USAARL Report No. 89-4

The Relationship Between Cognitive Ability and the Iconic Processing of Spatial and Identity Information

By

Robert L. Stephens

Biomedical Applications Research Division

February 1989

United States Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-5292

Notice

Qualified requesters

Qualified requesters may obtain copies from the Defense Technical Information Center (DTIC), Cameron Station, Alexandria, Virginia 22314. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of address

Organizations receiving reports from the U.S. Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

Disclaimer

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commerical items.

Human use

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Reg 70-25 on Use of Volunteers in Research.

Reviewed:

Gerald P. Krueger

GERALD P. KRUEGER, Ph.D.,
LTC, MS
Director, Biomedical Applications
Research Division

J.D. LaMothe

J.D. LaMOTHE, Ph.D.
COL, MS
Chairman, Scientific
Review Committee

Released for publication:

David H. Karney

DAVID H. KARNEY
Colonel, MC
Commanding

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USAARL 89-4	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Aeromedical Research Laboratory 6b. OFFICE SYMBOL (If applicable) SGRD-UAB-CS	7a. NAME OF MONITORING ORGANIZATION U.S. Army Medical Research & Development Command
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 577 Ft. Rucker, AL 36362-5292	7b. ADDRESS (City, State, and ZIP Code) Fort Detrick Frederick, MD 21701-5012
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 63002A PROJECT NO. 3M263002D995 TASK NO. WORK UNIT ACCESSION NO. AF 102

11. TITLE (Include Security Classification)
The Relationship Between Cognitive Ability and the Iconic Processing of Spatial and Identity Information

12. PERSONAL AUTHOR(S)
Robert L. Stephens

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM ____ TO ____	1989 February	56

16. SUPPLEMENTARY NOTATION
Data contained in this report were collected while the author was a graduate student in the Department of Psychology at the University of Alabama.

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
05	08	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Iconic processing, cognitive tests, individual differences, spatial location information, identity information

19. ABSTRACT (Continue on reverse if necessary and identify by block number)
The present investigation established the reliability of a classification technique which separates subjects into groups based on individual differences in the ability to process spatial location and identity information from tachistoscopically presented displays. Performance of the two groups then was compared on an iconic processing task which required the simultaneous processing of both location and identity information. Results indicated those subjects who process location information well performed significantly better on the Averbach-Coriell bar probe task than subjects who process identity information well. Subjects also were administered a battery of cognitive tests to determine whether differences at the iconic level are related to performance at more molar levels of cognition. Results of a series of correlational analyses indicated that a relationship does exist between iconic ability and more molar cognitive abilities.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION
22a. NAME OF RESPONSIBLE INDIVIDUAL Chief, Scientific Information Center	22b. TELEPHONE (Include Area Code) 205-255-6907 22c. OFFICE SYMBOL SGRD-UAX-SI

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

Acknowledgments

I would like to thank the many people of the United States Army Aeromedical Research Laboratory who have supported me in my efforts to complete this project.

I would also like to express my appreciation to my professors in the Department of Psychology at the University of Alabama for their time, effort, and invaluable advice.

Foreword

Data contained in this report were collected while the author was a graduate student in the Department of Psychology at the University of Alabama. The data analysis portion of this project was carried out at the United States Army Aeromedical Research Laboratory where the author is employed as a research psychologist in the Crew Stress and Workload Branch of the Biomedical Applications Research Division.

This research was submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Experimental and Clinical Psychology in the Graduate School of the University of Alabama.

Table of contents

List of tables

Table

List of tables (Continued)

List of figures

This page intentionally left blank.

Introduction

Much recent evidence from experiments incorporating tachistoscopic displays points to the fact that spatial location and identity information are processed independently and that individuals differ in their ability to process these two types of information. The existence of these individual differences in iconic processing ability possibly is linked to differences in more molar cognitive abilities. Yet, research directed toward definning the relationship between iconic processing and more molar levels of cognition virtually is nonexistent. Given that individuals differ in their iconic processing ability, any attempt to explore the relationship between iconic processing and higher level cognitive functions must employ a methodology which accounts for these individual differences. The present research is an attempt to perform such a synthesis of iconic-processing and individual-differences methodologies.

Iconic processing research

Since the early 1960s, iconic processing has been the focus of a great deal of psychological research. Although some researchers have argued against the need for such a concept (Holding, 1975a, 1975b), evidence for the existence of a very short-term visual memory is considerable (Averbach and Coriell, 1961; Coltheart, Lea, and Thompson, 1974; Dick, 1969, 1974; Neisser, 1967; Sperling, 1960; von Wright, 1968, 1970). Sperling demonstrated, through the use of the partial report paradigm, there was more information available from a brief visual presentation than could be reported under whole report conditions. He also demonstrated this storage system had an unlimited capacity and a duration of approximately 1 second.

The partial report paradigm Sperling (1960) developed was an ingenious method for determining the properties of iconic storage. In this paradigm, a stimulus array was presented briefly to the subject followed after some variable interval by a high, medium, or low frequency tone cue also of brief duration. The subject's task was to report the array items that appeared in the probed row. The proportion correct at each probed location provided an estimate of icon capacity. Also, by comparing performance at the various cue delays to performance in a no delay condition, the duration of the icon could be estimated.

Sperling (1960) developed the partial report task because introspective reports from his subjects suggested they had seen more than they could report in a whole report task. He reasoned that the most parsimonious treatment of partial report data is percent correct. However, this does not treat whole report data equally well because subjects in the whole report task are reporting a constant number of items, not a constant percentage. Therefore, he treated the partial report as a sample of the total number of items available to the subject at the time the cue was presented. For example, if a subject was correct 90 percent of the time when reporting one row of three letters in a 3/3/3 array, he or she was said to have 90 percent of the nine letters (8.1 letters) available for report at the time the cue was received. Comparing this value to the average number correct in the whole report task (4.3 letters), the partial report advantage becomes obvious. In his Experiment IV, Sperling delayed the cue 150, 300, 500, or 1000 ms and found that by 1000 ms the partial report advantage was eliminated completely. This provided evidence for the extremely short duration of the "image," as Sperling termed it.

Averbach and Coriell (1961) developed the partial report task further by replacing the auditory cue which Sperling (1960) had used with a visually presented bar probe cue. Results obtained with this task supported Sperling's conclusions about the nature of the icon except for the duration of the icon which Averbach and Coriell estimated to be approximately 250 ms. The use of the visual report cue limited the number of items to report to one per array making their task less susceptible to output interference and thereby maximizing the partial report advantage. Their task also was less susceptible to cue anticipation since the possible number of report cues was more than doubled. Another virtue of the visual report cue was it assured equal transmission rates for the array and probe. However, Dick (1974) cited evidence suggesting modality of the cue is not as important as Averbach and Coriell considered it. For example, Smith and Ramunas (1971) reported results similar to Averbach and Coriell's using a vibrotactile cue delivered to one of three fingers on either hand to indicate one item in a six-item array.

Dick (1969) conceptualizes the mechanism involved in the partial report paradigm as a sensory register. When the stimulus array is presented, it is encoded into the sensory register where it exists for a brief time before decay. After initial encoding, this information is recoded and some of it is transferred into short-term storage and eventually into long-term storage. Information not transferred is lost from the sensory register. Thus, loss of information from iconic storage is a function of the structural properties of the system. This sensory register concept has appeared many times in the literature under such various names as the icon (Neisser, 1967), visual information storage (von Wright, 1968, 1970), and short-term visual storage (Averbach and Coriell, 1961). It is usually described as an image-like memory that stores precategorical feature information.

In contrast to this popular single buffer account, other authors have offered more complex descriptions of the mechanisms involved in the processing of tachistoscopically presented information (Butler, 1975, 1980a, 1980b; Mewhort and Campbell, 1980; Mewhort et al., 1981). Butler (1975) hypothesized two different information processing stages to account for the category effect in a visual search task. He concluded the initial stage is a parallel process which extracts enough information for categorizing, but not identifying a stimulus. The second stage is sequential and operates on a limited subset of items extracting more information from each.

Mewhort and Campbell (1980; Mewhort et al., 1981) have suggested an information-processing account of the bar probe task which involves two data buffers, a feature buffer and a character buffer. In addition, their account includes two processing mechanisms, a character identification mechanism and an attentional search mechanism. The feature buffer is precategorical and can preserve spatial and physical attributes of the stimuli because of its unlimited capacity. Output from the feature buffer is sorted into bundles of features by the character identification mechanism which combines information about character shape with letter frequency information in order to identify the character.

The output of the character identification mechanism is an abstract representation of each character, but the spatial relationship of the items is maintained. This output is stored in the character buffer which is a postcategorical, but still spatial, representation of the array. The character buffer also absorbs time-of-arrival differences resulting from earlier processes. Finally, the attentional search mechanism locates an item in the character buffer using the probe as a cue to the item's spatial location.

Recent research (Chow, 1986; Irwin and Yeomans, 1986) challenges this notion of an "identify-then-select" mode of operation in the partial report task. For example, Irwin and Yeomans present evidence in support of a model of the partial report task which assumes a visual display creates a sensory representation which is likely a retinal coding. Information from this sensory representation is nonselectively translated into relatively durable item identity codes with associated abstract representations of the items' spatial positions within the display. Thus, location and identity information are processed simultaneously and nonselectively.

However once a cue is presented, it is used to select elements for translation. The translation process is a nonselective conversion of information which starts at stimulus onset. It extracts information from the sensory representation as long as the stimulus is present, but once the display is terminated the translation process has to rely on the persistence of stimulus information which exists in the form of a visual analog of the stimulus display and which persists for 150 to 300 ms after stimulus offset, regardless of exposure duration.

Information in the visual analog is maskable and spatially selectable through use of the cue. Thus, selection can occur prior to identification if the stimulus duration is short enough and the probed item has not been accessed by the translation process. While the Irwin and Yeomans model incorporates elements which could account for the Mewhort et al. (1981) data or evidence of a "select-then-identify" model, Chow offers a strict "select-then-identify" view of iconic memory which is in direct opposition to the Mewhort et al. (1981) model.

Independence of spatial and identity information

Numerous experiments have focused on the issue of how different types of information are handled in iconic storage. Of particular concern is the question of how spatial location and identity information are processed. The partial report technique is seen as an excellent means of determining the differential rate of loss of these types of information. Phenomenologically, there seems to be a unitary quality to the perception of location and identity information in the visual modality.

Yet, there is much evidence, both physiological and behavioral, to the contrary. Schneider (1969) provides evidence that, at least in hamsters, localization and pattern recognition are mediated by different areas of the brain, and he cites the research of others suggesting the same is true for primates. At the behavioral level, many experiments with humans point to this same independence of identity and location information (Butler, 1980a, 1980b, 1981; Dick, 1969; Kail and Siegel, 1977; Mason, 1980; Mewhort et al., 1981; Mewhort and Leppmann, 1985; Sagi and Julesz, 1985; Townsend, 1973).

The dual buffer account (Mewhort and Campbell, 1980; Mewhort et al., 1981) and the dual process account (Butler, 1975) provide a theoretical basis for the independence of spatial location and identity information. In the dual buffer account, the feature buffer stores spatial information, as well as the features of the stimuli. This information then is passed to the character identification mechanism which derives the character's identity based on information retrieved from a letter frequency memory contained within the character identification mechanism. Thus, the attentional search mechanism is performing a localization function in the character buffer which contains items which already have been identified.

Butler (1980a) again suggests perception may involve two quite separate processes, stimulus identification and stimulus localization. He bases this assumption on findings which indicate that attention instructions differentially affect the occurrence of intrusion errors and mislocation errors in a selective masking visual search task. Intrusion errors appear to reflect an identification process which is relatively insensitive to attention instructions suggesting identification is an automatic process.

On the other hand, mislocation errors appear to reflect a localization process which is affected by attention instructions suggesting localization may be the principal limited-capacity operation. Thus, it may be that stimulus identity information directs the localization operation in a visual search task. Why location information is required in the performance of a perceptual task is unclear. Butler suggests that the transfer from iconic to short-term memory may involve a spatio-temporal recoding, and therefore, spatial location must be determined prior to transfer. This account fits well with the dual buffer model (Mewhort and Campbell, 1980; Mewhort et al., 1981).

Many experiments have provided behavioral evidence of independent processing of spatial and identity information. Mason (1980) reports evidence from a comparison of highly skilled and less skilled readers' performance in a tachistoscopic task which suggests location and identity information are processed independently. Highly skilled readers and less skilled readers were equally proficient at identifying letters which were presented in the central field of view. However, when the task was to name the serial position of a letter among nontarget items (an uppercase x superimposed on a dollar sign) highly skilled readers were significantly better than less skilled readers. Furthermore, when position of the target letter among the nontarget items was known, there was no difference in performance for the two groups. But when the target letter had to be located first, the highly skilled readers again were significantly better than the less skilled readers. Thus, spatial and identity information must be processed at different levels of the visual system because there is no difference between groups on identity information tasks, whereas highly skilled readers are significantly more accurate than less skilled readers on location information tasks.

Kail and Siegel (1977) report results of an experiment exploring sex differences in retention of verbal and spatial information in short-term memory. Males remembered letter identity and letter position equally well while females remembered letters more accurately than positions. In explaining this effect, the authors proposed processing of letter identity and letter location could be related in one of three ways. First, location and identity information might be processed simultaneously. Second, processing of one type of information might be accomplished at the expense of the other. Third, location and identity information might be processed independently. Each of these possibilities has a different probability of recall associated with it. The probability of recalling location information should be greater than the product of the separate probabilities of recalling location and identity information if processing is simultaneous, less if one is processed at the expense of the other, and equal if location and identity information are processed idependently. Their results indicate that observed probabilities most closely resemble those predicted by independent processing of location and identity information.

Still another experiment (Sagi and Julesz, 1985) reports psychophysical evidence suggesting subjects can detect and locate feature gradients in a complex stimulus in parallel. However, in order to identify the orientation of the features, they must perform a serial inspection of the stimulus with focal attention.

Dick (1969) used the partial report technique to determine the differential rate of loss of identity, location, and color information from iconic storage by preparing a stimulus deck in such a way that he could have three groups of subjects extract one of these three types of information from the same deck. Each card consisted of four letters and four numbers arranged in two rows of four, with four of the items in red and four in black. A tone cue of high, medium, or low pitch informed the subjects what to report. The spatial location group reported either the top row, the bottom row, or the entire card depending on the pitch of the tone. The color group reported either the red, the black, or all the items. The class-of-item (identity) group reported either the numbers, the letters, or the entire card. His results indicated that as cue delays increased there was a rapid loss of color information, a slight loss of location information, and no loss of identity information.

This independence in the rate of loss of spatial and identity information led Townsend (1973) to design a series of experiments which would provide a more refined definition of spatial and identity information as they pertain to the bar probe task. She suggested there may be as many as three types of spatial information involved in the task considering not only the location of the bar probe relative to the letter display, but also the location of the bar probe relative to the bar probe display, and the location of the target letter relative to the array of letters.

In a series of three experiments, she presented the bar probe task and two subtasks of it. One subtask involved only spatial information about the location of the bar probe while the other involved only identity information about the array letters. She concluded that information is lost only when the subject is required to process both spatial and identity information simultaneously, as is required in the standard bar probe task. However, based on an error analysis of the standard bar probe task, it appeared subjects retained identity information, but did not retain information about the location of remembered items. She also suggested the apparent loss of spatial information in Dick's (1969) experiment could have been due to his subjects' inability to locate a letter relative to the letter display. Yet, none of her tasks was designed to examine loss of letter location information.

Using Townsend's (1973) variations of the partial report paradigm in a within-subjects design, Runcie and Graham (in press) compared retarded and nonretarded subjects to determine if there was a differential rate of loss of information for the two groups. Their results were in agreement with Townsend in that they failed to substantiate the assumption that location information is lost more rapidly than identity information (Dick, 1969) when loss of location information is defined as loss of information about the location of the bar probe relative to the letter display. Furthermore, their error analysis of the standard bar probe task revealed the same pattern for retarded subjects as Townsend's for nonretarded. They retained identity information, but not information about the location of remembered items. Yet, again none of these tasks was designed to explore loss of letter location information alone.

In other research, Stephens (1985) attempted to replicate and extend these earlier findings. In order to resolve the discrepancies in previous research, a fourth variation on the partial report task was added which was designed to test for loss of letter location information. This task used as a probe a letter presented above the middle position of the array. The probe letter always was present in the array, and subjects were required to indicate the probe letter's position in the letter display. Results of this letter location task revealed retarded subjects lost letter location information rapidly (within 150 ms after stimulus offset) while nonretarded subjects actually improved performance with increasing ISI up to 300 ms after stimulus offset.

Yet neither group showed a loss of location information in the bar probe location task which confirms the results of both Townsend (1973) and Runcie and Graham (in press). Results of the identity information task, however, did not confirm Townsend or Runcie and Graham in that nonretarded subjects showed a significant loss of identity information with increasing ISI. Retarded subjects showed a similar trend, but the loss of information was not statistically significant.

Furthermore, a post hoc correlation analysis revealed a negative correlation between scores on the letter identity task and scores on the letter location task indicating the existence of two types of information processors: (a) those subjects who processed location information well while processing identity information poorly, and (b) those subjects who processed identity information well while processing location information poorly. These correlations were highly significant for the retarded subjects, but only marginally significant for the nonretarded.

Individual differences in iconic processing ability

There are numerous reports of wide subject variability in performance on partial report tasks (Appelman, 1980; Coltheart, Lea, and Thompson, 1974; Doost and Turvey, 1971; Eriksen and Collins, 1969; Turvey, 1967; von Wright, 1970). However, because these investigations sought to explain the partial report phenomenon through the use of averaged group data, individual differences were viewed as the source of extraneous variability. Conclusions were drawn about the properties of iconic storage on the basis of these experiments, yet, as von Wright so adequately puts it, "no definite conclusions can be made as long as . . . . nothing is known about the determinants of individual differences in search and selection efficiency" (p. 285).

Sperling (1960), in his original work employing the partial report technique, occasionally found nonmonotonic decay functions with increasing cue delay; and Sakitt (1975, 1976) obtained similar results for one subject using the same procedure. Both researchers explained these findings in terms of individual differences in response strategies. In more recent research (Appelman, 1980), only one of eight subjects showed the classic monotonic decay function in the partial report task, although averaged data for the group showed just such a pattern. Moreover, the results of Mason (1980), cited earlier, provide further evidence of individual differences in the ability to process tachistoscopically presented information. The highly skilled readers in her sample were able to process location information significantly more accurately than the less skilled readers suggesting that differences in reading ability are at least partially attributable to differences in the ability to process location information in a tachistoscopic display.

The findings of Stephens (1985) also suggest individuals differ in their ability to process location and identity information from a tachistoscopically presented display. Given the fact that these differences exist, researchers are faced with the need to develop a methodology which takes their influence into account.

Differential psychology and information processing

Obviously, performance in the partial report task cannot be explained strictly in terms of visible or informational persistence. Subjects bring with them into the testing situation varying processing strategies and abilities which may or may not facilitate performance. While most models of information processing are designed to account for the data of an average subject, this approach relegates any individual differences in performance to the error term in an analysis. Yet, nearly a century of research on intelligence suggests individual differences do exist in cognitive abilities that could predict performance on components of information-processing tasks, such as those developed by Sperling (1960) and Averbach and Coriell (1961). Thus, to fully understand cognition, future research would benefit from a synthesis of individual-differences and information-processing methodologies.

Sternberg (1979) proposed research in the area of information processing and research in the area of individual differences should be combined in order to better understand the contribution individual differences in cognitive ability make to performance on laboratory tests of information-processing ability. Conversely, such a combination of methodologies could aid in determining if individual differences in performance on laboratory tasks are reflective of differences in the cognitive components involved in the solution of such tasks.

The goal of intelligence research long has been the prediction of individual differences, and there is a long list of psychometric instruments designed for the purpose. Previous research (Goldberg, Schwartz, and Stewart, 1977; Hunt, Frost, and Lunneborg, 1973; Hunt, Lunneborg, and Lewis, 1975) has shown it is possible to differentiate high- and low-ability individuals through the use of information-processing tasks. However, when a researcher's purposes are primarily predictive, there seems to be little justification for the use of such tasks since readily available psychometric tests have demonstrated reliability, and are generally easier to administer.

Instead of using measures of intelligence and aptitude primarily for purposes of prediction, present applications should emphasize their use in determining how intellectual performance can be improved. To achieve this goal, researchers must interpret individual differences in terms of processes that enhance or retard cognitive performance, and these processes must be incorporated into the teaching of prerequisite cognitive skills that facilitate learning.

The main advantage of using information-processing tasks, then, is they appear to be more suitable for assessing the influence of individual differences upon cognitive functioning. These tasks tap cognitive ability, but generally are designed to be relatively neutral with respect to knowledge. Such tasks, derived from a theoretically based model of cognition, might facilitate greatly the identification of those individuals who could possibly be trained to a high level of ability, even though they lack the requisite knowledge at the time of testing to perform well on a conventional psychometric test.

The goal of information-processing research has been to discover the processes and strategies individuals use in perceiving, integrating, and manipulating information. Unfortunately, most current information-processing models of cognition do not deal with individual differences in any detail. One reason is the methodologies used to develop these models fail to incorporate the differences between individuals on the specified parameters.

One such methodology is Sternberg's (1977) subtraction method in which the duration of a mental event is determined by comparing the amount of time a subject takes to arrive at a solution to a problem requiring that mental event, to the amount of time the subject takes to solve a problem identical to the first except for the absence of the mental event in question. Sternberg (1977) points out five problems with the subtraction method in addition to its lack of attention to individual differences: (a) parameters often confound multiple component processes, (b) alternative models often are indistinguishable, (c) large numbers of parameters are based on small numbers of data points, (d) the ordering of parameters is not specified mathmatically, and (e) the results of external validation may be distorted if estimates of component processes are confounded.

Sternberg (1979) proposes an alternative approach which he calls componential analysis. A central feature of this type of analysis is the breakdown of a composite information-processing task into a series of subtasks, each of which requires sucessively less information processing. This breakdown can be accomplished in several ways, one of which he calls the method of partial tasks. By decomposing a task, parameters that are confounded in the composite task can be separated, in most cases. This reduces the number of confounded parameters while, at the same time, allowing for testing of alternative models of information processing that might have previously been confounded.

Performance on the subtasks and performance on standardized tests of cognitive ability which are supposed to measure the component processes required to perform the subtasks are subjected to a correlation analysis. Validity of the model is tested in this way, and distortion of the validation results is guarded against by separating previously confounded parameters.

Cooper and Mumaw (1985) describe an approach they call the identification of quantitative individual differences. This information-processing approach involves the development of a model that defines the component processes required to perform some task. The goal is to isolate the subset of processes that best reflect individual differences in task performance.

The basic assumption is that a correlation should exist between individual variation in the speed or efficiency with which subjects carry out these component processes that are related to cognitive ability and individual variation in scores on an aptitude test of that cognitive ability. Further, there should be no correlation between variation on processes not related to the specific cognitive ability and variation on test scores. Since 1975 there has been a growing body of literature based on the information-processing approach, and two different methodologies have emerged. These two methodologies have been referred to as cognitive correlates analysis and cognitive components analysis (Pellegrino and Glaser, 1979).

In cognitive correlates analysis, subjects first are classified as high or low in ability based on some standardized aptitude test. After this classification process, the subjects are administered some laboratory test of their information-processing ability. Next, a correlation analysis is performed on the two measures, and it is assumed that patterns in the correlation that differentiate high and low ability subjects reflect basic processing differences between those groups.

In cognitive components analysis, however, the goal is to develop laboratory tasks based on a task analysis of the aptitude test. Thus, a more refined measure of ability is possible, yet it is derived from the same task as the aptitude measure. Both approaches have been employed recently, but Pellegrino and Glaser (1979) concluded: (a) cognitive correlates analysis is subsumed under cognitive components analysis, (b) the latter avoids the inability to determine causation inherent in correlational approaches, and (c) the cognitive components approach has the theoretical power to model individual differences in cognitive functioning.

Cooper and Mumaw (1985) offer, in contrast to the identification of quantitative individual differences approach, an alternative they call the identification of qualitative individual differences. This alternative approach attempts to interpret differences in aptitude in terms of the flexibility of strategy selection and global strategy differences among individuals.

Until the 1970s very little research focused on the importance of strategies as components of aptitude. Then, exploration of this relationship began to florish. MacLeod, Hunt, and Mathews (1978) showed that the relative levels of their subjects' verbal and spatial abilities could be used to predict performance on a sentence-picture verification task (Clark and Chase, 1972). In this task, subjects must decide as quickly as possible whether a given sentence is congruent or incongruent with a simple visual display. One strategy a subject could use is to derive a symbolic representation of the picture and then compare it to the linguistic representation of the sentence. Another strategy is to generate a spatial representation of the sentence and then compare that to the picture. The former strategy produces faster reaction times than the latter, and the results of MacLeod, Hunt, and Mathews (1978) indicate when verbal ability is constant, subjects with higher spatial ability scores are more likely to adopt the latter visual processing strategy while those with lower spatial ability scores are more likely to adopt the former verbal processing strategy.

Sternberg and Weil (1980) reported subjects who used a linguistic strategy to solve linear syllogisms showed correlations between solution times and level of verbal ability, but no correlations between solution times and level of spatial ability. Subjects who used a spatial strategy in solving the syllogisms showed the opposite pattern of correlations. Cooper and Mumaw (1985) reported subjects high in spatial ability were more likely to adopt a feature-analytic strategy in solving complex visual comparison problems while those low in spatial ability were more likely to adopt a more holistic, or pure spatial, strategy for solving these same problems. These studies point out the important role strategies play in the determination of aptitude.

In a series of experiments, Cooper (1976, 1982) examined strategy differences among individuals without relating them to differences in ability. The central focus of her research concerns how two visual stimuli are judged to be the same or different. In this paradigm, subjects are shown a random, angular shape. After removal of this standard shape, the subjects have to determine as quickly as possible whether a test shape is the same as or different from the memory representation of the standard shape.

Two distinct patterns of performance emerge. For some subjects, "same" responses are faster than "different" responses and "different" reaction times are not affected by the degree of similarity between the test shape and the standard shape. These subjects are referred to as holistic processors. For the remaining subjects, "same" responses are slower than the average "different" response, but faster than "different" responses to highly similar test shapes. In addition, "different" reaction times decrease monotonically with increasing dissimilarity between the test shape and the standard shape. These subjects are referred to as analytic processors. Error rates for the two types of subjects virtually are identical and are correlated positively with reaction times for analytic subjects.

These differences characterize the nature of Cooper and Mumaw's (1985) identification of qualitative individual differences because they involve patterns of performance rather than simple quantitative differences between individuals. It is difficult to characterize these differences in terms of a single, underlying processing parameter because overall response speed, relative speed of "same" and "different" responses, sensitivity of "different" responses to similarity of test and standard shapes, and the relationship between reaction time and accuracy all covary systematically within an individual and also differ between individuals.

Cooper (1982) suggests the difference exists in the nature of the strategies that subjects naturally use in the process of comparing internal representations of visual information with externally presented visual stimuli. Holistic processors are assumed to use a unitary, holistic comparison strategy seeking to verify that the two stimuli are the same. In this strategy, the emphasis is placed on achieving a match rather than on searching for stimulus differences or visual features that distinguish the internal representation from the test shape. When this verification process fails to find a match, the "different" response is generated by default. The "same" responses are faster as a result of the initial attempt to find a match. The lack of an effect of decreasing similarity on reaction time is accounted for by the assumption that "different" responses are generated by default rather than as a result of an analysis of visual feature differences.

Analytic processors are assumed to use the more familiar dual process comparison strategy in which two different and independent processes generate the "same" and "different" responses. One process specializes in detecting differences between memory representations and test shapes. As soon as this process finds a feature that distinguishes the two, a "different" response is generated. The second process, similar to the holistic subjects' single comparison process, operates simultaneously with the difference-detection process and under a time deadline. If a match is detected before the deadline has been reached, a "same" response is generated. Note, however, that this process cannot lead to a "different" response if a match is not found because the two processes are independent. The first process explains the monotonic decrease in reaction time with decreasing similarity between the memory representation and the test shape, and by assuming an intermediate duration for the deadline of the second process, the relative speed of "same" and "different" responses for analytic processors is explained.

An apparent problem with this explanation is correct "different" responses to the most similar mismatches are slower than correct "same" responses for analytic processors. While the dual process account of analytic processor performance explains the relative speed of "same" and "different" responses for these subjects, it seems likely they would show higher error rates for "same" responses than would holistic processors because once the deadline for the match-detection process is reached a "same" response cannot be generated. Yet, Cooper (1982) reports no "appreciable differences in either the magnitude or pattern of . . . errors [for the two groups]" (p. 82).

In summary, these various research methodologies appear superficially similar, but differ in some important respects. The quantitative individual differences approach is a global descriptor for those previously mentioned information-processing methodologies which define individual differences in terms of relative speed or efficiency of elementary cognitive processes. These include cognitive correlates analysis, cognitive components analysis, and componential analysis. The cognitive correlates approach proceeds from classification of individuals into groups, in terms of performance on aptitude tests, toward analysis of these groups' differences on laboratory tests proposed to tap the aptitude in question.

Sternberg's (1979) componential analysis and the cognitive components approach, on the other hand, proceed from a task analysis of an aptitude test to performance on subtasks designed to measure the resulting component processes involved in performance on the test. In contrast to these quantitative methodologies, the identification of qualitative individual differences attempts to go beyond the mere quantification of differences between high- and low-ability groups by identifying underlying strategy selection differences that will explain individual differences in aptitude. Each of these approaches has been employed in research on various cognitive abilities from analogy solution (Sternberg, 1977) and verbal ability (Hunt, Lunneburg, and Lewis, 1975), to spatial aptitude (Egan, 1978; Cooper and Mumaw, 1985) and visual comparison (Cooper, 1976, 1982). But literature searches have revealed no one who has directly addressed iconic processing ability within this framework.

Through the combined use of the componential analysis approach (Sternberg, 1979) and the partial report bar probe task, researchers can pinpoint the specific cognitive skills on which individuals differ. Furthermore, investigation of these individual differences could, as differential psychologists suggest, greatly facilitate the identification of individuals in need of training on specific cognitive skills to improve their levels of performance.

Statement of the problem

The objectives of the present research are fourfold. First, the separation of retarded subjects into groups of "localizers" and "identifiers," which was achieved in earlier research (Stephens, 1985), will be demonstrated to be generalizable to the nonretarded population.

Second, the reliability of the separation technique will be tested. This will be accomplished through the calculation of a test-retest reliability coefficient for the classification parameter.

Third, the resulting groups will be tested to determine if they differ in their ability to process location and identity information simultaneously, as is required in the standard bar probe task.

The Mewhort et al. (1981) model predicts identifiers will perform more accurately than localizers because, in the model, identification precedes selection on the basis of location information. In contrast, the Irwin and Yeomans (1986) model predicts localizers will perform more accurately than identifiers because information in the visual analog is selectable spatially, and localizers encode and utilize spatial location information more accurately than identifiers. Since translation of location and identity information is simultaneous, the issue becomes one of strategy selection differences among the two groups.

The most parsimonious explanation is that subjects select a processing strategy that is congruent with their particular processing abilities. In other words, identifiers automatically select a processing strategy which exploits their ability to encode and sort feature bundles into translatable units while localizers automatically select a strategy which utilizes their ability to encode spatial location information. Those subjects with the most accurate spatial coding will be the most able to utilize the location information provided by the bar probe to select the appropriate item for translation and report, if the item already has not been translated.

Fourth, it will be determined if these differences in the ability to process location and identity information at the iconic level are related to ability differences at more molar cognitive levels. It is predicted significant correlations will be found between variation in the efficiency with which individuals carry out the component processes involved in the standard bar probe task (i.e., localization and identification) and individual variation on aptitude tests of cognitive abilities related to the demands of the standard probe task. Further, it is predicted the correlations will show patterns which will differentiate between localizers and identifiers.

Experiment 1

The objective of Experiment 1 was to determine the reliability of the technique used to classify individuals as localizers or identifiers. This was accomplished through the use of a test-retest reliability check of the measures used in the classification process. The methodologies of Experiments 1 and 2 were identical except that subjects in Experiment 1 were tested twice on the iconic memory tasks. This allowed the data from subjects in Experiment 1 to be combined with the data from subsequent subjects in Experiment 2.

Method

Subjects

Twenty subjects (4 males and 16 females) participated in this first experiment. All had normal or corrected-to-normal visual acuity. For the purposes of this experiment, normal acuity was defined as 20/25 or better on a Snellen acuity chart. Subjects were recruited from introductory psychology classes at the University of Alabama, and they all received extra class credit for their participation. Ages ranged between 17 and 21 with a mean age of 18.35 years.

Materials

The experiment was conducted in three sessions. The materials for the first session consisted of a battery of cognitive tests drawn from the Kit of Factor-referenced Cognitive Tests 1976 Revision (Ekstrom et al., 1976). The tests selected were those relating to the factors verbal closure, visual memory, perceptual speed, and spatial orientation. One test relating to each factor was selected. These paper and pencil tests were administered to as many subjects as possible at one time.

The second and third sessions were laboratory tests of each person's iconic processing ability. The stimuli consisted of tachistoscopically presented arrays of upper case consonants arranged so eight letters appeared on a single line with each letter separated from adjacent letters by a distance of 0.55 cm. Each letter subtended a visual angle of 17.4 min horizontally and 26.4 min vertically. The entire array subtended a visual angle of 5 deg 6 min horizontally and 26.4 min vertically, and was centered on a black and white computer monitor. Letter selection was random without replacement for each array. Poststimulus cues consisted of a bar marker in one task and a randomly generated upper case consonant in the remaining two tasks. The bar marker cue appeared 0.1 cm above each of the eight serial positions of the array equally often. The letter cue appeared 0.1 cm above the middle of the array between positions four and five on every trial.

Apparatus

Stimulus generation and data recording for the second session of the experiment were controlled by a microprocessor. The monitor was placed on a table at the subject's eye level. The subject was seated at the opposite end of the table with his or her chin in a chin rest. The subject's viewing was binocular at a distance of 79 cm. Intensity of the stimuli was reduced to the point at which there are no persisting negative afterimages, and was held constant for all subjects.

Procedure

As stated, the experiment was conducted in three sessions. The first session was conducted in a large classroom with as many subjects as possible at one time. This session involved the administration of the cognitive test battery which tested the subjects' verbal closure, visual memory, perceptual speed, and spatial orientation abilities.

The test for verbal closure was called the Hidden Words Test and consisted of lines of letters with four-letter words interspersed among them. The subject's task was to find as many four-letter words as possible in 4 minutes. There are two parts to the test, and each part consisted of 20 lines of letters.

The test for visual memory is called the Building Memory Test and also consisted of two parts. Each part had a study page and a test page. The study page contained a street map with 12 buildings placed on it. The subject was allowed to study this map for 4 minutes. After studying the map, the subject was instructed to turn to the test page which contained the same map with the buildings arranged vertically along the left side of the page. The letters A through E had been placed on the map in both target and distractor locations. The subject had 4 minutes to select the letter which represented the appropriate location for each of the 12 buildings.

The test for perceptual speed was called the Finding A's Test and also consisted of two parts. Each part consisted of four pages of words arranged in five columns per page. Each column had five words containing the letter a. The subject's task was to find the words which contained the letter a and mark them by drawing a line through them. The subject was allowed 2 minutes for each of the two test parts.

The test for spatial orientation was called the Cube Comparison Test and also consisted of two parts. Each problem in the test consisted of drawings of pairs of cubes or blocks such as children play with, and each cube contained a different letter, number, or symbol on each of the six faces (the top, the bottom, and the four sides). The subject was told to decide whether the pair of cubes could represent two aspects of the same cube or two different cubes. Each part of the test consisted of 21 problems, and the subject's task was to solve as many of the 21 problems as possible in 3 minutes.

After the initial cognitive test battery, subjects were contacted individually for the remaining laboratory test sessions. During the first of these two sessions each subject's visual acuity was tested with a Snellen acuity chart. Upon completion of the vision test, he or she was taken to the experimental room and seated comfortably in front of the computer monitor and allowed to dark adapt while the experimenter read the instructions. Each subject was presented with three tasks. Order of task presention was constant for all subjects. The session consisted of 192 trials (64 trials per task). Each task was divided into blocks of 16 trials at each of four interstimulus intervals (ISIs). The ISIs employed were of 0, 150, 300, and 450 ms duration. ISI order was assigned randomly to each subject and was counterbalanced across subjects. Within a block of trials, each array position was probed twice.

Before each task began, the subject was shown examples of the fixation cross, the array, and the probe which would be used in that task, and the expected response was explained. Subjects also were told a reaction time measure would be recorded for each response, and therefore, they should make their responses as quickly as possible without sacrificing accuracy. Then a trial was shown tachistoscopically for practice. Each trial began with the experimenter saying "Ready" and then initiating the presentation of the fixation cross. The fixation cross appeared on the screen for 500 ms followed by a 50 ms array presentation, a variable dark ISI, and a 40 ms probe presentation. Subjects were required to respond at the end of each trial and were asked to guess if uncertain. Feedback was provided after each response.

Task 1 was a replication of the Averbach and Coriell (1961) task. On each trial, an array of eight letters was presented followed, after one of the four ISIs, by a bar marker probe centered above one of the eight positions of the array. The subject was instructed to report verbally the letter which had appeared in the probed position. This task differed from the Averbach and Coriell task in that feedback was provided at the end of each trial. This feedback consisted of showing the subject the stimulus array with the probe above the target letter and announcing whether the response was correct or incorrect.

In Task 2, the letter identity task, the array was presented as in Task 1. However, here, the probe was a randomly generated upper case consonant which appeared above the middle of the array between positions four and five after the variable ISI. The subject was asked to indicate whether or not the probe letter appeared anywhere in the stimulus array. Presence or absence of the probe letter was random with the restriction that it was present in half of the trials and absent in the other half. Again, feedback was provided at the end of each trial. In this task, the need to retain location information was minimized, and therefore, the task measured almost pure identity information.

Task 3 was the letter location task. Presentation of the array and probe was the same as in the letter identity task, but in this task the probe letter always was present in one of the positions of the array. The subject's task was to report the number of the position which the probe letter had occupied in the array. As before, feedback was provided after every trial. This task was designed to extract spatial location information about the letters relative to the letter display while minimizing the need to retain identity information.

Each subject's final session in Experiment 1 was conducted 1 week later. The procedure was identical to the second session except for the omission of the visual acuity test. Each subject received the same random ISI order as in their previous session.

Results and discussion

The classification of individuals into groups of localizers and identifiers was based on their performances on both the letter identity and the letter location tasks. By definition, a localizer is one who performs well in the letter location task and poorly in the letter identity task. The opposite is true of identifiers. Therefore, difference scores derived by subtracting each subject's mean location score (mean across ISI) from his or her mean identity score would yield a distribution of scores which would indicate an individual's relative abilities on the two component tasks. The median of this distribution was used to divide the subjects into two groups based on performance on the two tasks.

Those subjects who were in the top 50 percent on this difference score distribution were classified as identifiers. Those subjects who were in the bottom 50 percent on this difference score distribution were classified as localizers. Because of differences in the numbers of males and females in the present experiment, an ad hoc mixed factorial analysis of variance was performed on data from both Experiments 1 and 2 with sex as the between-subjects factor and task and ISI as the within-subjects factors in order to determine if the sex of an individual influenced iconic processing ability. Results indicated there was no sex main effect, nor were there any interactions with sex. Therefore in Experiment 1, the data for males and females were combined for the determination of test-retest reliability.

Test-retest reliability was assessed using a Pearson product moment correlation coefficient to measure the degree of relationship between difference scores derived from the two separate iconic processing sessions. The difference score exhibited a reliability coefficient of r_{xx} = .63, $p<.005$, between sessions which indicates it provides a moderately reliable means of classifying individuals, and it is sufficient to warrant the use of the classification procedure in Experiment 2.

Descriptive statistics then were calculated for both of the iconic processing sessions. Frequency distributions were plotted and medians were determined for both distributions. The median for the first session was 0.00 with no subjects obtaining the median score. This resulted in 10 subjects being classified as identifiers and 10 being classified as localizers. The median for the second session was -6.25 with three subjects obtaining the median value. Somewhat arbitrarily, those subjects falling at the median were classified as localizers. This resulted in 9 subjects being classified as identifiers and 11 subjects being classified as localizers.

Use of the median split for each of the distributions resulted in 65 percent agreement in classification between the first and second sessions. While it indicates that 7 of the 20 subjects shifted category from the first session to the second, this value is substantially above the chance level of 25 percent. However, there was a shift of the entire distribution toward negative difference scores (i.e., toward the localizer end of the distribution) from the first to the second session as indicated by the drop in the median from 0.00 to -6.25. This suggests performance may not have stabilized by the second session and reliability conceivably could be higher if subjects were allowed to practice the tasks until asymtotic levels of performance were reached.

Jones (1980) describes two processes involved in skill acquisition which support this conclusion. The first of these is an acquisition process in which subjects improve at different rates, and the second is a terminal process in which subjects reach their individual limits and their performance stabilizes. In other words, different subjects begin at different points initially and arrive at different final values through different pathways. Therefore, an intersession correlation matrix would present a distinctly different picture if performance was examined early versus late in practice. Early in practice correlations between adjacent sessions would be higher than comparisons which were more remote. More important, correlations of immediately adjacent sessions would be higher later rather than earlier in practice. Once the terminal process begins, the intersession correlations would become constant and there would cease to be any systematic variation related to temporal separation of sessions.

Additional support is provided by test-retest reliability information from earlier research (Stephens, 1985) in which the same tasks used in this study were presented to subjects for 3 consecutive days. Correlation of difference scores between the first and second sessions was only r_{xx} = .45, but correlation of difference scores between the second and third sessions was r_{xx} = .73. Furthermore, a number of studies have reported improvments in iconic processing ability with increased practice (Borkon, 1983; Schiller, 1965; Turvey, 1973; Ward and Ross, 1977) suggesting iconic processing is not as automatic as it initially appears. While further investigation of these practice effects would be of interest, the results of the present experiment suggest the performance of subjects classified in the above manner could be examined reliably in a second experiment.

Experiment 2

Given that the classification technique had an acceptable level of reliability, as determined in Experiment 1, then it was possible to employ the classification technique in a second experiment. The objectives of Experiment 2 were to determine if the two groups of information processors defined by this classification technique differed in their ability to perform a task which required the simultaneous processing of location and identity information from the same array, and to determine if differences in the ability to process information at the iconic level were related to ability differences at more molar cognitive levels. The standard bar probe task provided a situation in which a subject must extract both location and identity information from the same array while a battery of cognitive tests provided information about molar cognitive ability.

Method

Subjects

Sixty-seven additional subjects (36 males and 31 females) were recruited for Experiment 2. All had normal or corrected-to-normal visual acuity. Subjects were students enrolled in introductory psychology classes at the University of Alabama, and they received extra class credit for their participation. Ages ranged from 17 to 36 with a mean age of 19.74 years. Data from the subjects in Experiment 1 were combined with those of the subjects in Experiment 2. Thus, data were obtained on a total of 87 subjects (40 males and 47 females).

Materials

While Experiment 1 was conducted in three sessions, only two sessions were conducted for Experiment 2. The first session of Experiment 2 consisted of the administration of the cognitive test battery. The materials for this session were identical to those for Experiment 1. Again, these tests were chosen because it was assumed differences in the ability to process location and identity information at the iconic level would be reflected in performance differences in these cognitive abilities.

The second session consisted of a laboratory test of each person's iconic processing ability. Stimulus characteristics and presentation were identical to those for Experiment 1.

Apparatus

The apparatus for Experiment 2 was identical to that used in Experiment 1.

Procedure

The two sessions of Experiment 2 were conducted identically to the first two sessions of Experiment 1. The first session involved the administration of the cognitive test battery. The second session was the laboratory test of iconic processing ability.

Results and discussion

Subjects were classified as either localizers or identifiers on the basis of the location of their scores on the difference score distribution. If their score was above the median on the difference score distribution, they were classified as identifiers. If their score was below the median on the difference score distribution, they were classified as localizers. Those subjects whose score tied the median value were excluded from subsequent analyses. The median for the entire sample of 87 subjects was -1.56 with 5 subjects obtaining the median value. Thus, the classification process resulted in a group of 41 localizers and a group of 41 identifiers.

Percent correct scores on the standard bar probe task for these two groups were submitted to a two-way mixed factorial analysis of variance with group as the between-subjects variable and ISI as the within-subjects variable. Results indicated no significant interaction, however, there was a significant group main effect, $F(1,80) = 29.20$, $p<.0001$, and a significant ISI main effect, $F(3,240) = 34.83$, $p<.0001$. Figure 1 depicts the performance of the two groups as a function of ISI.

As can be seen, the group main effect is accounted for by the superior performance of localizers over identifiers across all ISIs. An orthogonal decomposition of the ISI main effect was conducted and indicated both a significant linear component, $F(1,80) = 82.36$, $p<.0001$, and a significant quadratic component, $F(1,80) = 11.23$, $p<.005$. Contrasts performed for the ISI main effect offer an explanation of these trends. The linear trend is accounted for by decreases in percent correct with increasing ISI for both groups as evidenced by significant differences between 0 ms ISI and 150 ms ISI, $F(1,80) = 42.74$, $p<.0001$, between 0 ms ISI and 300 ms ISI, $F(1,80) = 53.07$, $p<.0001$, and between 0 ms ISI and 450 ms ISI, $F(1,80) = 89.33$, $p<.0001$. The quadratic trend is accounted for by the reduction in the slope of the function beyond 150 ms ISI. In fact, beyond that point only the decrease in percent correct from 150 ms ISI to 450 ms ISI is significant, $F(1,80) = 8.34$, $p=.005$.

Thus, both processor groups show the characteristic decrease in performance with increasing ISI indicative of a rapid loss of information from iconic storage within the first 300 ms after stimulus offset (Averbach and Coriell, 1961; Dick, 1969, 1974; Neisser, 1967; Sperling, 1960; Townsend, 1973). Obviously, when an iconic processing task requires the extraction of both location and identity information, as the standard bar probe task does, the performance of localizers surpasses that of identifiers, yet both groups exhibit similar duration characteristics for the information in iconic storage. The difference must lie in the way in which the two groups organize and access this type of information.

The results of this analysis address the conflicting predictions made by the Mewhort et al. (1981) model and the Irwin and Yeomans (1986) model. According to the Mewhort et al. model, identification precedes selection on the basis of location information. In contrast, Irwin and Yeomans propose that translation of location and identity information is simultaneous, and while translation starts at stimulus onset information in the visual analog is spatially selectable (e.g., with a bar probe). Thus, localization could precede identification according to the Irwin and Yeomans model.

Apparently, localizers initially select a processing strategy which exploits their ability to encode and utilize spatial location information while identifiers initially select a strategy which exploits their ability to encode and sort feature bundles into translatable units. The findings of this

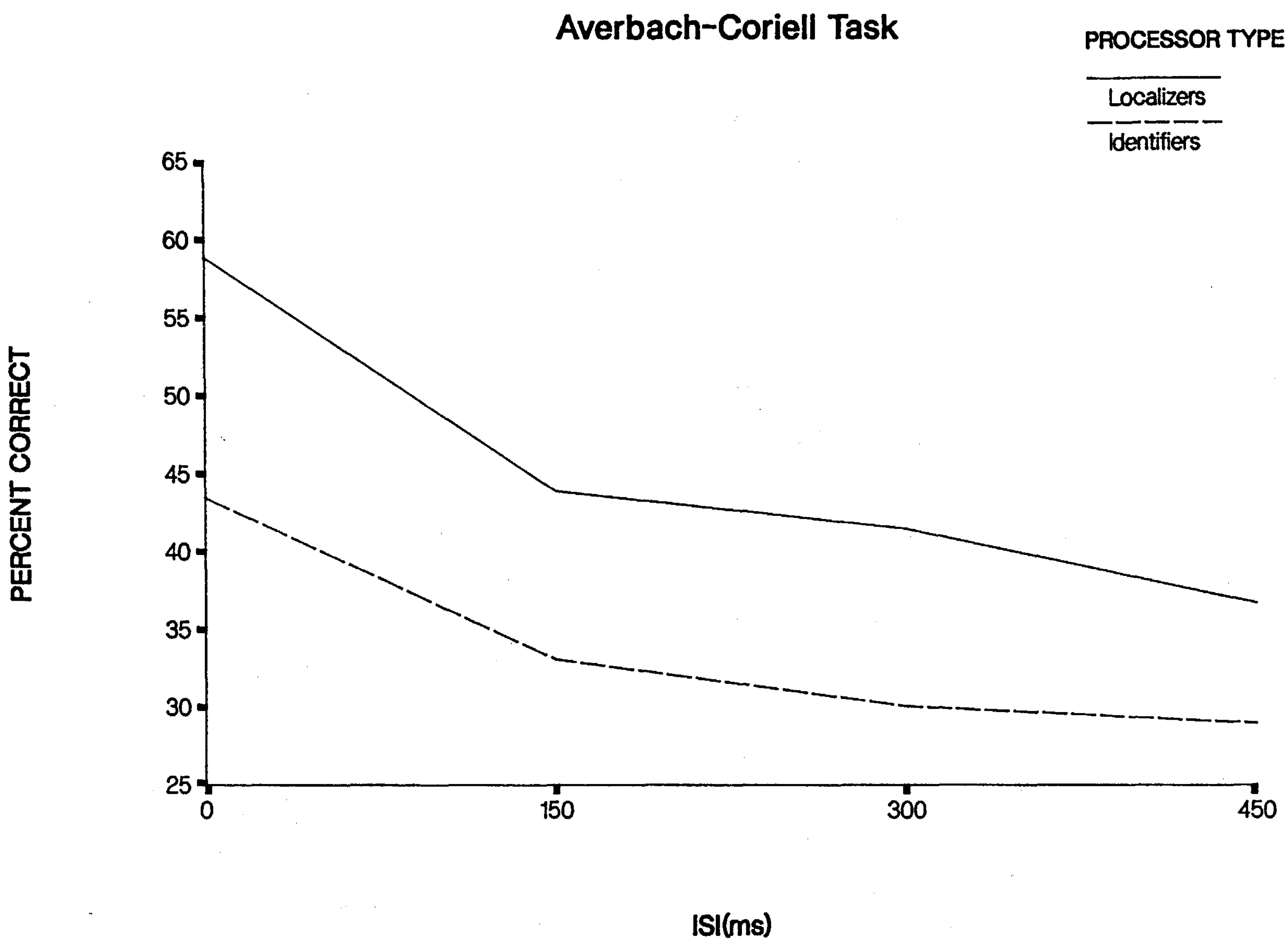

Figure 1. Percent correct as a function of ISI for localizers and identifiers on the Averbach-Coriell task.

investigation suggest performance in the standard bar probe task is dependent upon successfully encoding and retaining the spatial relationships among the items in an array. Successful translation of sorted feature bundles is of little use if the wrong item is selected for translation. Thus, the superior performance of localizers is accounted for by the assumption that those subjects with the most accurate spatial coding were the most able to utilize the location information provided by the bar probe to select the appropriate item for translation, as the Irwin and Yeomans model would predict.

The next analysis involved the derivation of a separate correlation matrix for each of the two processor groups. It was predicted significant correlations would be found between variation in the efficiency with which subjects carried out the component processes involved in the standard bar probe task (i.e., localization and identification) and individual variation on the cognitive tests related to the demands of the standard bar probe task. Further, it was predicted patterns of correlations within the two matrices would be different qualitatively. Table 1 contains the intercorrelations between iconic processing task scores and cognitive task scores for localizers. Table 2 contains the intercorrelations between iconic processing task scores and cognitive task scores for identifiers.

Note that localizers show negative correlations between their perceptual speed task score and letter location processing task scores, especially under short ISIs, while identifiers show positive correlations for these comparisons. Also note that a similar pattern is seen for the relationship between verbal closure task scores and letter location processing task scores for the two groups. Identifiers also show positive correlations between their visual memory task score and letter location processing task scores under the two early ISIs while localizers show no relationship between these scores. These findings suggest those identifiers who do well on the letter location task use either a different cognitive mechanism or a different processing strategy from those localizers who do well on the letter location task.

Tables 3 and 4 contain the intercorrelations between the cognitive task scores and reaction time (RT) for correct responses (Table 3) and RT for incorrect responses (Table 4) on the iconic processing tasks for localizers. Tables 5 and 6 contain the same intercorrelations for identifiers. Comparing Tables 3 and 5, it can be seen that localizers exhibit statistically significant negative correlations between their visual memory task scores and their RTs for correct responses on the letter location task at the longer ISIs while identifiers do not, suggesting the speed with which localizers

Table 1.

Intercorrelations between iconic processing task scores and cognitive task scores for localizers (n=41).

Iconic processing task score	Cognitive task: Verbal closure	Visual memory	Perceptual speed	Spatial orientation
Location 0 ms ISI	-.35*	-.14	-.44**	-.02
Location 150 ms ISI	-.15	.09	-.21	.16
Location 300 ms ISI	.13	-.14	-.16	.18
Location 450 ms ISI	.09	.03	-.04	.24
Identity 0 ms ISI	-.03	.11	.07	.05
Identity 150 ms ISI	-.15	-.26	-.20	-.25
Identity 300 ms ISI	-.11	.27	-.10	-.07
Identity 450 ms ISI	.10	-.20	.10	.11

* $p<.05$ ** $p<.01$

Table 2.

Intercorrelations between iconic processing task scores and cognitive task scores for identifiers (n=41).

Iconic processing task score	Verbal closure	Visual memory	Perceptual speed	Spatial orientation
	Cognitive task			
Location 0 ms ISI	.22	.39**	.36*	.16
Location 150 ms ISI	.20	.29	.27	.06
Location 300 ms ISI	.09	-.08	.22	.06
Location 450 ms ISI	-.03	-.21	.11	-.01
Identity 0 ms ISI	-.03	-.10	-.03	-.07
Identity 150 ms ISI	.05	.19	.12	.10
Identity 300 ms ISI	.01	.24	.16	-.24
Identity 450 ms ISI	-.08	.30	.05	.23

* p<.05 ** p<.01

Table 3.

Intercorrelations between reaction times (RTs) for correct responses on iconic processing tasks and cognitive task scores for localizers (n=41).

RT correct on iconic processing tasks	Cognitive task: Verbal closure	Visual memory	Perceptual speed	Spatial orientation
Location 0 ms ISI	-.15	-.14	-.24	-.14
Location 150 ms ISI	-.37*	-.30	-.30	-.29
Location 300 ms ISI	-.26	-.37*	-.21	-.27
Location 450 ms ISI	-.21	-.32*	-.20	-.20
Identity 0 ms ISI	.02	-.17	.08	.10
Identity 150 ms ISI	-.12	-.12	-.12	-.01
Identity 300 ms ISI	.02	-.11	-.13	.06
Identity 450 ms ISI	-.08	-.28	-.03	-.08

* $p<.05$

Table 4.

Intercorrelations between reaction times (RTs) for incorrect responses on iconic processing tasks and cognitive task scores for localizers (n=41).

RT incorrect on iconic processing tasks	Cognitive task: Verbal closure	Visual memory	Perceptual speed	Spatial orientation
Location 0 ms ISI	-.19	-.33*	-.26	-.17
Location 150 ms ISI	-.10	-.35*	-.23	-.11
Location 300 ms ISI	-.18	-.30	-.20	-.15
Location 450 ms ISI	-.15	-.18	-.27	-.05
Identity 0 ms ISI	-.01	-.23	.02	.03
Identity 150 ms ISI	-.14	-.05	-.18	.03
Identity 300 ms ISI	.01	-.10	-.11	.03
Identity 450 ms ISI	-.06	-.20	-.01	-.10

* $p<.05$

Table 5.

Intercorrelations between reaction times (RTs) for correct responses on iconic processing tasks and cognitive task scores for identifiers (*n*=41).

RT correct on iconic processing tasks	Cognitive task			
	Verbal closure	Visual memory	Perceptual speed	Spatial orientation
Location 0 ms ISI	-.18	.07	-.02	-.06
Location 150 ms ISI	-.01	-.35*	.02	.04
Location 300 ms ISI	-.10	.07	.04	-.03
Location 450 ms ISI	-.40**	-.01	-.08	.02
Identity 0 ms ISI	.08	-.03	.06	-.21
Identity 150 ms ISI	.06	-.08	.05	-.16
Identity 300 ms ISI	.03	.03	-.00	-.17
Identity 450 ms ISI	.01	.02	-.01	-.11

* $p<.05$ ** $p<.01$

Note: For comparisons involving RTs on the location task at 0 ms ISI and 300 ms ISI *n*=40 due to two subjects each responding incorrectly on all trials at one of those ISIs.

Table 6.

Intercorrelations between reaction times (RTs) for incorrect responses on iconic processing tasks and cognitive task scores for identifiers (n=41).

RT incorrect on iconic processing tasks	Cognitive task Verbal closure	Visual memory	Perceptual speed	Spatial orientation
Location 0 ms ISI	-.11	.07	.03	-.15
Location 150 ms ISI	-.04	.03	.01	.00
Location 300 ms ISI	-.07	.15	.09	-.05
Location 450 ms ISI	-.09	.12	-.01	-.01
Identity 0 ms ISI	.00	-.03	-.00	-.16
Identity 150 ms ISI	.14	.05	.04	-.12
Identity 300 ms ISI	.10	.07	.10	-.21
Identity 450 ms ISI	.05	.01	.04	-.22

correctly respond to letter location task items is related to their ability to memorize spatial relationships.

It is particularly interesting that these correlations are strongest at the longer ISIs when the iconic representation should no longer be present and transfer to longer term storage should have begun. Localizers also exhibit a negative correlation between their verbal closure task score and their RT on the letter location task at 150 ms ISI while no relationship exists between these scores for identifiers. However, no consistent pattern emerges for the other ISIs. Comparing Tables 4 and 6, it can be seen that localizers exhibit negative correlations between their visual memory task scores and their RTs for incorrect responses on the letter location task at the shorter ISIs. Identifiers show no relationship between these variables. In fact, identifiers show no significant correlations between any of their cognitive task scores and RTs for incorrect responses.

While the relationships discussed above are significant statistically, caution must be exercised when speculating about their implications given the magnitude of the correlations (r^2 values range from .09 to .16). Because of the large number of correlations calculated in the above analysis, a series of multiple regression analyses was performed in order to control for the possibility that these significant simple correlations were spurious results. Furthermore, multiple regression provided a means for assessing how well performance on the iconic processing tasks, as a whole, predicted performance on each of the cognitive tasks.

Information from the correlational analyses suggested, however, that multicollinearity would be a problem if all of the RT measures were included in the set of independent variables. Therefore, mean RTs for correct and incorrect responses were calculated across ISI for both the letter identity task and the letter location task. An additional correlation analysis was performed to determine the interrelatedness of these derived measures. Results indicated a high degree of correlation between the mean RT for correct responses and the mean RT for incorrect responses within each processing task. As a result, only the mean RTs for correct responses were included among the independent variables.

The resulting set of independent variables included percent correct at each of the four ISIs for the letter identity task, percent correct at each of the four ISIs for the letter location task, and mean RTs for correct responses for both the letter identity task and the letter location task. These independent variables then were regressed on each of the cognitive task scores separately. In addition, processor type was used as a grouping variable and separate multiple regressions were performed for each group.

The first set of multiple regression analyses involved the inclusion of all 10 independent variables at once for both groups combined and then for each group separately. Table 7 presents the R^2 and F values associated with each of the resulting multiple regression equations. Note that, in all cases, R^2 is larger for the individual group equations than for the combined groups equation. Also note that none of the equations is significant with the exception of the multiple regression equation for the visual memory task for both groups combined which has an associated R^2 of only 0.23 compared to 0.35 for the equations for each group separately. These findings suggested that processor group membership was an important predictor variable which was unaccounted for in the combined group regression equations. Yet, none of the equations for the separate groups was significant when all of the independent variables were included.

Therefore, a series of backward stepping multiple regressions was performed for each group separately for each of the tasks in the cognitive battery. This backward stepping procedure eliminated independent variables which made a nonsignificant contribution to the regression equation in an iterative manner and allowed for the comparison of equations to determine which variables were most predictive of cognitive ability for each group individually.

Table 8 contains the results of the backward stepping procedure for the "best" equation obtained for each group on each of the cognitive abilities. For localizers' verbal closure ability, the resulting equation included the variables percent correct on the letter identity task at 0 ms and 150 ms ISI and percent correct on the letter location task at all four ISIs. These six variables account for approximately 30 percent of the variance in verbal closure ability for localizers. The most significant of these six variables was percent correct on the letter location task at 0 ms ISI, $t(34) = -3.21$, $p<.01$. The backward stepping procedure never resulted in a significant equation for identifiers indicating iconic processing ability is not a good predictor of their verbal closure ability.

For localizers' visual memory ability, the "best" equation included percent correct on the letter identity task at 0 ms, 150 ms, and 300 ms ISI and percent correct on the letter location task at 150 ms and 300 ms ISI. It also included mean RT for correct responses on both the letter identity and letter location tasks. These seven variables explained roughly 34 percent of the variance in localizers' visual memory ability. The most significant predictor variable, given the other six

Table 7.

Summary of multiple regression analyses for each processor group separately and for both groups combined.

R^2 and F values	Cognitive tasks: Verbal closure	Visual memory	Perceptual speed	Spatial orientation
Localizers (n=41)				
R^2	.32	.35	.30	.37
F	1.38	1.58	1.26	1.79
Identifiers (n=41)				
R^2	.20	.35	.24	.14
F	0.74	1.60	0.95	0.50
Combined (n=82)				
R^2	.14	.23	.05	.11
F	1.13	2.14*	0.41	0.89

* $p<.05$

Table 8.

Summary of "best" equations from backward stepping multiple regression analyses for each of the two processor groups.

R^2 and F values	Verbal closure	Visual memory	Perceptual speed	Spatial orientation
		Cognitive tasks		
		Localizers (n=41)		
R^2	.30	.34	.28	.37
F	2.39*	2.40*	2.72*	2.36*
		Identifiers (n=41)		
R^2	---	.35	.21	---
F	---	2.49*	3.35*	---

* $p < .05$

Note: Entries are omitted for nonsignificant equations.

variables in the model, was the mean RT for correct responses on the letter location task, $t(33) = -2.58$, $p=.01$.

For identifiers' visual memory ability, the equation included percent correct on the letter identity task at 150 ms, 300 ms, and 450 ms ISI and percent correct on the letter location task at 0 ms, 150 ms, and 450 ms ISI. It also included mean RT for correct responses on the letter location task. These seven variables accounted for approximately 35 percent of the variance in identifiers' visual memory ability. The most significant predictor variable, given these seven in the model, was percent correct on the letter location task at 0 ms ISI, $t(33) = 2.01$, $p=.05$.

For localizers' perceptual speed ability, the equation included percent correct on the letter identity task at 150 ms and 450 ms ISI and percent correct on the letter location task at 0 ms, 150 ms, and 450 ms ISI. These five variables accounted for 28 percent of the variance in localizers' perceptual speed ability with percent correct on the letter location task at 0 ms ISI contributing most significantly, $t(35) = -3.05$, $p<.01$.

For identifiers' perceptual speed ability, the equation included percent correct on the letter identity task at 300 ms ISI and percent correct on the letter location task at 0 ms and 150 ms ISI. These three variables explained 21 percent of the variance in identifiers' perceptual speed ability with percent correct on the letter location task at 0 ms ISI contributing most significantly, $t(37) = 2.39$, $p<.05$. While the same variable contributes significantly for both localizers and identifiers, the associated slope coefficient was -0.61 for localizers and 0.40 for identifiers.

For localizers' spatial orientation ability, the resulting equation included percent correct on the letter identity task at both 150 ms and 450 ms ISI, percent correct on the letter location task at all four ISIs, and mean RT for correct responses on both the letter identity and letter location tasks. These eight variables accounted for 37 percent of the variance in localizers' spatial orientation ability with mean RT on the letter location task contributing most significantly, $t(32) = -2.88$, $p=.01$. The backward stepping procedure failed to produce a significant regression model for the identifiers' spatial orientation ability indicating that iconic processing ability is a poor predictor of their spatial orientation ability.

While the results of the backward stepping multiple regression analyses suggest a weak relationship between iconic processing ability and each of the cognitive abilities measured in this investigation, especially for localizers, the magnitudes of the R^2 values are a source of concern. On average, just over 30 percent of the variance in cognitive ability is explained by variation in iconic processing ability. This brings into question the true nature of the relationship between iconic processing ability and cognitive ability as measured in the present investigation.

In order to determine the nature of the dependency between these two sets of scores and as a means of exploring the structure of the relationships among these variables further, a factor analysis was performed on all 16 variables combined. Thus, a total of 16 factors was extracted. The initial extraction method employed was principal component analysis, and a varimax rotation was performed on the resulting factor loadings matrix.

The principal component analysis resulted in the extraction of six factors with eigenvalues greater than 1.00 (Harman, 1967). These six factors accounted for 70.26 percent of the variance in the data space. The unrotated factor loadings for each of the six factors are presented in Table 9. These factor loadings suggest Factor 1 represents mean RT on the iconic processing tasks and performance on the letter location task is linked to speed of responding. Factor 2 represents performance on the letter location task and suggests performance on the spatial orientation task shares similar characteristics to a lesser extent. Factor 3 represents performance on all the cognitive tasks, but particularly on the verbal closure and the perceptual speed tasks. While Factor 4 represents performance on the letter identity task, it is difficult to decern what construct underlies the bipolar nature of the loadings at the different ISIs. Perhaps some strategy shift occurs as information is lost from iconic storage which momentarily compensates for the loss of information at 300 ms, but which is ineffective at 450 ms.

Factor 5 might offer some clue to the interpretation of Factor 4 in that it correlates highest with performance on the visual memory task and somewhat less with performance on the letter identity task at 300 ms suggesting that visual memory ability may become important at the longer ISIs. Factor 6 correlates highly with performance on the letter identity task at 0 ms ISI, and it also correlates moderately with performance on the same task at 150 ms ISI. Notice, however, that the structure of the later factors is somewhat more complex than the earlier ones which makes interpretation difficult.

Varimax rotation helped to simplify the structure of the factors, and Table 10 presents the sorted rotated factor loadings. Factor loadings less .25 have been set to .00 to aid

Table 9.

Unrotated factor loading matrix for principal components.

Original variables	Factor 1	2	3	4	5	6
Identity 0 ms ISI	-.15	-.18	-.01	-.52	-.10	.72
Identity 150 ms ISI	.07	-.14	.13	.58	.09	.50
Identity 300 ms ISI	.01	-.48	.30	-.41	.42	.15
Identity 450 ms ISI	.09	-.08	.35	.67	.01	.27
Location 0 ms ISI	.42	.57	-.14	.05	.31	.02
Location 150 ms ISI	.31	.64	-.12	-.04	.27	-.01
Location 300 ms ISI	.47	.57	-.12	-.05	-.23	.18
Location 450 ms ISI	.25	.60	-.26	-.17	-.11	.36
Verbal closure	-.10	.34	.59	-.13	-.46	-.12
Visual memory	-.12	.28	.50	-.14	.68	-.02
Perceptual speed	-.07	.28	.57	-.17	-.24	-.09
Spatial orientation	-.08	.50	.38	.10	.06	.03
Identity mean RT correct	.84	-.27	.27	-.10	-.14	.05
Identity mean RT incorrect	.85	-.27	.29	-.07	-.09	.02
Location mean RT correct	.84	-.20	-.14	-.04	.10	-.15
Location mean RT incorrect	.92	-.11	.00	.02	.03	-.08

Table 10.

Sorted rotated factor loading matrix.

Original variables	Factor 1	2	3	4	5	6
Identity mean RT incorrect	.94	.00	.00	.00	.00	.00
Identity mean RT correct	.93	.00	.00	.00	.00	.00
Location mean RT incorrect	.88	.00	.00	.00	.00	.00
Location mean RT correct	.82	.00	-.29	.00	.00	.00
Location 450 ms ISI	.00	.75	.00	.00	.00	.26
Location 150 ms ISI	.00	.72	.00	.00	.00	.00
Location 0 ms ISI	.00	.71	.00	.00	.00	.00
Location 300 ms ISI	.00	.70	.00	.00	.00	.00
Verbal closure	.00	.00	.84	.00	.00	.00
Perceptual speed	.00	.00	.70	.00	.00	.00
Identity 450 ms ISI	.00	.00	.00	.79	.00	.00
Identity 150 ms ISI	.00	.00	.00	.78	.00	.00
Visual memory	.00	.00	.00	.00	.86	.00
Identity 300 ms ISI	.00	-.39	.00	.00	.57	.39
Identity 0 ms ISI	.00	.00	.00	.00	.00	.91
Spatial orientation	.00	.30	.45	.00	.00	.00

Note: Loadings less than .25 have been set to zero.

in examining the structure of each factor. As can be seen, the structure of the first factor remained virtually the same; however, the letter location task scores no longer correlate, making it purely a RT factor. The correlations between the letter location task scores and Factor 2 increased, and the contribution from the spatial orientation task was reduced somewhat, but was still present. This suggests that Factor 2 is a visuo-spatial information manipulation factor. The negative loading of the letter identity task at 300 ms is not inconsistent with this interpretation.

Factor 3 (the cognitive task factor) no longer correlates with the visual memory task. The new loadings suggest that it is essentially a visual scanning factor given that verbal closure and perceptual speed load heavily and spatial orientation loads less strongly. Notice the negative loading of the mean RT for correct responses on the letter location task indicating rapid responses on that task are associated with high scores on the visual scanning dimension. The letter identity task seems to be quite complex because the next three factors each receive contributions to their structure from it.

Factor 4 is solely a letter identity task factor given that only letter identity task performance at 150 ms and 450 ms ISI load on it. Factor 5 is still the visual memory factor, although the correlation with performance on the letter identity task at 300 ms ISI still is present. Factor 6 still represents performance on the identity task at 0 ms ISI. Apparently, a relationship does exist between certain aspects of iconic processing and more molar levels of cognitive function. Unfortunately, it is difficult to determine what effect group membership would have on the factor structure because factor analysis on each of the groups separately would leave too few subjects for reliable interpretation (Harman, 1967), and none of the variables included in the analysis can represent group membership by itself.

A solution to this problem lies in the inclusion of the difference score rather than the component scores which were involved in its derivation. Therefore, a second factor analysis was performed which included the four RT measures, the four cognitive task measures, and the difference score which was used to classify the subjects into groups.

Again, the method of initial extraction was principal component analysis, and a varimax rotation was performed on the resulting factor loadings matrix. There were now only nine variables in the analysis and, therefore, nine factors were extracted. The principal component analysis resulted in the extraction of three factors with eigenvalues greater than 1.00. These three factors accounted for 68.58 percent of the variance in the data space. Table 11 contains the unrotated factor loadings matrix. Factor 1 is again the RT factor, Factor 2 is the cognitive task factor, and Factor 3 correlates highly with the difference score, and to a lesser extent with the perceptual speed task and the spatial orientation task. Notice that the coefficients of the difference score and the perceptual speed task score are positive for Factor 3 while the spatial orientation task score coefficient is negative. This means large positive difference scores, associated with identifiers, are related to high scores on the perceptual speed task and low scores on the spatial orientation task.

Varimax rotation was performed next, and Table 12 presents the sorted rotated factor loadings matrix. Factor 1 remains the RT factor. The correlations between Factor 2 and the spatial orientation and visual memory tasks have been reduced considerably leaving the verbal closure and perceptual speed tasks to account for the majority of the variance explained by this factor. This suggests rotation has simplified Factor 2 into a visual scanning factor which is interesting given the weak negative correlation between this factor and the mean RT for correct responses on the letter location task.

Once again factor analysis implies that speed of responding in the letter location task is related to performance on cognitive tasks which have a visual scanning component. Finally, Factor 3 now correlates negatively with the difference score and positively with spatial orientation and visual memory task scores. Thus, rotation has emphasized the visuo-spatial information manipulation aspect of the cognitive test battery. Successful performance on these cognitive components is associated with large negative values on the difference score distribution which, in turn, are associated with classification as a localizer.

Conclusions

Even assuming that the reliability coefficient of the classification technique employed in this investigation would not increase if subjects were allowed to practice until asymtotic levels of performance were reached--an assumption which has been refuted by evidence presented above--the fact remains that subjects who have been classified in this manner exhibit significantly different levels of performance in the standard bar probe task. Previous research (Stephens, 1985) has shown retarded individuals exhibited a difference in performance between localizers and identifiers. The results of the present investigation have shown that this classification technique is generalizable to the nonretarded population as well.

Table 11.

Unrotated factor loading matrix for principal components using the iconic processing difference score.

Original variables	Factor 1	2	3
Identity mean RT correct	.89	.18	.23
Identity mean RT incorrect	.90	.19	.23
Location mean RT correct	.87	-.07	-.19
Location mean RT incorrect	.92	.09	-.15
Verbal closure	-.16	.69	.34
Visual memory	-.20	.51	-.18
Perceptual speed	-.13	.61	.43
Spatial orientation	-.19	.61	-.42
Iconic processing difference score	-.17	-.36	.66

Table 12.

Sorted rotated factor loading matrix using the iconic processing difference score.

Original variables	Factor 1	2	3
Identity mean RT incorrect	.93	.00	.00
Identity mean RT correct	.92	.00	.00
Location mean RT incorrect	.91	.00	.00
Location mean RT correct	.84	-.32	.00
Verbal closure	.00	.77	.00
Perceptual speed	.00	.76	.00
Iconic processing difference score	.00	.00	-.73
Spatial orientation	.00	.00	.72
Visual memory	.00	.32	.47

Note: Loadings less than .25 have been set to zero.

Furthermore, while the results of the present investigation indicate the existence of a relationship between iconic processing ability and more molar cognitive abilities, they also point out the complex nature of this relationship. Apparently, individual differences in the ability to perform such complex cognitive functions as visual search, memorization of visual input, and manipulation of visuo-spatial information could be, and probably are, the result of differences in those individuals' ability to perform a myriad of simpler subprocesses which converge to make up these more complex functions. The ability to process spatial location and identity information from a tachistoscopically presented display is only one example of such subprocesses, but it is a fundamental one. Considering the number of possible subprocesses involved in these complex cognitive skills, the magnitudes of the R^2 values observed in the the multiple regression analyses are not surprising. If the goal of the present investigation had been the explanation of the structure of the cognitive abilities measured, then identification and measurement of other subprocesses would have been included in the design. Instead, the goal was to establish the existence of a relationship between the subprocesses of localization and identification and cognitive ability, and this goal has been accomplished.

Interestingly, this accomplishment raises more questions than it answers. The present evidence is correlational in nature. What, if any, are the causal relationships? Furthermore, are the differences between individuals in their abilities to process spatial location and identity information a function of structural differences among the individuals or of strategy selection differences? While having speculated about the possibility of strategy selection differences, a definitive answer requires additional research. The shift of the difference score distributions in Experiment 1 toward the negative end during the second administration of the iconic processing tasks suggests these are not rigid structural properties. However, an experiment which involved the repeated administration of the processing tasks over several days until asymtotic levels of performance were reached would address more fully this question. In addition, subjects could be asked for their insights into what aspects of their behavior they consider to be important for successful performance on the iconic processing tasks. Then, the influence of instructions to perform the tasks in a specific way could be determined. If performance on the tasks was amenable to instruction, then the argument for the existence of a strategy selection difference would be strengthened.

Questions also arise about the existence of further relationships between iconic processing differences and cognitive abilities not measured in this investigation. How would different aspects of short-term memory ability be affected by iconic processing differences? For example, while localizers performed better than identifiers (admittedly not significantly so) on a task involving the short-term retention of the spatial arrangement of a street map, would the same be true for a task which involved the short-term retention of unfamiliar abstract shapes? What is the precise nature of the relationship between location and identity information processing and visual memory and spatial orientation abilities? Furthermore, is the relationship between iconic processing ability and cognitive ability the same for retarded individuals as it is for the nonretarded? These questions only begin to explore what promises to be a productive area for future research.

References

Appelman, I. B. 1980. Partial report and other sampling procedures overestimate the duration of iconic memory. American journal of psychology. 93: 79-97.

Averbach, E., and Coriell, A. S. 1961. Short-term memory in vision. Bell system technical journal. 40: 309-328.

Borkon, M. J. 1983. Practice effects and performance differences between retarded and nonretarded adults in central backward masking. Doctoral dissertation, University of Alabama, Tuscaloosa.

Butler, B. 1975. Selective attention and target search with brief visual displays. Quarterly journal of experimental psychology. 27: 467-477.

Butler, B. 1980a. Selective attention and stimulus localization in visual perception. Canadian journal of psychology. 34: 119-133.

Butler, B. 1980b. The category effect in visual search: Identification versus localization factors. Canadian journal of psychology. 34: 238-247.

Butler, B. 1981. Identification and localization in tachistoscopic recognition: The effects of data- and resource-limitations. Canadian journal of psychology. 35: 36-51.

Chow, S. L. 1986. Iconic memory, location information, and partial report. Journal of experimental psychology: Human perception and performance. 12(4): 455-465.

Clark, H. H., and Chase, W. G. 1972. On the process of comparing sentences to pictures. Cognitive psychology. 3: 472-517.

Coltheart, C., Lea, C. D., and Thompson, K. 1974. In defence of iconic memory. Quarterly journal of experimental psychology. 26: 633-641.

Cooper, L. A. 1976. Individual differences in visual comparison. Perception and psychophysics. 19(5): 433-444.

Cooper, L. A. 1982. Strategies for visual comparison and representation: Individual differences. In R. J. Sternberg (Ed.), Advances in the psychology of human intelligence (Vol. 1). Hillsdale, New Jersey: Erlbaum.

Cooper, L. A., and Mumaw, R. J. 1985. Spatial aptitude. In R. F. Dillon (Ed.), Individual differences in cognition (Vol. 2). New York: Academic Press.

Dick, A. O. 1969. Relations between the sensory register and short-term storage in tachistoscopic recognition. Journal of experimental psychology. 82: 279-284.

Dick, A. O. 1974. Iconic memory and its relation to perceptual processing and other memory mechanisms. Perception and psychophysics. 16: 575-596.

Doost, R., and Turvey, M. T. 1971. Iconic memory and central processing capacity. Perception and psychophysics. 9: 269-274.

Egan, D. E. 1978. Characterizing spatial ability: Different mental processes reflected in accuracy and latency scores. Pensacola, Florida: Naval Aerospace Medical Research Laboratory. Research Report No. 1224.

Ekstrom, R. B., French, J. W., Harman, H. H., and Dermen, D. 1976. Kit of factor-referenced cognitive tests 1976. Princeton, NJ: Educational Testing Service.

Eriksen, C. W., and Collins, J. F. 1969. Temporal course of selective attention. Journal of experimental psychology. 80: 254-261.

Goldberg, R. A., Schwartz, S., and Stewart, M. 1977. Individual differences in cognitive processes. Journal of educational psychology. 69(1): 9-14.

Harman, H. H. 1967. Modern factor analysis (2nd ed.). Chicago: University of Chicago Press.

Holding, D. H. 1975a. Doubts about iconic memory: A reply to Coltheart, Lea, and Thompson. Quarterly journal of psychology. 27: 507-509.

Holding, D. H. 1975b. Sensory storage reconsidered. Memory and cognition. 3: 31-41.

Hunt, E., Frost, N., and Lunneborg, C. 1973. Individual differences in cognition: A new approach to intelligence. In G. Bower (Ed.), The psychology of learning and motivation (Vol. 7). New York: Academic Press.

Hunt, E., Lunneborg, C., and Lewis, J. 1975. What does it mean to be high verbal? Cognitive psychology. 7: 194-227.

Irwin, D. E., and Yeomans, J. M. 1986. Sensory registration and informational persistence. Journal of experimental psychology: Human perception and performance. 12(3): 343-360.

Jones, M. B. 1980. Stabilization and task definition in a performance battery. New Orleans, LA: Naval Biodynamics Laboratory. Monograph No. NBDL-M001.

Kail, R. V., and Siegel, A. W. 1977. Sex differences in retention of verbal and spatial characteristics of stimuli. Journal of experimental psychology. 23: 341-347.

MacLeod, C. M., Hunt, E. B., and Mathews, N. N. 1978. Individual differences in the verification of sentence-picture relationships. Journal of verbal learning and verbal behavior. 17: 493-508.

Mason, M. 1980. Reading ability and the encoding of item and location information. Journal of experimental psychology: Human perception and performance. 6: 89-98.

Mewhort, D. J. K., and Campbell, A. J. 1980. The rate of word integration and the overprinting paradigm. Memory and cognition. 8: 15-25.

Mewhort, D. J. K., Campbell, A. J., Marchetti, F. M., and Campbell, J. I. D. 1981. Identification, localization, and "iconic memory": An evaluation of the bar-probe task. Memory and cognition. 9: 50-67.

Mewhort, D. J. K., and Leppmann, K. P. 1985. Information persistence: Testing spatial and identity information with a voice probe. Psychological research. 47: 51-58.

Neisser, U. 1967. Cognitive psychology. Englewood Cliffs, NJ: Prentice-Hall.

Pellegrino, J. W., and Glaser, R. 1979. Cognitive correlates and components in the analysis of individual differences. In R. J. Sternberg and D. K. Detterman (Eds.), Human intelligence: Perspectives on its theory and measurement. Norwood, New Jersey: Ablex Publication Corporation.

Runcie, D., and Graham, J. S. (in press). Loss of spatial and identity information from iconic memory in retarded and nonretarded subjects. American journal of mental deficiency.

Sagi, D. and Julesz, B. 1985. "Where" and "what" in vision. Science. 228: 1217-1219.

Sakitt, B. 1975. Locus of short-term visual storage. Science. 190: 1318-1319.

Sakitt, B. 1976. Iconic memory. Psychological review. 83: 257-276.

Schiller, P. H. 1965. Monoptic and dichoptic visual masking by patterns and flashes. Journal of experimental psychology. 69: 193-199.

Schneider, G. E. 1969. Two visual systems. Science. 163: 895-902.

Sperling, G. 1960. The information available in brief visual presentations. Psychological monographs. 74: 11, Whole No. 498.

Smith, M. C., and Ramunas, S. 1971. The elimination of visual field effects by use of a single report technique: Evidence for order-of-report artifact. Journal of experimental psychology. 87: 23-28.

Stephens, R. L. 1985. The rate of loss of spatial location and identity information from iconic storage in borderline, retarded, and nonretarded individuals. Master's thesis, University of Alabama, Tuscaloosa.

Sternberg, R. J. 1977. Intelligence, information processing, and analogical reasoning: The componential analysis of human abilities. Hillsdale, New Jersey: Erlbaum.

Sternberg, R. J. 1979. Intelligence research at the interface between differential and cognitive psychology: Prospects and proposals. In R. J. Sternberg and D. K. Detterman (Eds.), Human intelligence: Perspectives on its theory and measurement. Norwood, New Jersey: Ablex Publication Corporation.

Sternberg, R. J., and Weil, E. M. 1980. An aptitude x strategy interaction in linear syllogistic reasoning. Journal of educational psychology. 62: 226-236.

Townsend, V. M. 1973. Loss of spatial and identity information following tachistoscopic exposure. Journal of experimental psychology. 98: 113-118.

Turvey, M. T. 1967. Repetition and the preperceptual information store. Journal of experimental psychology. 74: 289-293.

Turvey, M. T. 1973. On peripheral and central processes in vision: Inferences from an information-processing analysis of masking with patterned stimuli. Psychological review. 80: 1-52.

von Wright, J. M. 1968. Selection in visual immediate memory. Quarterly journal of experimental psychology. 20: 62-68.

von Wright, J. M. 1970. On selection in visual immediate memory. Acta psychologia. 33: 280-292.

Ward, T. B., and Ross, L. E. 1977. Laterality differences and practice effects under central backward masking conditions. Memory and cognition. 5: 221-226.

Appendix A

List of abbreviations

ISI . . . . interstimulus interval

cm . . . . centimeters

deg . . . . degrees of arc

min . . . . minutes of arc

ms . . . . milliseconds

RT . . . . reaction time