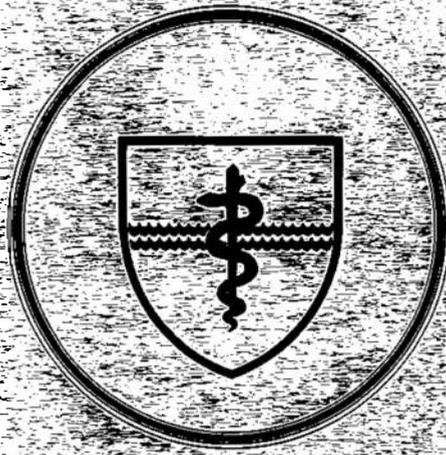


NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

SUBMARINE BASE, GROTON, CONN.



REPORT NUMBER 1073

THE EFFECT OF STIMULUS AND TASK VARIABLES
ON RESPONSE TIMES TO PICTURES AND WORDS

by

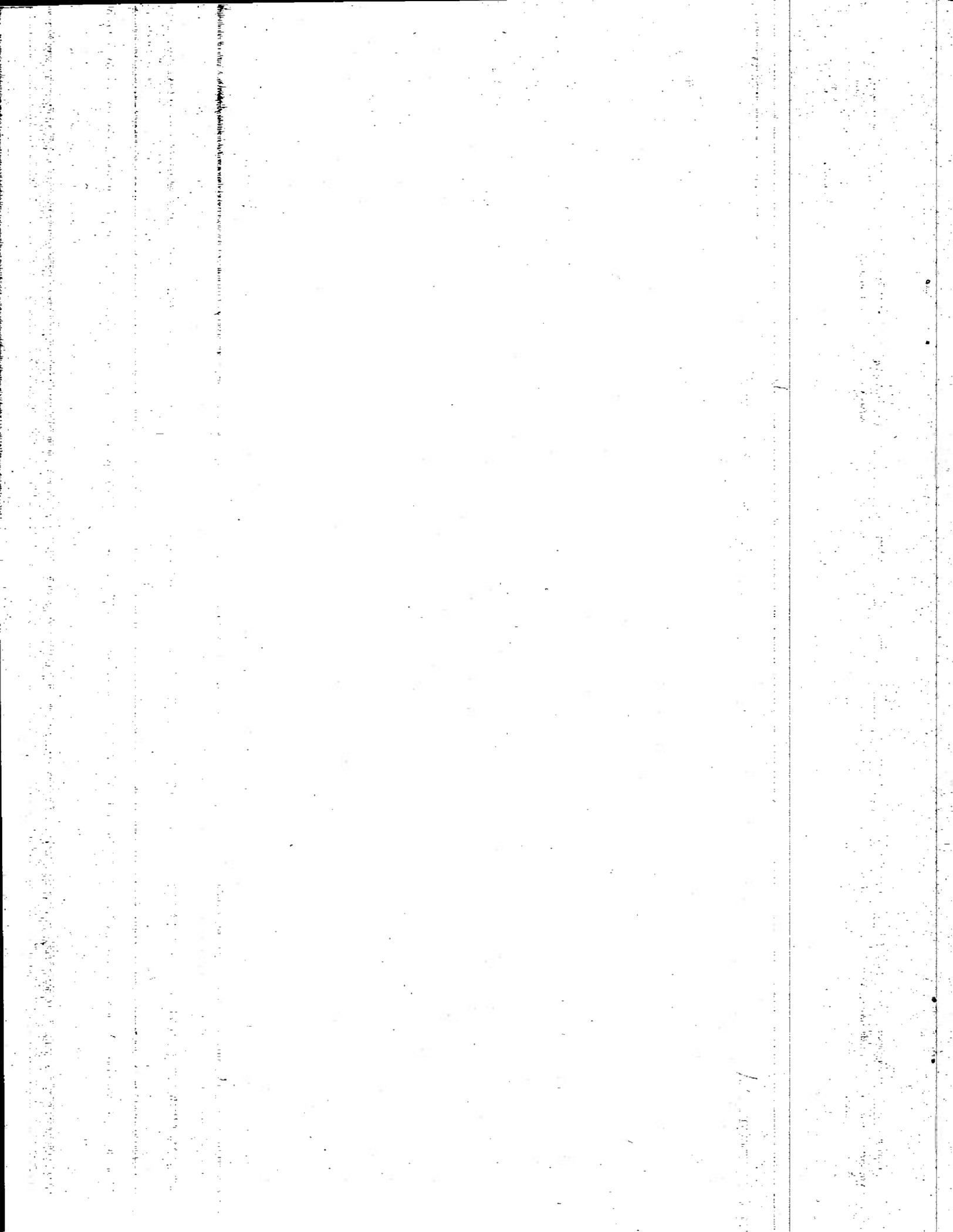
William H. Rogers

Naval Medical Research and Development Command
Research Work Unit M0100.001-1022

Released by:

C. A. Harvey, CAPT, MC, USN
Commanding Officer
Naval Submarine Medical Research Laboratory

27 June 1986



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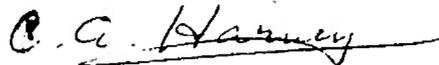
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SUMMARY PAGE

THE PROBLEM

In many instances, small sets of items to be represented on visual displays can be depicted by single words or simple pictures. Studies were conducted to determine if one kind of representation or the other can be more efficiently processed, leading to overall better operator performance.

THE FINDINGS

The pictures and words tested were visually recognized with equal facility. However, when decisions involving semantic interpretation of written representations were required, responses were faster when those representations were simple pictures than when they were single words. This picture advantage was found even for a task that was hypothesized to be 'verbal' in nature and was expected to lead to a word advantage. It is hypothesized that these response time differences reflect underlying differences in the cognitive processing of the two types of representations.

APPLICATION

These findings suggest that for small sets of concrete items, it is better to use pictures than words to represent them on visual displays. This conclusion appears valid regardless of the task involved or how other information on the display is represented.

ADMINISTRATIVE INFORMATION

This study was conducted as part of Naval Medical Research and Development Command Work Unit M0100.001-1022. The present report is Number 3 on this work unit. It was submitted for review on 23 April, 1986, approved for publication on 27 June, 1986, and designated as NavSubMedRschLab Report No. 1073.

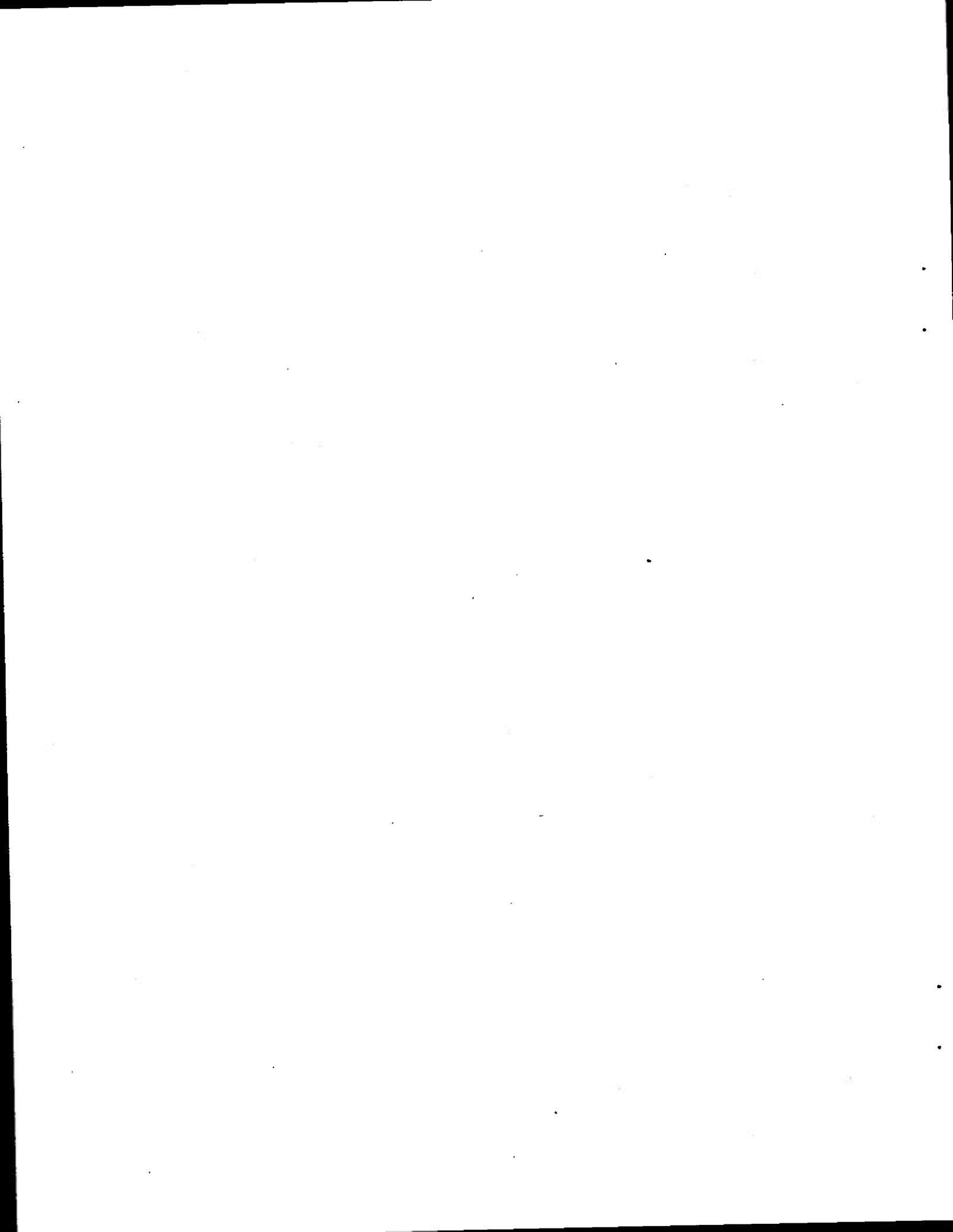
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ABSTRACT

Previous research has shown that for several different kinds of tasks, decisions requiring semantic interpretation of written representations can be made faster when those representations are simple pictures than when they are single words depicting the same items. These response time differences are thought to reflect underlying differences in the cognitive processing of the two types of representations. Despite the empirical evidence, there is reason to believe that the response time advantage for interpretation of pictures could be negated or reversed, depending on the specific set of pictures and words used and on the information requirements of the particular task used. If the picture advantage is indeed stimulus- or task-dependent, it would preclude any general rule of thumb for choice of representation.

Six pictures and six words representing a small set of concrete items were used in four different kinds of tasks to investigate the possibility that stimulus and task variables affect response times to pictures and words. The first task was a recognition task which tested whether perceptual characteristics of pictures and words accounted for response time differences. The other three tasks were memory tasks, two of which were hypothesized to lead to a picture advantage and the third of which was hypothesized to lead to a word advantage due to the nature of task requirements.

Results indicated that the speed of recognition of the picture and words sets was comparable, suggesting that perceptual differences between the sets of pictures and words were not responsible for response time differences in the memory tasks. When decisions involving semantic interpretation of the stimuli were required (the memory tasks), responses were faster for pictures than for words. This picture advantage was found even for the task that was hypothesized to lead to a word advantage. It is concluded that stimulus and task variables minimally affect response time differences between pictures and words. There appears to be an overall, robust processing advantage for pictures which is independent of stimulus and task variables.



The Effect of Stimulus and Task Variables on Response Times to Pictures and Words

Visual display terminals (VDT's) are one of the most important man-machine interfaces in many modern military combat systems, such as sonar and fire-control systems aboard submarines. The complexity of these systems, both in terms of the technological sophistication of the equipment involved and in terms of the problem domain itself, usually results in an overwhelming amount of information being provided to the system operator via VDT's and other interfaces. The sheer amount of information that must be processed, coupled with frequent time constraints, dictate that operators be able to read and interpret the visual symbols representing information on the VDT's as efficiently as possible.

There are many different kinds of visual symbols used on visual displays, including written words, alphabetic abbreviations, numerals, graphic symbols, and pictographs. In some cases, the same information can be depicted by more than one type of symbol or representation, such as a picture and its written word label to represent an object such as a submarine. If there are differences between different kinds of symbols, in how efficiently they can be processed by operators, then it makes good sense to use those kinds that are most efficiently processed if designers are free to choose among more than one kind of symbol for representation of certain information.

Much previous work comparing the processing time required to interpret pictures and words representing the same small set of concrete items (Paivio, 1975, 1978a; Pellegrino, Rosinski, Chiesi & Siegal, 1977; Hogaboam & Pellegrino, 1978; Potter & Faulconer, 1975; teLinde, 1982) has shown that pictures can consistently be interpreted faster than their word labels when a decision based on the underlying meaning of the item represented must be made. The majority of tasks used in these studies has required a decision about the category membership of the items represented (Nelson, Reed & Walling, 1976; Hogaboam & Pellegrino, 1978; Potter & Faulconer, 1975; Paivio, 1975; Pellegrino et. al., 1977; Snodgrass & Asiaghi, 1977). Other tasks have required judgments about the relative value of pairs of items on some dimension such as size (Paivio, 1975; teLinde, 1982), monetary value (Paivio, 1978a), or intelligence (Banks and Flora, 1977). The empirical support for faster interpretation of pictures is substantial. In addition, there is a large number of different kinds of tasks for which a picture advantage exists (Smith & Magee, 1980; teLinde, 1982; Kroll & Potter, 1984). The only tasks for which there seems to be a clear

advantage for words involve naming or pronunciation (Fraisse, 1968; Paivio, 1975), and this can be explained simply by the fact that words have faster access to phonological information than pictures.

Several other lines of research have converged on the conclusion that pictures can access meaning more quickly than words representing the same items, and/or items are better remembered when represented as pictures than when represented as words. One line of research has involved the use of priming paradigms (Vanderwart, 1984) and interference paradigms (Biederman & Tsao, 1979; Dhawan & Pellegrino, 1977; Babbitt, 1982) in conjunction with free recall. Other lines of research have involved visual field studies (Hatta, 1977; Sasanuma, Itoh, Mori & Kobayashi, 1977), and investigations of aphasic patients (e.g., Sasanuma, 1974). Although the magnitude of the picture advantage found varied considerably among studies and tasks, the consistent advantage of interpreting pictures versus words suggests that when no other constraints dictate choice of representations for a small set of concrete items, pictures should be used instead of words.

There are at least two problems with this conclusion in light of the studies to date, however. First, in most of the studies which investigated picture-word response time differences, with the exception of Fraisse (1968) and teLinde (1982), the picture and word sets were not compared for perceptual recognition time. If perceptual processes account for interpretational differences between pictures and words, it is much more likely that these differences are dependent on the particular picture and word sets tested. Many stimulus attributes, such as visual extent or size, discriminability, confusability, familiarity, etc., can affect how quickly stimuli are perceptually processed. If picture advantages are stimulus set-specific, then a general rule of thumb for any set of pictures is inappropriate.

Second, one of the current psychological theories of memory processing that has been used to explain picture-word response time differences, dual-coding theory (Paivio, 1975), suggests that words should be processed faster than pictures for a certain class of tasks. Dual-coding theory assumes the existence of two separate long-term memory (LTM) systems, one designed for the coding, storage, manipulation, and retrieval of verbal or language related information and the other designed for the coding, storage, manipulation, and retrieval of visual or spatial information. Picture stimuli have faster access to the visual LTM and word stimuli have faster access to the verbal LTM. Paivio (1975, 1978b) has suggested that the variety of tasks that have been used to date to compare the processing of pictures and words have been heavily weighted toward information that would be likely be stored in the

visual LTM, and hence pictures have been generally processed faster. Paivio's theory predicts, however, that if tasks require information which is more verbally-oriented, then words should access that information more efficiently than pictures. In practical terms, this would mean that the rule of thumb for designers to use pictures to represent small sets of concrete items on visual displays would be conditional, dependent on the kind of information required for the task.

A series of experiments was formulated to address the issues of the possible dependence of the efficiency of interpretation of pictures and words on the particular stimulus sets used and on the kind of information required for the task. First a recognition task was used to evaluate whether visual recognition times were comparable for the sets of pictures and words used. Additionally, performance in three different tasks using the same picture and word sets, but differing in the kind of information required, was studied. The profile of picture-word response times across tasks will: 1) determine the contribution of recognition differences between pictures and words to response time differences in memory tasks; and 2) test the prediction of the dual-coding hypothesis that the picture advantage is task-dependent. On the practical level, this study will determine whether the rule of thumb, use pictures to represent small sets of concrete items, is generally applicable across stimulus sets and tasks.

Experiment 1

In this experiment subjects had to determine whether or not a picture or word test stimulus represented the same item as a picture or word cue. It was designed to determine if the picture and word sets used for the subsequent experiments were comparable in terms of recognition speed.

Method

Subjects. Twenty-eight males ranging in age from 18 to 42, with a median age of 19, volunteered to participate in Experiment 1a. Nineteen were students entering basic submarine school at the Subase, Groton, CT., and nine were staff members at the Naval Submarine Medical Research Laboratory, Subase, Groton, CT. Fourteen male staff members at the Naval Submarine Medical Research Laboratory volunteered to participate in a second part of this experiment (1b). These subjects ranged in age from 20 to 43, with a median age of 26. Volunteers were naive as to the specific hypotheses being investigated, but were told, in general, that the purpose of the tests was to determine how people mentally process

pictures and words under various conditions.

Stimuli. The stimuli for this experiment were six words and six pictures (see Figure 1) whose referents are real world objects that are commonly detected by sonar or radar on a submarine or ship. The pictures were simple computer generated outline drawings.

All stimuli subtended a maximum of 4 degrees visual angle horizontally and 1.6 degrees vertically from a viewing distance of 43cm. The shorter words, such as SUB, SHIP and MINE subtended a smaller visual angle horizontally than did the longer words, as did the picture of the mine.

Apparatus. The displays were presented on a Tektronix 4010 display terminal driven by a Data General NOVA 1220 minicomputer. Responses were made by pushing keys at the ends of the bottom row of the terminal's keyboard, that is, the 'z' and '/' keys. The keys were labelled 'yes' and 'no', counterbalanced so that half the subjects had the 'yes' key on the left and half had it on the right. The index fingers of both hands were used to respond. Response times were measured internally by the computer via a real time clock which was started after the stimuli were drawn and stopped upon a key press. The stimuli were completely drawn within 30 msec and appeared to be presented instantaneously. Responses and response times were recorded by the computer.

Task. For the recognition task, subjects were presented with a cue in the upper left corner of the CRT. The six words of the stimulus set were used as cues for Experiment 1a, and the six pictures of the stimulus set were used as cues for Experiment 1b. One second after presentation of the cue, a picture or word test stimulus was presented in the center of the screen. Both the cue and the test stimulus remained visible until a response was made. Both Experiments 1a and 1b consisted of two blocks of 36 trials. For one block of trials the test stimuli were always pictures and for a second block of trials the test stimuli were always words. The subject's task was to determine if the stimulus in the center of the screen represented the same referent as the cue item. For example, if the cue was a picture of the 'MINE', and the test stimulus was the picture or the word 'MINE', the subject pushed a key marked 'yes', and if the cue was the word 'TORPEDO', and the test stimulus was either the picture or word 'PLANE', he pushed a key marked 'no'.

Within a block of trials, each of the six cues was paired with a matching test stimulus three times and three randomly chosen non-matching test stimuli once each. This resulted in 18 correct 'yes' and 18 correct 'no' responses. The order of presentation of trials within a block was randomized each time the task was

administered. The order of blocks (picture or word test stimuli) was counterbalanced for practice and test sessions, such that half the subjects performed the picture test stimulus block first and half the subjects performed the word test stimulus block first in each session. There were three practice sessions and one test session. Experiment 1b was administered after completion of Experiment 1a.

Procedure. At the beginning of the first practice session, subjects were given written instructions describing the general nature of the experiment and the stimuli and specific instructions for performing each task. While it was made clear that these were response time tasks, it was stressed that accuracy should not be sacrificed for speed. Any questions were answered at any time during the experiment at subjects' requests. Practice and test of the tasks included in the different experiments were administered concurrently to the subjects. The order of practice on the different tasks was balanced across subjects. All tasks were practiced three times before the test session for that task. Pilot data had indicated that asymptotic response times on these tasks were achieved rapidly. If subjects made more than 10% errors on any practice session, they were reminded not to sacrifice accuracy for speed.

Practice and tests were performed in a quiet, darkened room. The sessions were self-paced in that subjects pressed a key on the keyboard to begin each trial. After each response, the subject's response time, response, and whether the response was correct or not, were displayed on the VDT screen. Trials on which errors were made were rerun at the end of a block of trials so that response times for correct responses were obtained for all trials. Each day's practice required about two hours per subject. On test days, the order of task presentation was again balanced across subjects. The test day consisted of identical warm-up and test sessions for the recognition task.

Results and Discussion

Analyses of variance (ANOVA's) computed on response times for correct responses for 28 subjects were used to analyze all data, unless otherwise specified. Both multivariate and univariate test statistics were computed for each analysis¹. Error rates were less than 10% for all experiments reported here and were not statistically analyzed. Inspection of errors indicated that they generally supported the response time data, that is, conditions leading to longer response times also generally led to more errors.

Three-way repeated measures ANOVA's (Stimulus Type (ST) x Cue Item (ITEM) x Response (RESP)) were computed on response times for

the recognition task with word cues (Experiment 1a) for the first day's practice and the final test session. The main intent of analyzing the practice data was to determine if there was a picture-word difference on initial presentation of the stimuli. There was a main effect of stimulus type for the first practice ($p < .001$), with responses to the words being faster than to the pictures (mean response times of 417 msec and 481 msec, respectively). While most other effects analyzed were also significant for the practice data, they did not appear to confound the picture-word differences, and are not addressed here.

There was a main effect of stimulus type for the test session ($p < .05$), words being responded to faster than the pictures (mean response times of 357 msec and 371 msec, respectively). 'Yes' responses (339 msec) were significantly faster ($p < .001$) than 'no' responses (391 msec). There were also significant differences ($p < .001$) among responses to the six cue items. There were also significant Stimulus Type x Cue Item and Cue Item x Response interactions found for the test session response times. Tests of simple effects were computed to elucidate these interactions. Simple effects of stimulus type for each cue item showed that pictures were responded to significantly faster than words for 'mine' ($p < .05$), words were responded to significantly faster than pictures for 'plane' ($p < .05$), 'ship' ($p < .05$), and 'sub' ($p < .001$), and there were no significant picture-word response time differences for 'missile' and 'torpedo'. The mean response times for pictures and words for each cue item are shown in Figure 2. Simple effects of response for each item showed that 'yes' responses were significantly faster than 'no' responses for all items ($p < .01$), indicating the Cue Item x Response interaction was due to differences in the magnitude of the 'yes' advantage among stimulus items. The mean response times for 'yes' and 'no' responses for each item are shown in Figure 3.

Although I assumed that the appropriate perceptual representations were generated from the word cues since subjects knew what kind of test stimulus to expect, it was noted that the word cues might bias response times in favor of the word test stimuli through the mechanism of visual priming, that is, the word test stimuli matched the cues visually, while the picture test stimuli did not. One could argue that the word advantage was due to this bias, and if this bias did not exist, picture stimuli might be responded to faster than word stimuli. To address this argument, 14 subjects served in Experiment 1b, for which the task was identical to the recognition task already administered, except that the cues were pictures instead of words. The procedure was identical to that used in Experiment 1a.

A three-way ANOVA (ST x ITEM x RESP) computed on test session

response times showed that 'yes' responses were significantly faster than 'no' responses ($F(1,13) = 36.69, p < .001$), and that Stimulus Type interacted with Item ($F(5,65) = 2.39, p < .05$). Overall, pictures and words were responded to comparably (354 msec and 358 msec, respectively). Tests of simple effects computed on the ST x ITEM interaction showed that the pictures were responded to significantly faster than words for 'missile' ($p < .05$) and words were responded to marginally faster than pictures for 'sub' ($p = .11$). There were no differences between pictures and words for the other four items. The mean response times to pictures and words for each item are shown in Figure 4.

As stated at the outset, much previous work in the area of picture-word processing differences (Paivio, 1975, 1978a, 1978b; teLinde, 1982; Smith & Magee, 1980; Potter & Faulconer, 1984) has hypothesized that memory processes rather than perceptual processes are responsible for picture-word response time differences, but few studies have included appropriate tests of possible perceptual processing differences between pictures and words. The recognition task included here was a test of whether there were differences between the picture and word sets when the processing involved was perceptual or 'front-end' in nature. The fact that the picture-word response time differences in the recognition tasks were small (Experiment 1a with word cues) or negligible (Experiment 1b with picture cues) indicated that any major picture-word processing response time differences in the memory tasks using the same picture and word stimulus sets could not be attributed to differences in perceptual attributes of the items of the sets.

The fact that there was a substantial advantage for the processing of words in the first practice session of the task indicates that subjects might have entered the experiment with greater familiarity with the word set than with the picture set. This greater familiarity might also account for the small but significant advantage for words in the test session with word cues. Since that initial word advantage was greatly reduced after exposure to the stimulus sets, it is suggested that familiarity with the stimuli had a typical learning curve effect on processing time. Although initially there were different starting points for pictures and words on the learning curve, by the time the test session was administered, familiarity with both the picture and word sets was such that performance was near asymptote, thus accounting for the closing of the picture-word processing time gap.

That the picture-word response time differences varied from item to item indicates, at the individual item level, that it is difficult, if not impossible, to equate pictures and words on all those variables that do affect recognition, such as

discriminability, visual extent, confusability, etc. Even though the sets of pictures and words were fairly comparable in terms of recognition time, all the individual items were not. The picture of the mine might have been faster than the word 'mine' because its shape was so unique compared to the shapes of the other pictures. The words 'sub', 'plane', and 'ship' might have been faster than their picture representations because the words subtended less visual angle and were less confusable. The point, again, is that at the individual item level it is likely that pictures and words differ in stimulus characteristics which affect recognition, but at the level of a set of items, these factors offset each other to produce overall comparability in picture and word recognition.

The advantage of 'yes' responses for this task is consistent with much previous work. This advantage is often explained as due to an extra processing stage for 'no' responses: more stringently verifying that an item is not the one cued for.

Experiment 2

This experiment involved a task similar to categorization tasks that have been used in previous studies. Since tasks of this kind have typically led to consistent response time advantages for pictures, it was hypothesized that this task would also lead to a picture advantage.

Method

Subjects. The twenty-eight males from Experiment 1a volunteered for this experiment also.

Stimuli and Apparatus. The stimuli for this experiment were the six words and six pictures used in Experiment 1 (see Figure 1).

Task and Procedure. The stimulus items for this experiment were categorized in three different ways: by the maximum speed of the contact (fast or slow), function (weapon or platform for a weapon), and normal location in relation to the surface of the ocean (above or below). The stimulus items were assigned to the categories such that three of the items belonged to each category. The items assigned to each category were: FAST- plane, missile, torpedo; SLOW- sub, ship, mine; ABOVE- plane, missile, ship; BELOW- sub, torpedo, mine; WEAPON- mine, missile, torpedo; and PLATFORM- sub, ship, plane. Subjects were required to learn this categorization for this task, but it was, of course, consistent with any pre-existing knowledge the subjects had about these items.

One of the category names, the cue, was presented in the upper

left section of the screen followed by a question mark (e.g., FAST?) and one second later one of the test stimuli was presented in the center of the screen. The cue and the test stimulus remained on the screen until a response was made. Subjects pressed the 'yes' key if the test stimulus was described by the cue represented and pressed the 'no' key otherwise. Each session of the categorization task consisted of 72 trials, each of the six category cues being presented on 12 trials. In these twelve trials each of the six test items (three positive instances and three negative instances) was presented twice, once as a picture and once as a word. Picture and word test stimuli were not blocked as in the recognition task, but rather all test stimuli were presented in a single session, with a different random sequence for each of the subjects.

The sequence of events was identical to that described in Experiment 1. The categorization task was practiced on three consecutive days, followed by a warm-up and test session on the test day.

Results and Discussion

A three-way ANOVA (Stimulus Type (ST) x Category (CAT) x Response (RESP)) was computed on response times from the test session for the categorization task. Response times for pictures (621 msec) were faster than those for words (664 msec) ($F(1,27) = 10.39, p < .005$). 'Yes' (599 msec) responses were significantly faster than 'no' (655 msec) responses ($F(1,27) = 28.31, p < .001$). Mean response times to the six categories were significantly different (Pillais = .747, Approx $F(5,23) = 13.58, p < .001$). This main effect of Category was further analyzed using Newman-Keuls tests. The Newman-Keuls tests showed that: responses to the 'slow' category were significantly slower than responses to all other categories ($p < .01$); responses to the 'below' category were significantly slower than responses to the 'platform' ($p < .01$) and 'weapon' ($p < .05$) categories; and responses to the 'fast' category were significantly slower than responses to the 'platform' ($p < .01$) category. The mean response times to the different categories are depicted in Figure 5. There were no significant interactions.

The significant overall picture advantage in this task, 43 msec, is consistent with previous research (e.g., Paivio, 1975; Pellegrino et. al., 1977), that is, it falls in the range of response time advantages commonly reported. Since the picture advantage reported here is not due to how fast the stimulus items were recognized, there must be a difference between pictures and words in the way they are coded or processed subsequent to visual recognition. Differences among categories indicate that the ease of determining category membership depends on the category, regardless

of whether items are presented as pictures or words.

Experiment 3

This experiment involved a relative judgment task, here termed the LTM task. This task was also designed to be comparable to relative judgment tasks that have been used in previous studies. The aspect of each item that was judged in this task was its threat level. A picture advantage was expected in this task also, as previous studies using similar tasks consistently showed robust picture advantages. Since the same stimulus sets were used for this task as for the categorization task, absolute differences in the processing of pictures and words between the two tasks can be attributed to different task demands.

Method

Subjects. The same subjects participated in this experiment as in Experiment 2.

Stimuli and Apparatus. The stimuli and apparatus for this experiment were the same as used in Experiments 1 and 2. The 'z' and '/' keys used to respond were labeled 'left' and 'right' for this task.

Task and Procedure. For the task used in this experiment, the LTM task, the six stimulus items were ordered from highest to lowest threat, based on their general threat level to a submarine under a variety of scenarios. Starting with the highest threat, the order was: TORPEDO, MISSILE, SUB, SHIP, MINE, PLANE. Again, this order was generally compatible with subjects' pre-existing knowledge about the items, as evidenced in the ease of learning.

On each trial, two stimuli were presented side by side in the center of the screen, either both pictures or both words. Subjects were required to press a key on the left or right of the keyboard, indicating which of the two stimuli was the greater threat as instructed. There were 15 possible stimulus pairs, consisting of each item paired with every other item. Each pair was presented with each item in both the left and right positions on different trials, both as pictures and as words, resulting in four presentations of each pair and 60 trials total. As with the categorization task used in Experiment 2, trials with picture and word stimuli were mixed within the same session. Stimulus combinations were randomized for each session.

As in Experiment 1, the task was practiced on three consecutive days, followed by a warm-up and test session on the test day.

Results and Discussion

A three-way ANOVA (Stimulus Type (ST) x Stimulus Pair (PAIR) x Response (RESP)) was computed on response times from the test session for the LTM task. Pictures (637 msec) were responded to significantly faster than words (776 msec) ($F(1,27) = 62.99, P < .001$), 'left' (693 msec) responses were faster than 'right' (721 msec) responses ($F(1,27) = 7.35, p < .01$), and there were significant response time differences among the stimulus pairs (Pillais = .921, Approx. $F(14,14) = 11.67, p < .001$). Additionally, there was a significant ST x PAIR interaction ($F(14,378) = 5.99, p < .005$).

Simple effects tests were computed to determine the effect of stimulus type for responses to each stimulus pair. These tests showed that pictures were responded to significantly faster than words ($p < .01$) for all stimulus pairs except five. Those five were: torpedo-missile; torpedo-plane; torpedo-ship; torpedo-sub; and sub-missile. For those five stimulus pairs there was no difference in response times to pictures and words.

The 139 msec picture advantage for the LTM task is consistent with picture advantages found for similar tasks by other researchers. Relative judgments involving comparison of pairs of pictures and words on various attributes such as size, monetary value, intelligence, pleasantness, and ferocity of the items represented have shown picture advantages ranging from less than 100 msec to about 800 msec.

'Left' responses were faster than 'right' responses probably because of the practice of reading from left to right: The left stimulus was read first and thus processing of that stimulus proceeded ahead of processing of the right stimulus. The Stimulus Type x Pair interaction which was due to a picture advantage for all stimulus pairs except five, apparently was linked to the threat level of the correct response. Four of the five pairs for which there was not a picture advantage included the 'torpedo', which was the greatest threat. The lack of a picture-word difference for pairs including the greatest threat might have been due to qualitatively different processing when the greatest threat was one of the test pair (e.g., a response could be based on an absolute judgement rather than on a relative judgement), or it might have simply been due to the fact that responses to the greatest threat were faster, and the rapidity of the responses simply did not allow picture-word differences to occur. The pairs of pictures for which a picture advantage did not occur might simply have been more difficult to differentiate because of their visual similarity (e.g., the picture of the torpedo and sub are very similar in appearance).

Experiment 4

This experiment involved a relative judgment task similar to the one used in Experiment 3, with the difference being that this task was designed to require storage of the information needed to perform the task in short-term memory (STM) rather than in long-term memory. The STM task as a whole was considered to be a verbally-oriented task, because of the articulatory mechanism commonly posited as the mechanism used to retain information in STM. Hence it was predicted that the picture advantage might be negated or reversed in this task. Addition of STM requirements to the task was assumed to generally require more verbally-oriented processing than if the task required only LTM processing.

There is also evidence (e.g., see Zhang & Simon, 1985) that there are separate visual and auditory short-term memories, and it is assumed that pictures and words might be differentially processed in the two STM's. Hence several STM parameters were varied which were hypothesized to change the likelihood that information would be stored in the visual or auditory STM. It was assumed that pictures would have faster access to the visual STM and words would have faster access to the auditory STM. It was predicted, therefore, that the combination of manipulations which led to the greatest probability of information being stored in the auditory STM would be more likely to lead to a word advantage and that the combination of manipulations which led to the greatest probability of information being stored in the visual STM would be most likely to lead to a picture advantage.

Method

Subjects. The same 28 males participated in this experiment as participated in Experiments 1a, 2 and 3.

Stimuli and Apparatus. The stimuli for the STM task used in this experiment were the same six words and six pictures as used in the other experiments (see Figure 1). The test displays consisted of pairs of pictures or words as described in Experiment 3. A memory display was presented preceding the test display, consisting of three to five of the picture or word stimuli arranged in either a tabular or spatial format (see Figures 6 and 7). From a viewing distance of 43 cm, the tabular display subtended a visual angle of 7.2 degrees horizontally and 12.5 degrees vertically, and the spatial display subtended a visual angle of 14.2 degrees horizontally and vertically. The tabular display listed each stimulus in a separate row, accompanied by the number '1' or '2', reflecting that item's priority. The spatial display consisted of

two concentric circles with the pictures or words spatially distributed within them. A stimulus item placed within the inner circle was equivalent to a priority of '1' on the tabular display, and an item placed within the outer circle was equivalent to a priority of '2' on the tabular display.

The apparatus was the same for this experiment as for the previous experiments. The 'z' and '/' keys were again used to make manual responses, and as in Experiment 3, they were labeled 'left' and 'right'.

Task and Procedure. The task used in this experiment was similar to the LTM task used in Experiment 3 in that subjects were required to judge which item of a pair of picture or word test stimuli was the greater threat. In order to assure that the task tapped STM, subjects derived threat order from a display presented immediately prior to the test stimuli on each trial. Memory displays (see Figures 6 and 7) were varied in three ways. They were either tabular or spatial (memory display format), contained either picture or word stimulus items (memory display stimulus type), and contained three, four or five stimulus items (short-term memory load). Additionally, the interval between the onset of the memory display and the onset of the test display was varied.

The impetus for the number of item and memory interval manipulations is the evidence (e.g., see Sperling and Speelman, 1970) that the visual STM decays more rapidly and retains fewer chunks of information than the auditory STM. Hence when only a few memory items are stored for a very brief time, the visual STM might be used to store these items. However, as the number of items stored and storage time increase, the probability is greater that items will be coded and stored in the auditory STM. The assumption underlying the memory display stimulus type (picture/word) and memory display type (spatial/tabular) manipulations is that textual/linguistic material would be more likely to be stored in the auditory STM and spatial/pictorial material would be more likely to be stored in the visual STM. Which STM is used to store the memory items is hypothesized to affect the speed at which the test pictures and words can be processed: Pictures are assumed to have faster access to information stored in the visual STM and words faster access to information stored in the auditory STM.

Each of the three memory loads (three, four or five items) was presented as pictures and words on spatial and tabular memory displays, resulting in 12 possible combinations of the memory display variables. Two memory displays were generated for each of these combinations, resulting in 24 different memory displays. Each memory display was paired with eight test stimulus pairs, consisting

of four different pairs presented as both pictures and words. This resulted in a total of 192 trials.

Memory display stimulus items and test stimulus items were generated such that each stimulus item appeared equally often as both a memory and test item. Stimulus items were assigned to specific memory displays randomly, with the restriction that the number of platforms and weapons on each display were equal for four item displays or differed by one for three and five item displays. Additionally, whenever possible, one weapon and one platform were given the same priority (tabular display) or were located in the same circle (spatial display) to provide a basis for determining threat order.

The test stimulus pairs were generated randomly from the items presented on the appropriate memory displays, with the aforementioned restriction that each stimulus item appeared an equal number of times, and that each stimulus item was the greater threat and the lesser threat of the pair equally often. The 192 trials were randomized for each session.

The subjects were given three instructions for ordering the stimulus items on the memory display according to threat level. First, items within the inner circle on the spatial display and listed as priority '1' on the tabular display were a greater threat than items in the outer circle or listed as priority '2'. Second, for priority '1' items, weapons were a greater threat than platforms. Third, for priority '2' items, platforms were a greater threat than weapons.

The interval between the onset of the memory display and the onset of the test display (short-term memory interval) was varied among test sessions for the STM task. With the exception of the shortest short-term memory interval, the memory display was always presented for two seconds; For the shortest short-term memory interval, the memory display was presented for 700 msec. Five short-term memory intervals were tested: 1.5 sec, 3 sec, 4 sec, 6 sec, and 8 sec. Finally, in one test session, trials with picture test stimuli were separated from trials with word test stimuli so that trials were blocked by test stimulus type.

The procedure for this task was basically the same as for the tasks used in the other experiments. Each practice day included at least one practice session on this task. Practice and tests were performed in a quiet, darkened room. The sessions were self-paced in that subjects pressed a key on the keyboard to begin each trial. On practice days, the short-term memory interval for the STM task was set at five seconds. The order of presentation of STM task test

sessions was counterbalanced across subjects. The test sessions were no different than the practice sessions, except for the short-term memory interval or blocking.

Results

The type of memory display (tabular versus spatial), showed no significant main effects or significant interactions in any of the initial analyses. Hence all STM task data were re-analyzed combining the data from the trials using tabular and spatial memory displays, and these latter analyses are the ones reported.

Several different analyses were computed on STM task data. The STM intervals (time from onset of the memory display to the onset of the test stimuli) were different for the first 14 and second 14 subjects. Preliminary analyses of the first 14 subjects' data indicated that STM interval did not have the hypothesized effect on the processing of pictures and words. I decided at that point that the intervals tested (3, 4 and 6 seconds) might not sample a wide enough range of intervals to show the hypothesized effect, so the STM intervals for the second 14 subjects were set at 1.5, 4, and 8 seconds. The first 14 subjects were also given a 4-second STM interval session in which the trials were blocked so that subjects knew what type of memory display stimuli and test stimuli, that is, pictures or words, they would encounter on each set of blocked trials. The preliminary analysis also indicated that the blocking variable did not change the profile of results across the other variables of interest in any meaningful way, and hence the second 14 subjects were given only unblocked trials. Since all 28 subjects were tested on the unblocked 4-second STM interval session, analysis of that session was used to assess the other variables of interest. Separate analyses (with 14 subjects) were used to investigate STM interval and blocking (blocked versus unblocked).

Analysis with all subjects. A three-way ANOVA (Memory Display Stimulus Type (MDST) x Test Stimulus Type (TST) x Short-Term Memory Load (STML)) was computed on all 28 subjects' response times for the unblocked 4-second STM interval test session. Overall, pictures were responded to 51 msec faster than words (598 msec and 649 msec, respectively) ($p < .005$). There were also significant response time differences among the three short-term memory loads ($p < .001$) and several two- and three-way interactions. Tests of simple effects computed on the two-way interactions showed the following: (1) MDST x TST interaction ($p < .005$)- picture test stimuli were significantly faster ($p < .001$) than word test stimuli following picture memory display stimuli, but only marginally ($p = .07$) faster than word test stimuli following word memory display stimuli (Figure 8); and (2) TST x STML interaction ($p < .05$)- picture test stimuli were

significantly faster than words for STM loads of three ($p < .001$) and five ($p < .005$), but there was no difference between picture and word test stimuli for a STM load of four (Figure 9).

There was a significant ($p < .01$) MDST x TST x STML interaction which appears to result from the fact that the larger advantage for picture test stimuli following picture memory display stimuli than following word memory display stimuli (the source of the MDST x TST interaction) only held for STM loads of three and four. With STM loads of five, the picture test stimuli advantage was equivalent following picture and word memory display stimuli.

Analyses based on 14 subjects. The first 14 subjects performed four test sessions of the STM task. The three 'unblocked' sessions had STM intervals of 3, 4, and 6 seconds. The 'blocked' session, in which subjects knew what kind of memory stimuli and test stimuli they would be presented, had a STM interval of four seconds. Two primary analyses were computed on data from these test sessions: A four-way ANOVA (STM Interval (STMI) x Memory Display Stimulus Type (MDST) x Test Stimulus Type (TST) x Short-Term Memory Load (STML)) was computed on response times from the three unblocked sessions; and a four-way ANOVA (Block (BLK) x MDST x TST x STML) was computed on response times from the two (blocked and unblocked) 4-second STM interval sessions.

The main effects and interactions involving STM interval (STMI) were the primary reasons for computing the first analysis. There were no significant effects involving STMI. The significant main effects and significant interactions not involving STMI were not explored since they all duplicated those found and discussed in the primary analysis of the unblocked 4-second STMI with 28 subjects.

The primary concerns of the second analysis were the main effects and interactions involving blocks. Responses to the blocked session (575 msec) were significantly faster ($F(1,13) = 8.88, p < .05$) than responses to the unblocked session (615 msec). There was also a significant Block x STM load interaction ($F(2,26) = 3.81, p < .05$). Tests of the simple effects of block for each level of STM load indicated that the BLK x STML interaction was due to the fact that responses in the 'blocked' session were significantly faster than responses in the 'unblocked' session for STM loads of three ($p < .001$) and four ($p < .05$), but there was no difference between response times for the 'blocked' and 'unblocked' sessions for a STM load of five.

Again, all significant effects not involving 'block' duplicated those found for the primary analysis of 28 subjects in the unblocked 4-second STM interval session and will not be further explored here.

The second 14 subjects participated in three test sessions of the STM task, at 1.5-, 4-, and 8-second STM intervals. A four-way ANOVA (STM Interval (STMI) x MDST x TST x STML) was computed on response times for the three test sessions. The primary concern of this analysis was the effect of STM interval. There was a significant difference among response times to the three STM interval sessions (Pillais = .547, Approx. $F(2,12) = 7.26$, $p < .01$). Newman-Keuls tests computed to clarify this main effect showed that response times for the 1.5 STMI session were significantly faster ($p < .01$) than response times for either of the other STMI sessions, which were not different from each other. There was also a significant STMI x TST x STML ($F(4,52) = 2.58$, $p < .05$) interaction. There appears to be no simple explanation for this three-way interaction involving STMI, but it does not seem to confound, to any serious degree, the simpler interactions and main effects.

All main effects and interactions not involving STM interval duplicated those found in the primary analysis of the unblocked 4-second STM interval with 28 subjects.

Discussion

The experimental manipulations for the STM task were designed to change the likelihood of memory items being stored in visual or auditory STM. The hypothesis underlying these STM manipulations, as stated earlier, is that fewer memory items, shorter memory intervals, picture memory display stimuli, and spatial display formats, are more likely to cause memory information to be stored and manipulated in a visual STM, and more memory items, longer memory intervals, word memory display stimuli, and textual display formats are more likely to cause memory information to be stored and manipulated in an auditory STM. Further, if items committed to short-term memory are stored in the visual STM, a task which requires access to that information would be performed faster with pictures than with words. Conversely, if items committed to short-term memory are stored in the auditory STM, then a task requiring access to that information would be performed faster with words than with pictures.

The overriding result for the STM task was that pictures were responded to faster than words, although the magnitude of this advantage was not as great as it was for the LTM task. This indicates that addition of an STM requirement did enhance word processing relative to picture processing compared to a task without the STM requirement, but that a significant advantage for pictures remained even with the STM requirement.

Some of the STM manipulations which were hypothesized to affect

the probability of using a visual or verbal STM did indeed affect picture-word response time differences, but even for the conditions in which the auditory STM should have been most likely to be used, words never were responded to faster than pictures. There were four independent variables that were hypothesized to change the probability that visual or auditory STM would be used to store the memory items and consequently affect picture-word response time differences. These were STM interval, memory display stimulus type, memory display format, and short-term memory load. Additionally, block (BLK) was analyzed for potential clues as to how pictures and words are processed in STM. The relevance to picture-word processing of the results involving each of these variables will be discussed separately.

Memory display format. The memory display format, tabular or spatial, had no effect on picture-word processing; there were no significant main effects or interactions involving memory display format in any of the analyses. Apparently, the background or context in which stimuli are presented has little or no effect on how those stimuli are memorially coded in STM.

Memory display stimulus type. Memory display stimulus type (MDST) and short-term memory load (STML) were primarily assessed in the 28-subject analysis. Both variables significantly interacted with test stimulus type, that is, pictures and words. Pictures were always responded to faster than words. The magnitude of the picture advantage was less following word memory display stimuli than following picture memory display stimuli, indicating that the word memory display stimuli did enhance test word processing, but not enough to offset the robust response time advantage for pictures.

Short-term memory load. The STML x TST interaction is difficult to interpret on first inspection. A picture advantage exists for short-term memory loads of three and five, but not for a load of four. I hypothesized that as the STML increased, the picture advantage should decrease, disappear, or even be reversed. The negation of the picture advantage when the STML was increased from three to four is consistent with the hypothesis, but the reappearance of a picture advantage with an STML of five is not. However, some evidence suggests that the processing that occurred with a load of five was qualitatively different than that with loads of three or four. Trends in the data, across three and four memory items were not sustained for the data with five memory items. This is reflected in the BLK x STML and MDST x TST x STML interactions, both of which resulted from differences between the trials with a STM load of five and the trials with STM loads of three or four.

These changes with a STM load of five and anecdotal reports by

subjects of a strategy change with a STM load of five suggest that on trials with five memory items subjects only remembered three of them. This change in strategy apparently occurred because five items in this experiment approached or exceeded STM capacity. When five memory items were presented, subjects apparently committed the first three threats to memory, and performed the task as usual if either member of the test pair was one of the three items they remembered. If the test pair included both items (the fourth and fifth threat from the memory display) they had not remembered, then they responded to the platform since they knew the platform was always the greater threat of the last two in the threat order. Since different strategies seem to be used with a short-term memory load of five, depending on which pair was presented as the test pair, this condition might not have been a legitimate test of the STM load of five condition.

If a short-term memory load of five is accepted as a special case, then the change in picture-word processing across STM loads of three and four becomes interpretable: a STM load of four enhances word processing relative to picture processing. This appears to mirror the effect of the memory display stimulus type, that is, both word memory display stimuli and a larger STM load reduce the picture advantage, but in neither case is a word advantage produced.

Short-term memory interval. STM interval did not change picture-word response time differences in any systematic way. The hypothesis was that as the STMI became longer, visual STM, which is presumably shorter-lived than auditory STM, would be less likely to be used to store memory items. Although there was one higher order interaction involving STMI, it did not indicate any systematic changes compatible with the hypothesis. This finding suggests that there was no change in the way memory items were stored across STM intervals of 1.5 to 8 seconds. There were absolute response time differences due to STM interval, resulting mainly from the rapidity of responses in the shortest (1.5 sec) STM interval session. This response time advantage for the shortest STM interval might reflect a classic shift in speed-accuracy strategy, as this session led not only to faster response times but also to more errors than the other STM interval sessions. The shift in speed-accuracy strategy toward speed for the 1.5 second STM interval might have been induced by the increased tempo of the display presentations, since both the memory display presentation time and the interval between the memory display and the test display were considerably shorter than for any other STM interval session.

Block. Response times were faster overall in the blocked session than in the unblocked session. This indicated that there was a general advantage to having knowledge about the type of stimuli

that would be presented but this advantage did not appear to change, in any meaningful way, the difference in processing pictures and words. One explanation of the picture advantage for sessions in which subjects did not know whether a picture or word would be presented on each trial, is that subjects used a strategy favoring pictures, that is, they anticipated picture stimuli and so were more primed for pictures. However, if this were the case, the picture advantage should have been eliminated for the blocked session since subjects always knew whether they would be presented with pictures or words, and therefore they could have anticipated the appropriate stimulus type in all cases.

General Discussion

The goal of this series of experiments was to determine if faster response times to pictures than to words found in previous experiments were stimulus- or task-dependent. The finding that there was a picture advantage in the memory tasks, coupled with the absence of any substantial picture-word response time differences in the recognition tasks, suggests that the faster response times to pictures result from some cognitive processing advantage for pictures in general, and not from a perceptual processing advantage for the visual properties of a particular picture set. Hence the response time advantage of pictures found here is not caused by, nor restricted to, a particular set of pictures.

The change in the magnitude of the response time advantage for pictures among the three memory tasks used in this study indicates that the picture advantage is affected by task demands, that is, the size of the response time advantage for pictures depends on the particular task involved. However, the STM task, for which a word response time advantage was predicted on the basis of dual-coding theory, led instead, to a picture advantage. Additionally, task manipulations made within the STM task which were expected to increase the likelihood that words would be responded to faster, reduced the picture advantage, but never reversed it. Apparently, both within and across tasks, there are variations in task demands which change the relative efficiency of processing pictures and words, but overall, there is an advantage in the processing of pictures which cannot be easily altered by biasing the task heavily in favor of verbal processing.

In the absence of practical constraints, such as space or computer power, it seems that a small set of items that can be easily represented by simple pictures or single word labels should be represented by pictures regardless of the task demands. Assuming that there are no visual properties of the picture and word sets that give an advantage to one or the other set in speed of

recognition (such as a large number of items for which the pictures are difficult to discriminate from one another), the rule of thumb to use pictures appears to have general applicability.

Footnotes

1. If either Bartlett's test of sphericity or the Fmax statistic was significant, then the multivariate results for an effect are reported, which include the Pillais value, and the approximate F and degrees of freedom based on multivariate computations. Otherwise, the univariate statistics are reported.

Figure 1. Picture and Word Sets Used for All Tasks

STIMULI

<u>WORDS</u>	<u>PICTURES</u>
MISSILE	
PLANE	
SHIP	
SUB	
TORPEDO	
MINE	

Figure 2. Stimulus Type x Item Interaction for Recognition Task with Word Cues

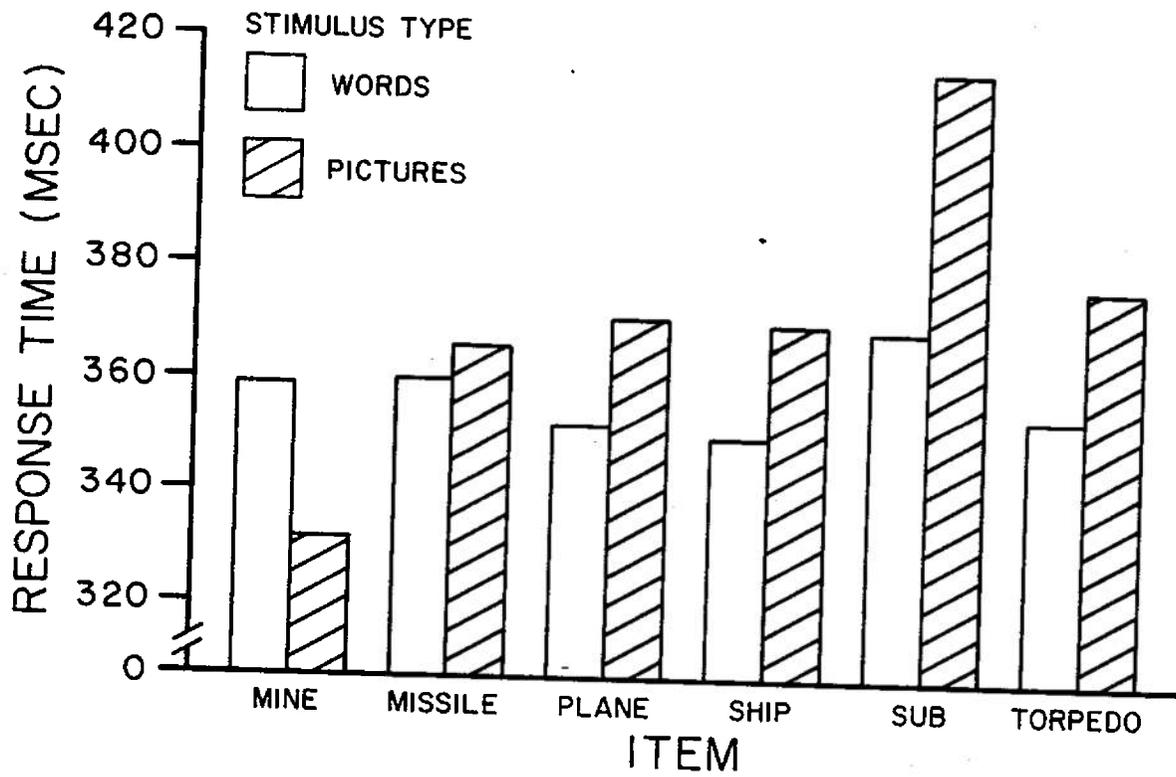


Figure 3. Response x Item Interaction for Recognition Task with Word Cues

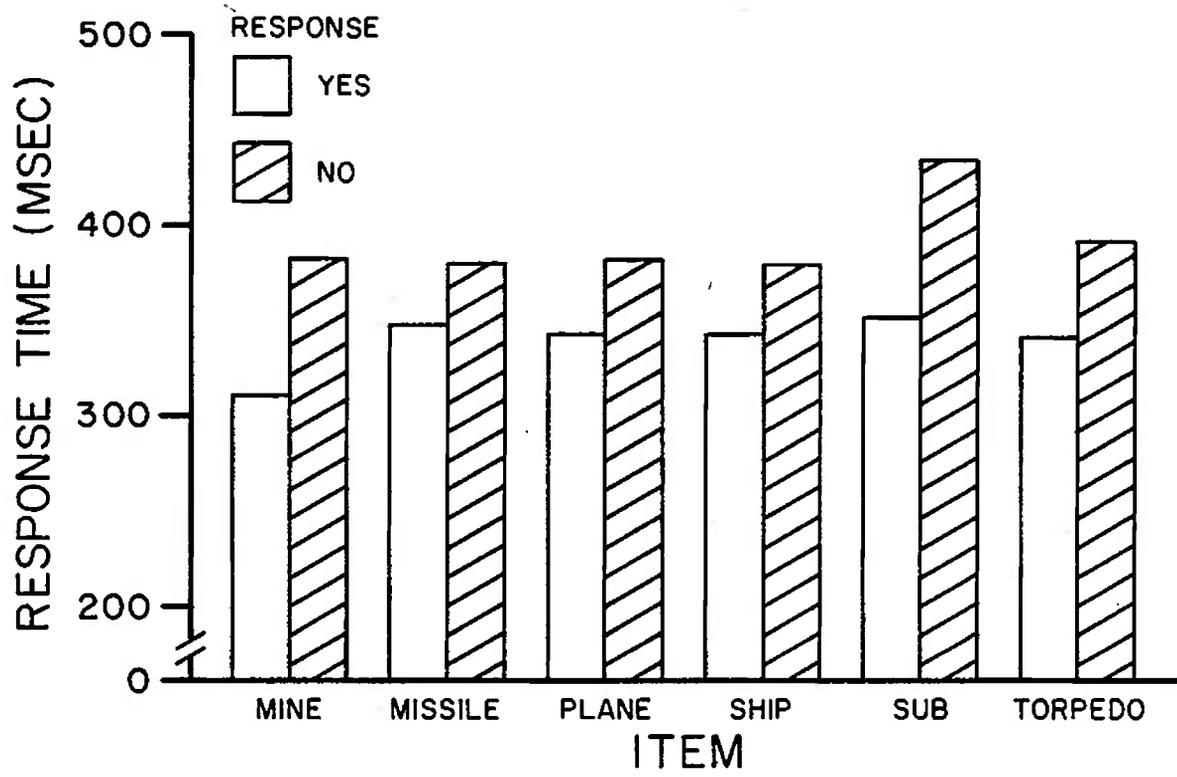


Figure 4. Stimulus Type x Item Interaction for Recognition Task with Picture Cues

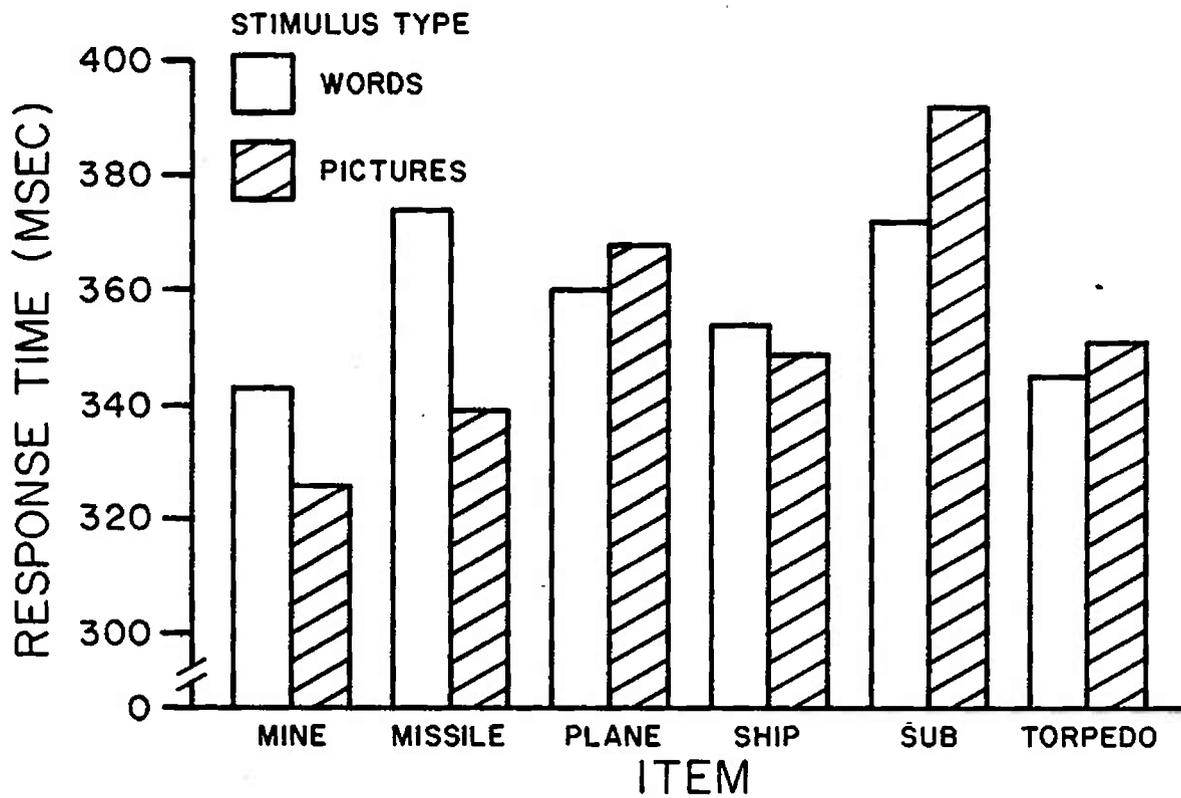


Figure 5. Main Effect of Category for Categorization Task

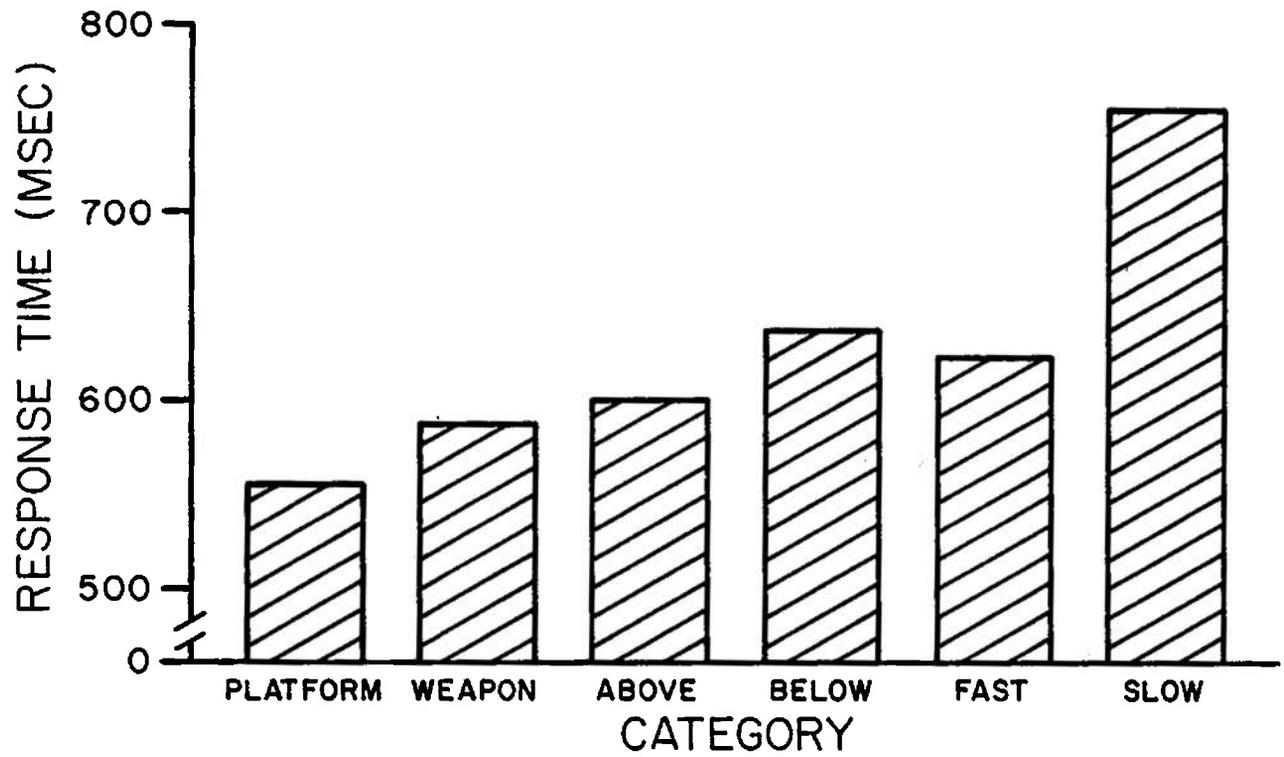


Figure 6. Examples of Tabular and Spatial Memory Displays With Word Stimuli

CONTACT	P
SUB	2
PLANE	1
MINE	2

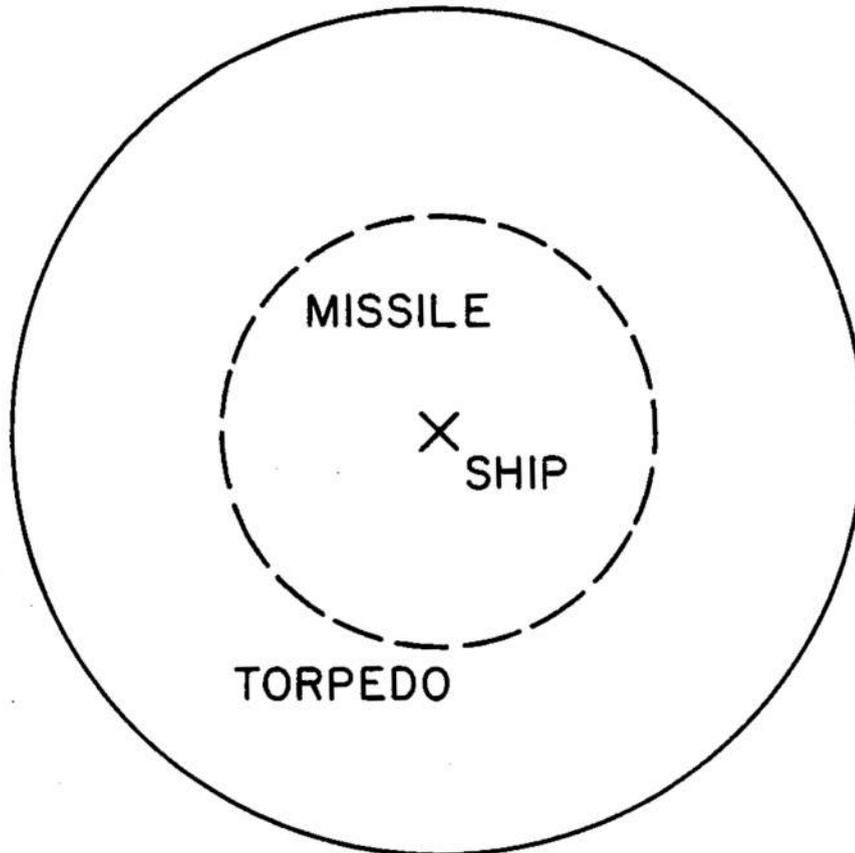


Figure 7. Examples of Tabular and Spatial Memory Displays with Picture Stimuli

CONTACT	P
	1
	2
	1
	1
	2

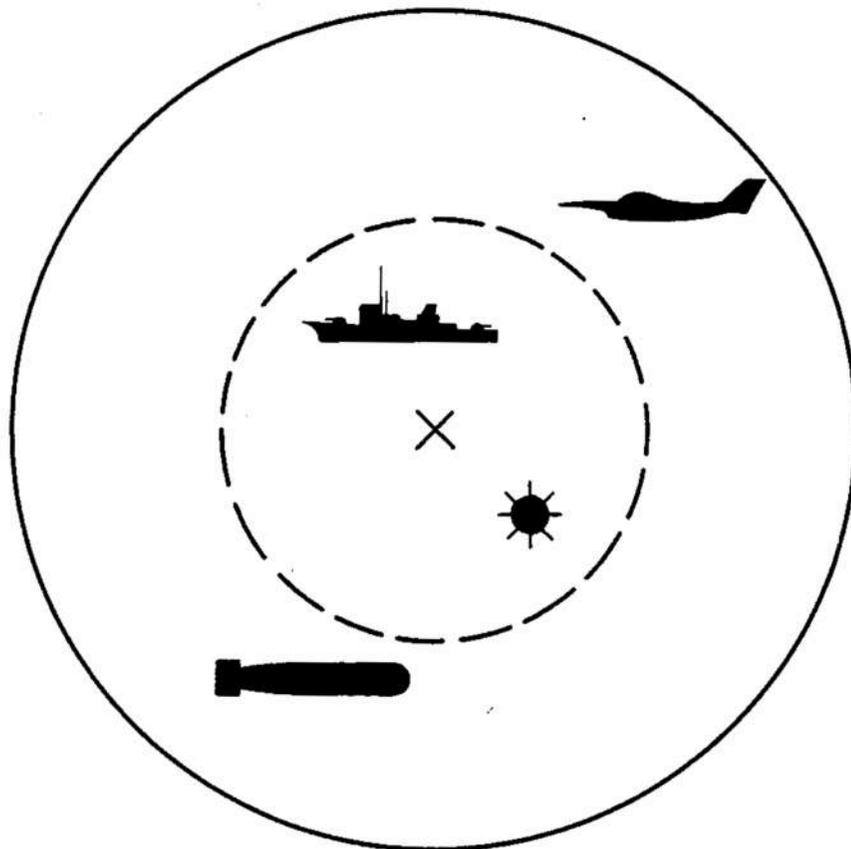


Figure 8. Memory Display Stimuli Type x Test Stimuli Type Interaction for STM Task (N=28)

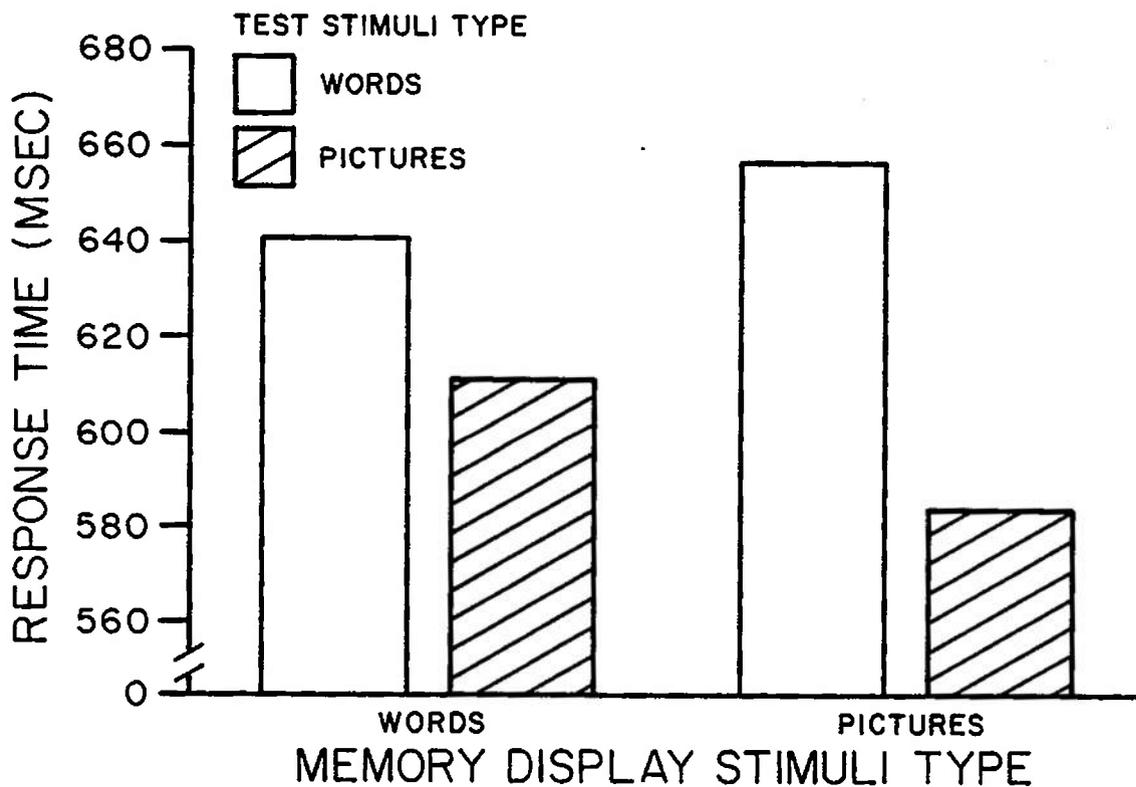
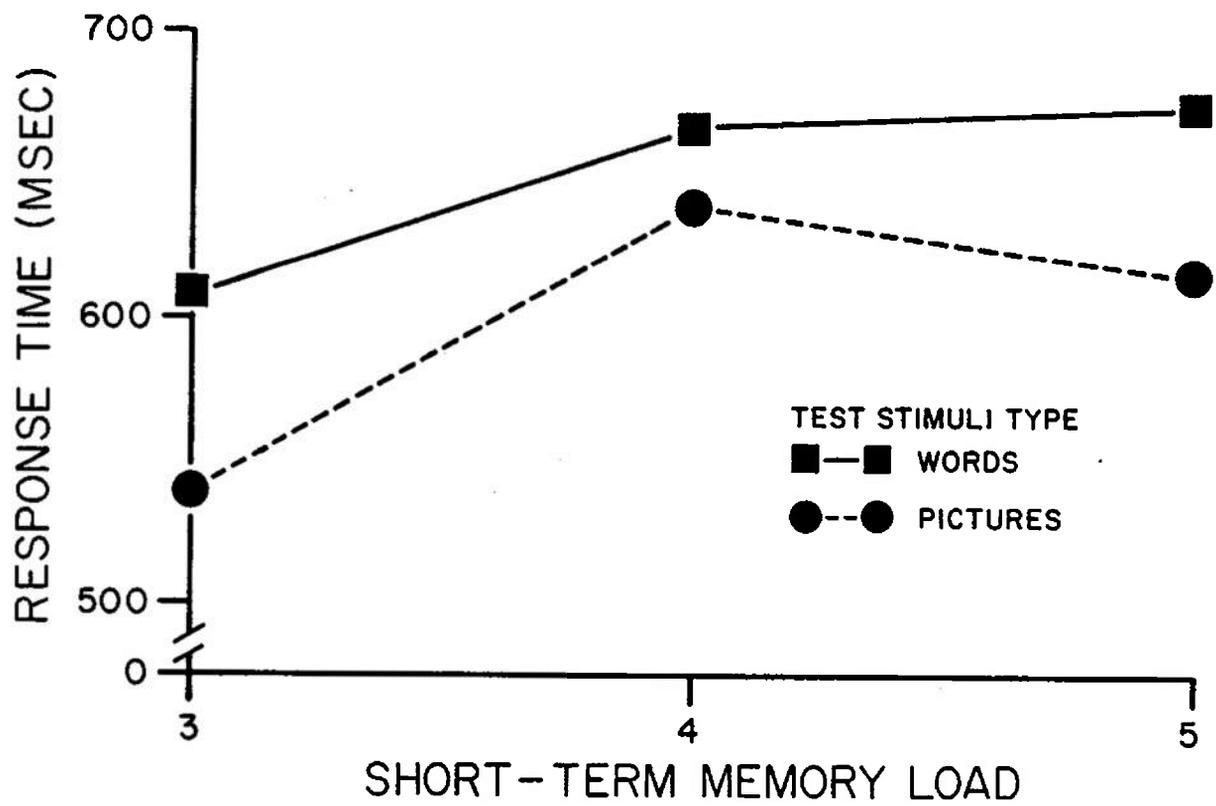


Figure 9. Test Stimuli Type x Short-Term Memory Load
Interaction for STM Task (N=28)



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Manual response times were measured across four tasks using a set of six pictures and six words as stimuli. The stimuli represented items that might be seen on a radar or sonar screen. The pictures were computer generated line drawings, and the words were computer generated written word labels of comparable size representing the same items.		

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Item No. 20--continued

Tasks required recognition, categorization, or relative judgment of information stored in long-term memory or short-term memory. Analysis of results within and across tasks allowed determination of the effect of stimulus and task variables on response time differences between pictures and words.

Results indicated that the picture and word sets were recognized in comparable time. In the memory tasks, however, pictures enjoyed a response time advantage, the size of which depended on the specific task requirements. Pictures were responded to faster even in a task which was hypothesized to lead to a word advantage. It appears that while the magnitude of the picture advantage can change depending on stimulus and task variables, overall, pictures are responded to faster than words across a variety of memory tasks, suggesting that a rule of thumb to use pictures to represent small sets of concrete objects on visual displays has wide applicability.

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