

Insert Figure 1 about here

As expected, single task RTs did not differ (ranging, across conditions, from 804 to 812 msec). This should be the case since pilot data had shown that the different button mappings used for each orienting condition were comparable in difficulty. The single task data represent the averaged pre and post dual task trials since they also did not differ (i.e., no practice effects). An orienting X difficulty ANOVA was performed on the dual task RT data and showed that the main effect of difficulty was significant, [$F(1,15)=18.48$, $p < .001$, $MSe = 6557$]. Neither the main effect of orienting nor the interaction were signficant (Fs < 1). These results do not support Eysenck and Eysenck's position that semantic tasks require greater processing resources than structural tasks.

Separate analyses comparing the dual task RTs to single task RTs also did not provide support for the Eysenck and Eysenck hypothesis. Both "difficult" orienting conditions (orient 2 & 4) differed from the single task performance ($p < .01$) but the "easy" conditions (orient 1 & 3) did not statistically differ from the single task. The analyses involved comparing each dual task condition to the single task by the Newman-Keuls analysis of variance test (see Keppel, 1973, pp. 420-421). The present data indicate that it is the difficulty of the primary task not the levels of processing that determines secondary task preformance.

Recognition performance. Figure 2 shows the subjects' ability to differentiate rehearsed (i.e., critical) from non rehearsed (i.e., non critical) words. The figure presents the average of the individual subjects' sensitivity measure (A'). The A' measure of sensitivity was used

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Insert Figure 2 and Table 1 about here

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because it is more robust than d' to violations of distribution assumptions (see Craig, 1979; Norman, 1964). The use of A' necessitates the knowledge of hits and false alarms (FA). The equation for A' is

$$1-.25[p(FA)/p(HIT) + p(MISS)/p(CORRECT\ REJECTION)]$$

For the A' measure of sensitivity, .5 is chance and 1.0 represents perfect performance. (The average percentage of hits and FAs are provided in Table 1. In addition, the averaged d' values for each condition are provided. Although the d' measure (for the present data) parallels the A' measure in the direction of effects across conditions, the present absolute values of d' must be taken with caution since many subjects in the semantic conditions produced no FAs.) The analysis of variance of the transformed (arc sine) A' scores indicated the main effects of orienting and task difficulty were significant, [$F(1,15)=20.18$, $p < .001$, $MSe=.058$ and

$\underline{F}(1,15)=6.72$, $\underline{p} < .025$, MSe=.019], respectively. The interaction did not reach statistical significance, [$\underline{F}(1,15)=2.35$, $\underline{p}=.14$, MSe=.028]. These results, in conjunction with the secondary task data, do not support the Tyler et al hypothesis. In fact, the analysis indicated that greater effort led to poorer memory (i.e., the main effect of task difficulty).

Discussion

Figures 1 and 2 show that in the semantic conditions memory for the rehearsed stimuli (measured by recognition performance) decreased as effort increased (measured by secondary task performance). In the graphic conditions, increased effort had no effect on recognition performance. One conclusion that emerges from the present data is that no simple relationship exists between type of processing, processing resources expended and learning. The primary task demands (as measured by secondary task RT deficit) did not reflect the "levels of processing". In addition, the secondary task methodology indicates that the amount of processing resources expended is not predictive of recognition performance. Secondary task performance is related to primary task difficulty, not "levels-of-processing".

The present results are thus not consistent with the Eysenck and Eysenck (1979, p. 481) statement that "semantic processing tasks involve greater expended processing capacity than physical processing tasks." They also conflict with the Tyler et al.'s prediction (p. 616) that cognitive effort within levels of processing is related to learning. Why the differences? The answer appears to lie with the inadequacy (due to potential practice effects) of the secondary tasks previously used to access processing load and the failure to utilize primary and secondary tasks which tap a large portion of the same resource structure. These problems make dual task decrement scores hard to interpret.

The present experiment met the three proposed criteria. The first criterion was met since the primary and secondary tasks did tap common resource structures. In addition to the a priori literature showing that varied mapping search tasks and word encoding tap a common resource pool, the data showed that the more difficult versions of our primary task led to poorer secondary task performance (i.e., there was difficulty sensitivity). The second criterion of maintenance of single and dual primary task performance was basically met. Interpreting the primary task performance level is problematic since performance was near ceiling. However, our data indicate that subjects did not trade-off primary task performance to improve secondary task performance. The slight decrease in primary task performance (in the difficult versions of the primary tasks) did not lead to improved primary task performance, thus satisfying the concerns giving rise to criterion 2. The third criterion that the secondary task require the same amount of control processing throughout was met since there were no secondary task practice effects throughout the experiment.

It seems appropriate to comment on the Tyler et al. (p. 616) proposal that cognitive effort is an "important determinant" of performance in memory tasks. In our opinion, one must be concerned with the interaction between three task characteristics: 1) the current state of memory; 2) the task appropriateness of the cognitive effort; and 3) the amount of cognitive effort.

The current state of memory will influence recall without necessarily influencing cognitive effort. There is no evidence to indicate that the amount of cognitive effort is any greater or less at the first trial in a proactive inhibition (PI) situation than when PI is built up or when release from PI occurs (D. D. Wickens, Note 2; also see D. D. Wickens, 1972 for a discussion of PI). Performance, in the PI situation, is dependent on the state of memory.

The task appropriateness of the effort determines whether the effort modifies memory in a manner which improves recall or recognition performance. For example, it appears that operating in memory at a given "level" will not necessarily lead to a given degree of performance. Performance can be shown to depend upon the task appropriateness of the level of processing. Task appropriateness may depend upon the subsequent test of learning (see, Morris, Bransford, & Franks, 1977). In a simple sense, the performance on the memory test is the result of the multiplicative effect of characteristics of the state of memory, appropriateness, and effort. A simple assessment of effort alone will not predict performance.

In conclusion, while we have attempted to present a description of some problems often encountered in dual task research, this presentation is not exhaustive. Clearly, one must examine carefully the assumptions inherent in any dual task experiment. One simply cannot pair any two tasks together and hope to observe meaningful results. Although the use of dual task methodology is potentially fruitful, inappropriate use of this approach can yield misleading results.

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Footnotes

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[1] When performance trade-offs are calculated (dual task performance minus single task performance) we see that for positive trials Deep processing (visual secondary task mode) the trade-off was minimal being 32 and 44 msec for the Deep 1 and 2 attribute conditions, respectively. However, the trade-off for the Shallow one and two attribute conditions was -41 and 157 msec, respectively. This differential trade-off hinders one's ability to draw conclusions from the secondary task data. Auditory positive trials performance trade-offs showed an opposite pattern.

[2] Note, a recognition test was chosen because pilot studies had shown subjects' free recall of the critical words to be very poor, four to 15 percent correct recall across subjects. Therefore, the recognition test was considered to be a more sensitive measure of incidental learning than free recall.

Table 1

Primary Task Accuracy Measures and Averaged d'

Orienting

	Graphic		Semantic	
Primary task difficulty	1	2	1	2
% Hits	68.800	63.600	86.100	83.600
% False Alarms	17.200	13.300	5.900	14.700
d'	1.872	1.719	3.368	2.493

Figure Captions

Figure 1. Secondary task probe reaction time data. Dashed line represents averaged single task probe reaction times.

Figure 2. Recognition sensitivity for Graphic and Semantic orienting tasks. Primary task difficulty refers to the number of critical words to be held in memory at any given time.

TABLE 1

Probe RT error rates

	Orienting			
	Graphic		Semantic	
Primary task difficulty	1	2	1	2
Single task	.02	.02	.04	.07
Dual task	.03	.07	.04	.09

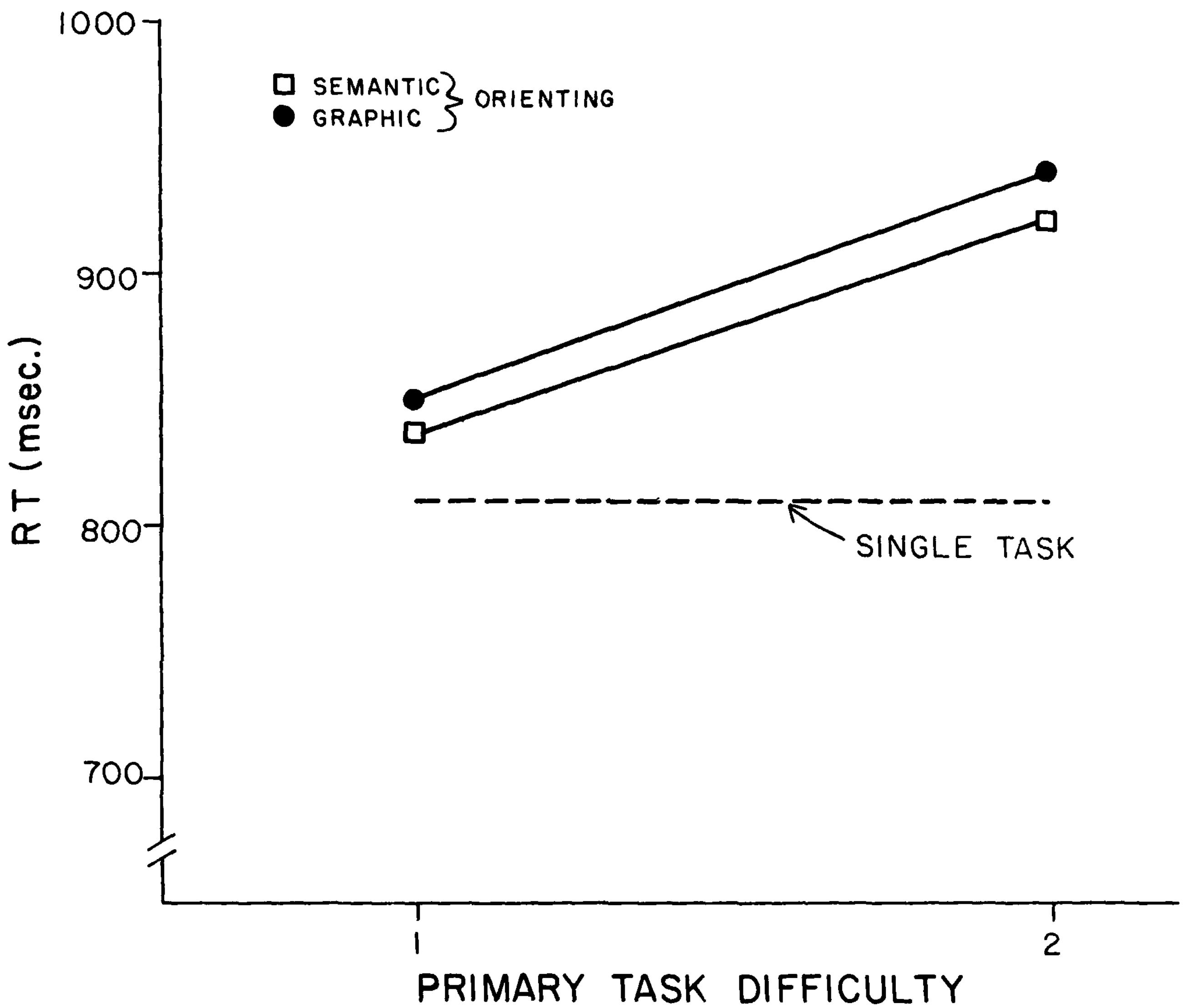
1000
900
800
700
RT (msec.)
SEMANTIC
GRAPHIC
ORIENTING
SINGLE TASK
1
2
PRIMARY TASK DIFFICULTY

Figure 1.

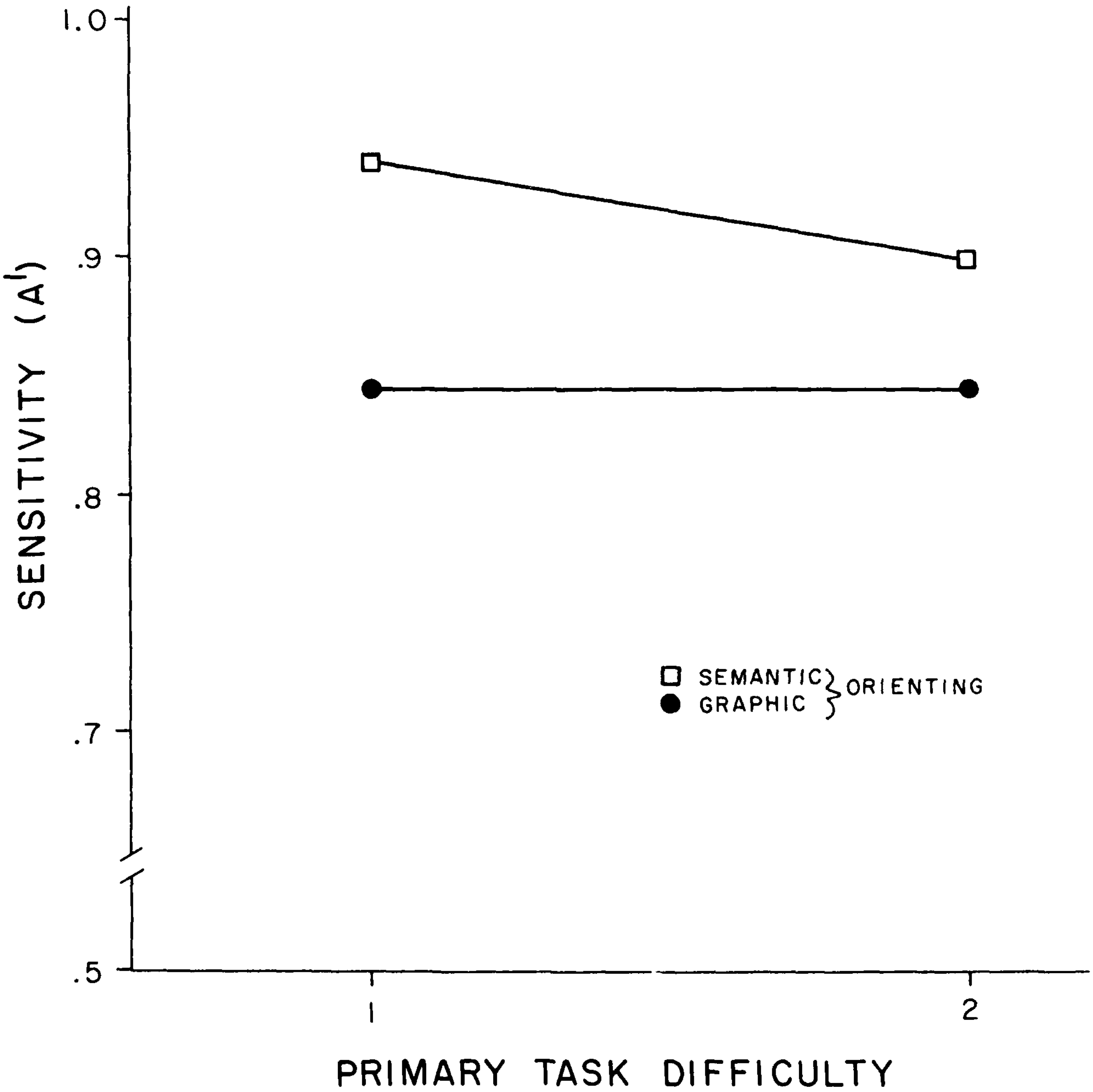
1.0
.9
.8
.7
.5
SENSITIVITY (A')
SEMANTIC
GRAPHIC
ORIENTING
1
2
PRIMARY TASK DIFFICULTY

Figure 2.

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