The Effectiveness of Mental Rotation and Visual Scan Tasks In Assessing Individual Differences

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Abstract

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The long-term goal of this research is the development of a cognitive test for the early detection of premorbidity in individuals at-risk for Huntington's disease. Any test for this purpose must be well standardized on a group of normal, untrained subjects. It is the immediate goal of this study to describe individual differences in performance in naive normal subjects in a task involving spatial abilities, namely, mental rotation (the Shepard and Metzler (1971) paradigm), and in a task involving selective attention; namely, visual scan (Neisser, 1963). Performance was assessed across apriori defined increasingly difficult conditions within each paradigm for each subject in order to partial out nonrelevant differences in performance. Because comparisons of the normal group will eventually be made with a neurologic group, subjects in this study were administered a neuropsychological test battery. While 70% of the subjects had no trouble rotating letters, only 57% were able to adequately perform mental rotation on the 3D figures. Fewer subjects still (35%) showed mental rotation when one of the 3D figures had to be held in memory. Systematic scanning was found both when lists contained 4 letters per row and 8 letters per row,

and especially when the task demanded search for a row in which a critical letter was missing (over 75% of the subjects scanned systematically in "absent" lists). Furthermore, with respect to individual differences, consistency in performance within subjects was maintained for many individuals across task difficulty. Furthermore, it turned out that how well a subject did across the tasks within each paradigm was related to his joint Vision subtest score plus Memory subtest score on the Luria-Nebraska Neuropsychological Test Battery. In particular, the relationship between the number of tasks in the mental rotation paradigm completed to criterion and the Luria subtest score was significant ($X^2 = 14.261$, df = 3; $p \angle .003$). Our attempt to demonstrate an association between the visual scan task and the Luria subtest scores unfortunately only yielded inconclusive findings. These results at least showed that we were on the right track and gave us confidence to proceed with our research plan.

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"....Huntington's disease has been called "diabolical" because it affects both mind and body. At first a patient may merely seem to be clumsy, but movements later become uncontrollable. In addition, the patient may become forgetful and irritable, or withdrawn, until finally memory and reasoning are gone....."

(The Gazette, Thursday, August 16th, 1979)

Huntington's disease (HD) is an inherited neurological disorder in which a mutant gene is responsible for progressive degeneration within the basal ganglia-extrapyramidal motor system and within the cerebral cortex, most prominently in the frontal regions (Barbeau, 1973; Earle, 1973; Klintworth, 1973; Forno and José, 1973). The disease is characterized by abnormal, exaggerated, involuntary movements, or chorea; by a serious affective breakdown often involving suicidal tendencies; by mental deterioration referred to as dementia; and finally, by early death. Reports have it that the mean age at death is between 52-54 years while the average duration of the illness is around 15 years (Myrianthopoulos, 1966; James, Mefferd and Kimbell, 1969). The disease has an autosomal dominant mode of genetic transmission signifying that each offspring of an HD gene-carrier has a 50-50 chance of inheriting the disorder. Hence all offspring are considered to be "at-risk" for the disease. Inheritance is the main culprit of the disease prevalence since the mutation rate to this atypical state is extremely low (Myrianthopoulos, 1966; Paulson, 1976). In his original paper on HD in 1872, George

Huntington described the inheritance laws of the disorder in this way: ".... When either or both parents have shown manifestations of the disease.... one or more of the offspring almost invariably suffer from the disease, if they live to adult age; but if by chance these children go through life without it, the thread is broken and the grandchildren and great-grandchildren of the original shakers may rest assured that they are free from the disease... Unstable and whimsical as the disease may be in other respects, in this it is firm, it never skips a generation to manifest itself in another....." (Huntington, 1872; cited in Barbeau, Chase, and Paulson, 1973).

Another major characteristic of the disease is that the symptoms only become manifest around middle age. Some reports give 35 years as the average age of onset of clinical symptoms (Bell, 1934; Panse, 1942; Reed and Chandler, 1955) and some give 44 years of age (Wendt, 1959; Lyle and Gottesman, 1977) with a standard deviation of 12 years. On the basis of these statistics, the period of greatest risk can be calculated to range from around 23-32 years of age to approximately 47-56 years of age. The delay in symptom manifestation until some time around or after the child-bearing years causes the question of uncertain genetic transmission of the disease to hand over the head of every at-risk person.

Any variance in the manifestations of the disease, such as in age of onset, rate of progression, pattern of symptom onset, types and severity of symptoms, may all be accounted for by the different phenotypic expressions of the gene (Goodman, Ashkenazi, Adam, and Greenfield, 1973). It also accounts for the two variant and somewhat less prevalent forms of HD - the Westphal form found mostly in young adult cases of HD (average age of 22.5 years) and characterized by rigidity and akinesia, and dementia; and the childhood form also characterized by rigidity and akinesia as well as by tremor and seizures (Myrianthopoulos, 1969).

At present there is no remissive therapy. While ameliorative treatment of the chorea is still in the experimental stages, it has been found that the affective symptoms respond well to the familiar anti-schizophrenic and anti-depressant drugs (Ringel, Guthrie, and Klawans, 1973; Barbeau, 1973; James, Mefferd, and Kimbell, 1969; Chase, 1976; Whittier, 1969; Waszczak and Walters, 1979; Perry, Wright, Hanson, and MacLeod, 1979).

A recent report (Saturday, October 7th, 1979) in the Montreal newspaper, the Gazette, cited 25,000 as the estimated number of people in North America afflicted with HD and another approximately 75,000 are estimated to be at-risk (The Gazette, August 16th, 1979).

Despite the current lack of treatment, early detection of the gene carriers from among the at-risk individuals is not without benefit. Being labelled "at-risk" for the major portion of one's life certainly has handicapping consequences, which, if a means for early prediction of diagnostic outcome could be devised, could be prevented. Prediction of premorbidity would also have some positive import. For example, the reality of the fact may lead to the instigation of direct and 'real' programs for genetic guidance, psychological support, and financial security. Furthermore, because the onset of HD can be so insidious and can undermine behavior in such a variety of ways, at-risk individuals are all too often, in the early phases of the disease, misdiagnosed as schizophrenic, alcoholic, or brain-damaged (Bruyn, 1973; Buxton, 1976). Some measure of assurance of the presence of the HD gene before the actual appearance of the characteristic symptoms could guard against early diagnostic confusions. James, Mefferd, and Kimbell (1969) point out that predictive assessment would be extremely important in the case that should a remissive treatment become available, it would be crucial to begin selective therapy on premorbids before further brain damage can take place. From a strictly experimental perspective, early detection research is one way to get a closer view of the source and pattern of the degenerative process.

Because facts concerning the action of the HD gene are not yet available, early presymptomatic identification necessarily depends upon the validity of a very important assumption. The rationale for this premise is that since the disease is progressive, it may be understood that neurological changes begin to occur in the brains of HD gene carriers long before clinical symptoms become overtly manifest. In other words, it is assumed that the disease does have an insidious onset and does not result from a sudden triggering of the gene action. The above statements are not unwarranted in the light of some as yet unvalidated studies with at-risk individuals. On measures such as eye movements (Petit and Milbled, 1973), motor control (Falek, 1969; Falek and Granville, 1962; Myers and Falek, 1979; Petajan, Jarcho, and Thurman, 1979), L-dopa loading (Klawans, Paulson, Ringel, and Barbeau, 1973), dermatography (Koepper, Whittier, and Korenyi, 1969) electromyography (Baro, 1973), as well as in psychological tests (Goodman, Hall, Terango, Perrine, and Roberts, 1966; Baro, 1973), differences in the at-risk samples are evident. Two validated studies (Lyle and Gottesman, 1977; and Lyle and Quast, 1976) indicate furthermore that psychometric indices can be predictive. At the present time, physiological, genetic, and psychological means of early detection are being vigorously researched (Pericak-Vance, Conneally, Merritt, Roos, Vance, Yu, Norton, and Antel, 1979; Butterfield and Markesbery, 1979; Neophytides, Di Chiro, Barron, and Chase, 1979; Bala Manyam, Hare, Katz, and Glaeser, 1978).

Chapter 1

Introduction

The development of a means of early detection of HD gene carriers via psychological or cognitive parameters of brain function is the long-term goal of this research. There are, however, a number of intermediary stages of investigation that need to be completed first. The first stage is to try and describe or define as accurately as possible the pattern and nature of the cognitive degeneration in HD individuals and those at-risk. From here, the second step is to select a test which will be the most efficient and precise in assessing the impairments characteristic of HD. This test must then be standardized on normal subjects so that test outcomes can be said with confidence to be consistent despite individual differences. This analysis is particularly important because it will provide information concerning the sublety and strength of the resultant test measures. It is with these preliminary stages of early identification research that the present study is concerned. Future papers hope to report on the subsequent phases of the project, namely, the testing of at-risk individuals and HD patients as well as numerous control groups, and validation through a long-term follow-up report. Controls, such as Parkinson's disease patients, Korsakoff's syndrome patients, schizophrenics, and patients with related basal ganglia disorders such as Alzheimer's disease are necessary to define the selectivity of the test. The expected results within the at-risk group is ideally a bimodal distribution of test measures upon which the follow-up study on the at-risk individuals, at some time in the future when diagnostic outcomes can be determined (10-20 years hence), will be based. These data will then provide information helping to specify the area of brain function and/or mechanism(s) of cognitive processing which can reasonably be said to be either fully or partially responsible for the abnormalities observed.

To begin with, an examination of the trends and recent findings on the nature of the dementia or more properly the pre-dementia state of individuals with HD and those at-risk is presented.

Early clinical and anecdotal reports on HD stressed the progressive nature of the disease that works on the integrity of both the mind and body. Huntington (1872) described it as "...increasing by degrees and often occupying years in its development, until the hapless sufferer is but a quivering wreck of his former self." Waters in a paper in 1841 said: "This derangement of muscular action is by no means uniform; in some it exists to a greater in others to a less extent, but in all cases it gradually induces a state of more or less perfect dementia." Through this early emphasis of the progression to complete deterioration, the term 'dementia' - the "complete breakdown in intellect and personality" (Miller, 1977, p. 6-7) became identified with the HD syndrome. Having become associated with dementia, HD found itself classified as one of the presenile dementias along with other progressive dementing disorders such as Alzheimer's disease and Pick's disease (Boll, Heaton, and Reitan, 1974). Categorized as a 'presenile' syndrome, it became of interest to find out whether the dementia of HD was similar (perhaps not in degree) to the senility of old age. In a recent study on this issue, Aminoff, Marshall, Smith, and Wyke (1975) compared the performance of 11 HD patients with data from a previously published set of scale scores of a group of normal aged subjects on the Wechsler Adult Intelligence Scale (WAIS). There turned out to be a high positive correlation between the pattern of mean WAIS scores of the choreic subjects and those of the aged controls over the various subtests of the WAIS with the HD group obtaining lower scores on the whole than the aged group. In addition, they also specifically tested the immediate memory of 10 healthy but elderly subjects and the same HD subjects using the Corsi's block tapping test which is a nonverbal analogue of the digit span test; digit span forward; and immediate recall of objects and drawings. They found a significant correlation between IQ and composite memory scores for both groups indicating that memory was not specifically more impaired in HD. In general, they concluded from their data that though the HD group did worse on all tests than the aged group, the overall decline in intellectual performance seen in aged subjects was indeed qualitatively similar to the pattern of impairment found in HD patients.

It soon became apparent as research on the presenile syndromes progressed that each one had its own distinguishing characteristics, giving diagnosis a boon. Reports (Aminoff, Marshall, Smith, and Wyke, 1975; McHugh and Folstein, 1975) stated that in all of the presenile dementias (Alzheimer's disease, Pick's disease, Jakob-Creutzfeldt's disease...) except for HD, the dementia is either accompanied or preceeded by focal neurological signs of specific cortical brain-damage such as agnosia, apraxia, and dysphasia. Furthermore, it was pointed out that HD patients are unique among dementia victims in that they seem always to remain oriented to time, place, and person to the extent even of retaining an uncanny insight into their own condition (Bruyn, 1968; Aminoff, Marshall, Smith, and Wyke, 1975). Because of the distinctiveness of HD, particularly the absence of specific cortical pathology, McHugh and Folstein (1975) believe it advantageous to stress the notion that HD is more of a "subcortical dementia syndrome" than a "cortical dementia syndrome" as in the case of the other progressive dementias.

Further delineation of the nature of the intellectual decline in progressive neurological syndromes was achieved when researchers began administering neuropsychological test batteries which are designed to evaluate the organic integrity of brain functions (Boll, Heaton, and Reitan, 1974; Norton, 1975). Boll, Heaton, and Reitan (1974) were the first to follow suit with HD. The study was carefully designed to cover the main areas of "human adaptive functioning" in order to maximize the possibility of detecting the presence and absence of focal deficits. It was hoped that the results would provide a pattern or profile of neuropsychological performance unique to HD. They tested 11 HD patients and 11 normal controls matched for age (HD = 46.9 years and NC = 46.5 years) and education (HD = 12.2 years and NC = 12.1 years) on the Wechsler-Bellevue Intelligence Scale, the Halstead-Reitan Neuropsychological Test Battery, and the Trail Making Test. Together these tests covered 10 categories of cognitive functioning, namely, 1) motor 2) motor plus problem-solving component 3) problem-solving plus some motoric component 4) verbal information storage and retrieval 5) simple and complex auditory perception 6) memory and alertness to incidental stimuli 7) attention and concentration 8) visual and auditory alertness plus a problem-solving element 9) concept formation and flexible thinking 10) overall summary measures of IQ (Verbal IQ, Performance IQ, and Full IQ as well as a score on the Halstead Impairment Index). It was found that within each and every category of functioning, the HD group performed significantly less adequately than the normal controls. As for individual test scores, the difference between the two groups reached the .001 level for 18 out of the 28 tests, the .005 level for 8 of the tests, and the .02 level for the remaining 2. Furthermore, these last two subtest scores, namely, the Information and Vocabulary subtests, were the only ones to fall within the average range.

While the HD patients did poorly on all subtests of the Wechsler in comparison to the normal group, their summary scores surprisingly enough all fell within the normal range (Full Scale IQ = 92.81, Verbal = 95.54, Performance = 92.90). This finding is somewhat disconcerting especially in the light of the formal description of HD in which dementia figures as one of the main characteristics of the disease. The above data indicates that these HD patients, despite the fact that they were already well into their progressive disease at the time of testing (about 5.62 years since diagnosis), are not by definition demented, and hence their poor performance on the Wechsler subtests can not be attributed to a total cognitive breakdown or deterioration (namely, to dementia). This is not to say that the HD patients are neurologically normal since the results from the Halstead Neuropsychological Impairment Index clearly label them as being organically damaged. What then causes the poor performance in all areas of cognitive functioning tested? Seeing as a dementia etiology must be discarded, what kind of deficit would result in this type of profile?

It is possible to generate two experimental hypotheses concerning the nature, and hence, assessment and early identification of the cognitive impairment in HD.

1) Diffuse neurological damage has reduced the overall efficiency of brain functioning. The important implication is that from the onset of the initial neurological deterioration the effect on cognitive functioning is going to be global because of the diffuse, non-specific nature of the degeneration. In other words, the pattern of progressive cognitive degeneration

can not be described as being a cumulative selective breakdown. It would also follow from this that the best measure of the impairment would be provided by neuropsychological test batteries or by psychometric indices.

In support of the validity of the global deterioration hypothesis and its usefulness in early detection is a follow-up study reported by Lyle and Gottesman (1977). It shows that the premorbid at-risk subjects' psychometric and neuropsychological performance on tests administered 15-20 years earlier already differentiated them from the still-normal subgroup of the at-risk subject population. Even when the premorbid group was divided into early and late onset sub-groups (within 2 years of original testing and within 6-18 years, respectively) both subgroups' scores on the WAIS, the Bender Visual Motor Gestalt Test (which involves the copying and reproducing from memory of simple designs), and the Shipley-Hartford Retreat Scale (which measures intelligence and has a correlation of .79 with the Wechsler) were significantly different at initial testing from the still-normal group. ..."The still-normal group performed significantly better ($p < .05$) than the premorbid group on all the 1950's intellectual measures. Except for the Shipley Verbal subtest, all differences were statistically significant at the .01 level or higher. For all 3 Wechsler IQ measures, the differences were significant at less than the .001 level"... The significance levels across the comparison groups for all of the tests is presented in Table 1. (Normal Verbal IQ = 103.6, Premorbid = 94.7; Normal Performance IQ

TABLE 1

Significance Levels for t Tests for Differences Between Groups

Comparison	Shipley-Hartford			Bender Recall	Wechsler		
	Verbal	Abstract	Total		VIQ	PIQ	FSIQ
Still normal vs. premorbid	.05	.01	.01	.01	.001	.001	.001
Still normal vs. late onset	—	.05	.05	.05	.01	.001	.01
Still normal vs. early onset	.05	.01	.01	.001	.01	.001	.001
Late onset vs. early onset	—	—	—	—	—	.10	—
Premorbid vs. affected when tested	—	—	—	—	—	.05	—
Late onset vs. affected when tested	—	—	—	—	—	.05	—
Early onset vs. affected when tested	—	—	—	—	—	—	—
Still normal vs. affected when tested	.05	.001	.001	.01	.01	.001	.001

Note: VIQ = Verbal IQ; PIQ = Performance IQ; and FS IQ = Full Scale IQ.

(Lyle and Gottesman, 1977, p. 1015)

TABLE 2

Prediction of Future Huntington's Disease Status of Huntington's Disease Offspring from Test Scores

Test	o/o hits[a]	o/o misses	o/o true negatives	o/o true positives	X^2
Shipley Verbal	63	37	73	41	.52
Shipley Abstractions	74	26	81	59	6.85 **
Shipley Total	72	28	82	55	6.51 *
Bender Recall	72	28	78	58	6.60 *
Wechsler Verbal IQ	72	28	81	55	10.37 **
Wechsler Performance IQ	72	28	78	48	5.07 *
Wechsler Full Scale IQ	69	31	79	52	6.75 **

Note: Yates's correction was used with chi-square.

[a] To be compared with 55o/o – 57o/o "hits" if test results were randomly distributed.

* $p < .05$.

** $p < .01$.

(Lyle and Gottesman, 1977, p. 1018)

= 106.2, Permorbid = 91.9, Normal Full Scale IQ = 105.1, Permorbid = 93.1) (Lyle and Gottesman, 1977). When the early onset group's scores were not included the differences were not as large but they were still significant (.05 for the Shipley, .05 for the Bender, .01 for the Verbal IQ and Full Scale IQ, and .001 on the Performance IQ). Furthermore, the late onset group's scores and the early onset group's scores were very similar, the former's being higher than the latter's but not significantly so. In fact, Lyle and Gottesman (1977) state: "In test performance the late onset group was closer to the affected when originally tested group than to the still-normal group." In brief, then, this means that the late onset individuals who were not to manifest outward symptoms of disease for an average of another 12.5 years from the time of original testing, already demonstrated a deficient test performance which was almost as bad as that shown by individuals already affected by the disease.

Calculation of the prediction statistics by Lyle and Gottesman (1977) yielded the following table of hit rates for the correct early detection of gene carriers (Table 2). For example, using the Full Scale IQ score correct predictions as to normalcy and premorbidity can be made 69 percent of the time. In particular, this score can yield 79 percent correct predictions of true negatives (predicted normal and still-normal) and 52 percent correct predictions of true positives (predicted premorbid and were premorbid). Such hit rates are indicative that the cognitive impairment in HD can be identified in advance of the clinical manifestation of the disease, that its development is indeed insidious. With respect to pre-symptomatic diagnosis these hit rates certainly don't inspire much confidence. It is evident that the use of psychometric tests as prediction tools can not be very efficient due to the variability found in IQ measures. Random non-HD-gene-related brain damage can also be expected to confound the outcome segregation of scores.

2) Specific neurological damage unique to HD has affected some basic mechanism in the 'assembly line' of the information-processing system causing the subsequent undermining of many explicit cognitive functions. If this hypothesis is correct then the implementation of information-processing paradigms borrowed from contemporary experimental cognitive psychology to probe the cognitive deficits in HD patients may result in the discovery of some specific impairment(s). Prediction instruments could then be custom-built and hence highly sensitive and selective to the HD-gene versus non-HD-gene distinction. Most of the studies following this new approach were first reported last November (1978) in San Diego, California, at the Second International Symposium on Huntington's Disease (to be published in Advances in Neurology, Volume 23, edited by Thomas N. Chase et al., Raven Press, New York, 1979). Thus far, only memory and some perceptual/attentional functions have received consideration yet it already seems apparent that identification of distinguishing dysfunctions in HD is possible and that furthermore some of these abnormalities may be detectable before symptom onset (Fedio, Cox, Neophytides, Canal-Frederick,

and Chase, 1979). Because these recent information-processing studies are not yet able to be validated, prediction hit rates from these measures can not be compared with the Lyle and Gottesman (1977) correct prediction percentages. Such a comparison will be the final test of the two experimental hypotheses. Before describing the tests used in the present study, the recent findings presented in San Diego will be briefly described since they influenced the selection of tasks used in this study.

It is clear from the nature of the theoretical paradigm under which these investigators are working, that the distinctions they will hopefully come up with from their careful probing and mapping of the information-processing system may be subtle and focal. This means that it is going to be very important to find ways to maximize measures of task-related variability across subject groups. For instance, one way to define the specific characteristics of a neurologic group is to compare it to another neurologic group which manifests similar impairments in order to reveal selective deficits which can distinguish the two. This general experimental strategy has been adopted by many investigators involved in HD research (Butters, Tarlow, Cermak, and Sax, 1976; Butters and Grady, 1977; Meudell, Butters and Montgomery, 1978; Oscar-Berman, Sax, and Opoliner, 1973). As to what specific processes to examine first, many investigators basically take a shotgun approach. For example, because HD patients and Korsakoff's patients both have quantitatively similar defects in STM (short-term memory) (Butters, Albert, and Sax, 1979), different experimental techniques have been challenged to try and make qualitative distinctions between these disorders. Using STM paradigms Meudell et al. (1978) have demonstrated the differential tendency of Korsakoff's patients to make prior item intrusions during list recall and for HD patients to make omission errors. Proactive interference is known to be the culprit in the amnesic disorder and hence probably rules out this explanation for the deficit found in HD, leaving inadequacies in rehearsal, encoding, and perhaps consolidation mechanisms in STM as the remaining possibilities. The Butters' et al. (1976) study pitted Korsakoff's patients, HD patients, and non-amnesic alcoholics as controls against distracted delays (0, 3, 9, and 18 seconds of counting backwards by two's) and against various degrees and conditions of interference in a STM task. While immediate recall in all groups was fine, increases in the retention interval resulted in decrements in recall performance for both the Korsakoff and HD groups. Interference, on the other hand, caused particular disruption within the Korsakoff group but not so in the HD group. Butters' et al. (1976) also assessed the ability of their subjects to recall words cued by semantic category as well as their ability to recognize previously presented words from a list of words containing various types of distractor words (semantic associates, homonyms, synonyms, and new words). The first manipulation revealed an inefficiency in the use of semantic organization as an aid to memory in both Korsakoff and HD patients. The latter task, false recognition, produced differential errors in the two groups which may either be process related or response bias related. In particular Korsakoff subjects made more semantic and homonym confusions whereas HD patients just generally made more omission errors. As the investigators said: "These findings show differences between Korsakoff's and HD but they don't provide any clear explanation for the HD impairments."

Caine, Ebert, and Weingartner (1977) probed into the issue of encoding strategies in memory. The experiment was designed to test subjects' use of internal organizational constructs involving contextual, categorical, and/or semantic "matrices" to facilitate retrieval. HD subjects were competent in performing a task requiring them to form categorical clusters indicating that their background semantic network was well-organized. However, when successful retention of items in the memory task demanded the use of these organizational-encoding strategies because of the contextual nature or sequencing of the items (cued recall, false recognition, serial-learning, selective remembrance, digits backwards), HD patients were unable to fulfill these demands and hence performed poorly.

Weingartner, Caine, and Ebert (1979) studied another type of encoding-influencing manipulation, namely, depth of processing. Experimental psychology tells us that elaborate processing of input results in more enduring memory traces. Certain kinds of information, like semantic information, necessarily involve elaborate processing whereas other kinds of information such as the visual and auditory features of a stimulus require less central processing, resulting in the observed differences in recall (Craik and Lockhart, 1972). In the case of HD, however, depth of processing is not reflected in the recall scores of different kinds of information. Hence processes involved in memory trace construction such as encoding strategies are implicated in this study to be impaired.

Oscar-Berman, Sax, and Opoliner (1973) worked with aphasic, Korsakoff, and HD patients using an information-processing paradigm called focussing. In this task the subject goes through a systematic hypothesis testing routine involving a win-stay/lose-shift strategy similar to that used in the game of "20 questions". The subject must eventually name the predetermined relevant stimulus cue in visually presented stimuli. Included in the test was a standard and a memory-aid condition in which the alternatives remained visible to the subject and were, furthermore, following the subject's choice, labelled as correct or incorrect. The task allowed investigators to assess attention to stimulus dimensions, ability to switch attentional focus following feedback information, as well as the importance of efficient memory in problem-solving. Normal controls and aphasics were indistinguishable on all measures recorded, while Korsakoff patients did the most poorly of all the groups. Not only did they demonstrate weak hypothesis testing behavior (win-stay/lose-shift), they also were unable to generate as many hypotheses as normals, that is, they tended to perseverate. HD patients, on the other hand, were proficient at hypothesizing, since they used the same number of hypotheses as did the normals but they made more errors, that is, arrived at the correct hypothesis less frequently. The memory component of the task did not seem to be the source of the trouble since all groups improved consistently from their standard level of performance under the memory-aid condition. It seems, therefore, that attentional switching and focussing may for some reason be inefficient in the HD group.

In general, the above results show that the HD memory deficit can be distinguished from that of Korsakoff's disease, though as yet, in the case of HD, they fail to provide a clue as to the particular source of difficulty. Any of the memory processes, encoding, retention and/or retrieval may be culpable. On the other hand, the poor memory evidence may in fact be reflecting distractibility or other attentional defects related to selective perception. Suggestion of attentional problems would be consistent with the Oscar-Berman et al. (1973) results as well as with evidence forwarded by Baro (1973). Baro found that HD patients tend to be "slow, fatigable, perseverative, distractible, and to make omissions" on clinical tests of attention such as the Grünbaum Test (consisting of a board on which are scrambled digits to be placed in the correct numerical order by the subject) and the Seguin Form Board (in which subjects must fit forms into the appropriate slot on a board without looking). Physical measures of attention such as electromyography of muscle tone (EMG) and visual search efficiency as recorded by infrared eye tracking techniques also reveal abnormalities in comparison to a normal control group. Furthermore, 7 out of 19 offspring of these HD patients also showed tendencies towards abnormality on these same psychological and physical tests.

Fedio, Cox, Neophytides, Canal-Frederick, and Chase (1979) offers some preliminary data on the as yet vague issue of perceptual/attentional dysfunction in HD. At-risk individuals were also tested in this study. A broad range of perceptual functions such as visual discrimination, spatial judgment, directionality, and perceptual-motor integration and memory was assessed by a composite battery of clinical tests. Included in the battery were the following: The Mosaic Comparisons Test which is a visual discrimination task involving complex random designs; Money's Road Map Test of Directional Sense in which subjects imagine travelling along a route to some goal point indicating as they go turns to the right and to the left - in addition, the second half of the route is reversed so that the subject must either spatially rotate himself or reverse his left-right decisions; the Rey-Osterrieth Complex Figures Test which has subjects copy and then reproduce from memory complex designs; and finally, a Stylus Maze task.

The results showed the HD group to be significantly impaired on all measures in comparison to the normal and at-risk subjects. The test profiles of the at-risk individuals were similar to that of the normal controls with the following exceptions. The overall score of the at-risk group on the Mosaic Comparisons Test was significantly poorer than the overall score for the normal group; more errors were made by the at-risk group on the reversed half of the Road Map Test than by the normals; and error scores on the Stylus Maze showed the group of at-risk subjects to be less efficient than the normal group.

An examination of a finer aspect of perception, namely, selective attention, was carried out in the same study with the help of experimental psychology paradigms. This series of tests was composed of a monaural and dichotic listening task, a dihaptic recognition task for three-dimensional forms, and a visual recognition-threshold task for simple words and for complex designs. In this latter task, the stimuli were presented in a tachistoscope and the stimulus duration incremented in 3 millisecond steps until recognition was attained (i.e., until the subject could either spell or read the word and could identify the correct design out of a possible six choices).

In this series of experimental tests, the HD patients performed badly. One outcome that should be pointed out is that in the visual task whereas normals and at-risk subjects find visual patterns easier to recognize than words, HD patients have greater difficulty with abstract patterns. This finding has implications for those on the look-out for clues as to specific deficits. In this series of tests, the at-risk group was not distinguishable from the normals.

This completes the overview of some of the research done thus far on the cognitive aspects of HD. To recapitulate a little, it has been suggested that the cognitive impairment suffered by HD individuals can be reflected in poor scores on neuropsychological tests such as the Halstead Battery (Boll, Heaton, and Reitan, 1974) and may be foreshadowed by IQ (WAIS) or psychometric scores (Shipley-Hartford) (Lyle and Gottesman, 1977). While subtest score profiles from neuropsychological tests don't seem to be able to provide clues as to the underlying focal deficits, information-processing techniques seem to be useful in probing the qualitative features of the observed dysfunctions. So far, the studies suggest that the damage seems to involve some fundamental process or processes functionally related to memory, perception, and selective attention. The present study is a contribution towards the development of an information-processing test battery specifically designed to delineate the dimensions of the malfunction(s) uniquely characteristic of HD.

Chapter 2

Rationale for the Choice of Tasks

The selection of the first task, which involves the phenomenon of mental rotation (Shepard and Metzler, 1971; Cooper and Shepard, 1973), was incited by the validated follow-up studies of Lyle and Gottesman (1977) and Lyle and Quast (1976). In these reports it was shown that the Bender Visual-Motor Gestalt Test differentiated among the premorbids and still-normals in an at-risk sample as early as 20 years previous to the onset of clinical symptoms. Hence, there were reasons to believe that inspection of the perception of and memory for designs as well as related functions such as spatial perception and perceptuo-motor abilities might be profitable (Zusne, 1970). Subtests on other neuropsychological test batteries (Boll, Heaton, and Reitan, 1974; Norton, 1975; Fedio, Cox, Neophytides, Canal-Frederick, and Chase, 1979) also indicated impaired ability in these areas of cognitive functioning. In addition, Fedio et al.'s (1979) recognition threshold task with patterns and words support the notion that HD subjects have difficulty with pattern perception.

The 'mental rotation' paradigm was adapted to test the above functions by requiring subjects to perform a spatial operation, namely, rotation, on simple, familiar visual patterns (letters) and on complex (three-dimensional line perspective drawings), abstract visual patterns in both a standard and a memory condition. Originally, Shepard and Metzler (1971) had highly practiced subjects state whether a pair of line perspective drawings of complex three-dimensional shapes were identical or not. "Different" pairs were mirror-images of each other in order to avoid the possibility that distinctive features would indicate disparity. Whether the two stimuli were the same or different, they differed from each other in orientation. Decision times for making "same" judgments turned out to have an increasing linear relationship with degree of angular disparity between the stimuli. This trend was the same whether the orientation disparity between the drawings was set in the plane of the picture or whether it was in depth. On the basis of this data, as well as on the consistency of introspective report, Shepard and Metzler argued that mental rotation was the operation performed to accomplish the task. In particular, subjects were postulated to conjure up a mental image of one of the stimuli and mentally rotate this inner representation until the configuration of this representation became congruent with the other stimulus or until a decision of incongruence could be reached. Furthermore, the extreme consistency of the results allowed the rate of rotation to be calculated and it turned out to have a fixed rate of 60° per second.

In the Cooper and Shepard (1973) experiment they required subjects to make "same"/"different" decisions based on letters. In this case, determination of congruence was arrived at by comparing a visually presented angularly displaced letter with the stored representation of that letter in long-term memory. The results did not show the same consistent increase in slope as that found in the Shepard and Metzler (1971) study. The irregularity in the linearity was clearly explained by Hock and Tromley (1978) as being due to the wide range of perceptual uprightness enjoyed by letters that are physically tilted resulting from the familiarity of their feature combinations. They showed that the slopes of the lines plotted for comparisons of letters outside of their range of perceptual uprightness were linear, that is, necessitated the operation of mental rotation to reach a decision.

The choice of the second task, a visual search paradigm first introduced by Neisser (1963) and Neisser, Novick, and Lazar (1963), was based on two completely different bodies of information. Firstly, the studies on the memory deficits in HD mentioned above all leave the question as to the nature of the fundamental dysfunction unanswered. Hence, a good place to begin would be to examine the initial process of information pick up or input registration. Since selective attention modulates stimulus registration, a test of selective perception was chosen in order to evaluate the efficiency of this function in HD subjects and in those at-risk. Visual scanning was seen as an appropriate test of selective attention. The second body of evidence which influenced the choice of this area, namely, selective attention, for study comes from work on the neuroanatomical, neurophysiological and neurobehavioral aspects of the movement disorder in HD. The major neurological damage is found, as mentioned in the beginning of this paper, in the basal ganglia (Barbeau, 1973; Earle, 1973; Klintworth, 1973; Forno and José, 1973), which play a significant role in the production of and coordination of movement (mainly involuntary movements such as postural adjustments, accessory movements). Current work (Gallistel, 1979, in press; Marteniuk, 1976) on the production, coordination, and sequencing of smooth motor movements has revealed the great extent to which the motor system relies on sensory and sensorimotor integration. Anatomical findings show that the motor system is intricately connected to sensory relays (Gardner, 1976). Albé-Fessard et al. (1966, cited in Gaull, 1973, Chapter 9) have demonstrated that the same striatal neurons in the basal ganglia receive inputs from proprioceptive and visual afferents and that they respond with an algebraic summation of these stimuli. Speaking in connection with the basal ganglia, Hans-Lukas Teuber (1976) argues that the perceptual system with which the basal ganglia is hooked up, can be selective in its choice of what information to relay on to the basal ganglia and hence can selectively modify outcome motor responses. Damage to this selective modification loop could cause the basal-ganglia motor system to function without sensory guidance. On a descriptive level this explanation seems consistent with Denny-Brown's (1968) close look at the movement disorder of choreic patients "... the movements of HD are each determined by peripheral stimuli, turning of the hand to chance contact, adjustments of the limb and pressures on the skin, turning of the head and eyes indiscriminately to any movement in the visual field or to sounds..." Furthermore, there is a complete absence of chorea during sleep. It is intriguing to contemplate that if this selective attention mechanism was disrupted in HD, that all functions dependent upon it might suffer, both cognitive and perceptual-motor.

Neisser's visual search paradigm is believed to assess selective attention since the subject's task is to locate as quickly as possible a target symbol among distractor symbols. Each symbol in the visual display must be compared to a memory representation of the target symbol. Under the demand of high speed, the perceptual system can, according to the theory (Neisser, 1967; Neisser, 1976) prime itself to pick up only the relevant combinations of features, namely, those of the target symbol and to pass quickly over all other combinations. Only primed features receive further perceptual processing so that non-target symbols are not really 'seen'. Because sequential scanning is fairly systematic, search times and target positions within the symbol list are linearly related in highly trained subjects. Slope, then, can be defined as a measure of scanning efficiency on the part of the selective perception system.

Neisser (1963) and Neisser et al. (1963) found that certain parameter manipulations produced longer reaction times. These increases resulted when the number of symbols to be scanned (per row) was increased, when the critical property under search was the absence of the target letter in an item (i.e., in a row), and when the context symbols had similar and hence confusable features to the target symbol. Kaplan and Carvellas (1965) also found that reaction times went up as the number of target symbols to be searched for were increased. Each of these factors was tested in different conditions in this experiment since it was assumed that elevations in reaction times reflected increased task demands.

Thirdly, we administered the Luria-Nebraska Neuropsychological Test Battery to our subjects despite the fact that they were considered to be normal non-brain-damaged-non-HD-gene carriers. The inclusion of a neuropsychological test battery provided us with an auxiliary check on our experimental manipulations. That is, since the present study is a contribution towards the information-processing approach and since the predictive powers of such an approach can not be gauged until future follow-ups can be completed, a finding showing that performance on our experimental tasks correlated with neuropsychological subtest scores known at present to be fairly discriminative with respect to HD-gene carriers and non-HD-gene carriers (Baro, 1973; Lyle and Gottesman, 1977; Lyle and Quast, 1976; Fedio et al., 1979), would suggest that at least we are on the right track, in that, our tasks may also turn out to be discriminative. Should no significant correlations result, no conclusions can be reached since it could either mean that the experimental and neuropsychological tests are tapping different functions or that one of the tests is not as sensitive as the other.

Now that the general theoretical background has been laid down and the paradigms selected, the question still remains as to what the best approach to uncovering subtle differences among non-gene carriers and premorbid gene carriers is. To simply obtain absolute test scores on these tasks would not be very useful since there would be no way to partial out individual differences resulting from such sources as variations within processing strategies, from individual to individual, variations in base-line reaction times, and from such factors as personality differences with respect to degree of conservatism in the face of response uncertainty. One way to circumvent this problem would be to train subjects on the tasks to asymptotic performance, recording both level of proficiency attained as well as rate of improvement across trials. However, because the present work must also be conducted with a patient population (diagnosed HD patients) such a repeated measures design requiring many daily sessions may not be feasible.

The approach which was decided upon was to administer, within each of the two paradigms selected for study, a series of conditions determined apriori to be of increasing difficulty. This way the experimental session could be of a suitable duration and the subjects could still act as their own controls across conditions. The only factor on which it was difficult to get a complete handle over is practice. In an attempt to minimize practice effects each condition was given different stimulus dimensions and furthermore, the conditions were ordered according to the apriori notions of increasing difficulty, so that difficulty could work against practice. In other words, decrements in performance from easier to harder conditions would reflect subjects' inability to cope with the increased demands of the task despite the fact that he was also becoming more practiced at it. Hence, this way the systems under scrutiny could be assessed not by observing their ultimate level of efficiency but by seeing how well they could cope as they became progressively more and more taxed. It should also be mentioned that it is our intention to use only those measures or tasks which show sufficient performance variability in order to ensure that differences, subtle or not, will be revealed.

Chapter 3

Methodology

General Procedure

The ability to perform mental rotation and the ability to engage in systematic visual search with efficiency in terms of speed and accuracy has been confirmed by Shepard and Metzler (1971) and Neisser (1963), respectively, for highly-trained experienced subjects. In the present study, then, the first question addressed is whether the performance of untrained-naive normal subjects would parallel that of the well-practiced subjects on these tasks.

Since the general purpose of this research is to find out whether the chosen tasks of mental rotation and visual search would be suitable to use as impairment measures for HD patients and prediction measures for at-risk individuals, the immediate goal of this paper is to standardize the tasks with respect to normal untrained subjects. This job especially involves finding out whether or not the different conditions of graded difficulty which were adapted versions of the original paradigms did in fact produce changes in performance indicative of increased difficulty and to ensure that most normal naive subjects can perform successfully all of the tasks.

Forty normal subjects, twenty female and twenty male, were tested on the two experimental tasks, namely, mental rotation and visual scan, as well as on the Luria-Nebraska Neuropsychological Test Battery. The order of task performance was counterbalanced so that half of the females and half of the males began with visual search while the other half of these groups started with the mental rotation task. The final test session for all subjects was the Luria test. The order of condition presentation was fixed for both tasks according to the apriori hypotheses regarding the increasing difficulty of the conditions.

All subjects had normal or corrected vision as assessed by the Keystone School Vision Test. All subjects were given a demographic sheet to fill out concerning first language, ethnic background, age, education, occupation, as well as outstanding personal or family medical history.

The average age of these subjects was 24.03 years (S.D. = 5.96) with the youngest being 14 years old and the eldest being 51 years of age. The average years of schooling in this group was 15.11 years (S.D. = 12.41; range = 10 years to 18 years). Twenty-two of the 40 subjects were students, 13 were working, one was unemployed, and one was a housewife. One subject had a family member with Parkinson's disease, and one subject's mother has Alzheimer's disease. Of the 40 subjects, 27 had never heard of Huntington's disease. Three subjects did not complete the demographic sheet.

Method Section for Mental Rotation

Materials and Apparatus:

A three channel projection tachistoscope was used to present the stimulus slides. The first set of stimuli consisted of capital letters (lettraset standard medium type, 3/4 inch) each surrounded by a large circle (2 inches in diameter). The second series of stimuli consisted of copies of the original shepard and Metzler (1971) two-dimensional perspective drawings of three-dimensional objects composed of strings of cubes in which there were four arms projected at right angles to each adjacent arm. There were ten cubes per object, four in each of the central two arms, three in one of the end arms and one in the other end arm. These drawings were also encased in circles (2 inches in diameter). Since the slides were prepared by photographing the above letters and drawings from paper, the stimuli appeared on the screen as white lines on a black background. Once projected, the surround circles became 8.8 cm in diameter. The subject sat at a distance of about 82 cm from the viewing screen, making the viewing angle of one stimulus alone 6.13° and the viewing angle of the pair of stimuli 12.11°. The fixation slide consisted of a black X on a white background and it was projected exactly between the pair of stimuli in the center of the screen. A chin rest was used in order to restrain subjects from rotating their heads.

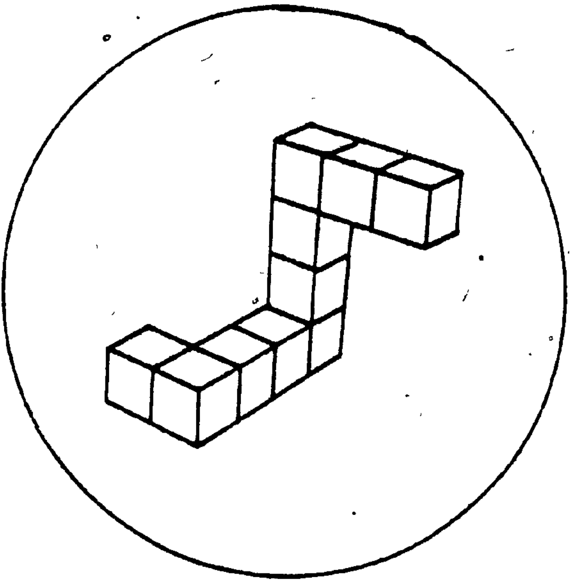
Stimuli:

Letters - F, G, J, L, and R were selected for presentation since these capital letters are asymmetrical and have asymmetrical mirror-images. Photographs of these letters and their mirror-images were taken at various angular orinetations in the picture plane. Since angular disparity between two letters is an important parameter, 10 different degrees of disparity were examined, namely, 20 degree differences from 0° to 180°. Pairs were therfore constructed such that each letter type was represented in each one of the 10 different degrees of angular disparity. This was accomplished by selecting letters at different orientations from the pool of photographs. Furthermore, for each letter type, and for each angular difference, one pair was a "same" or congruent pair (both letters were either in normal or mirror-image positions) and one pair was a "different" or incongruent pair (one in normal position and one in reflected position). Hence, there were two types of pairs that were classified as "same" stimuli, namely, pairs of letters photographed in the mirror image position. There were, therefore, 50 classified "same" stimuli and 50 classified "different" pairs. Figure 1 presents examples of the stimuli used.

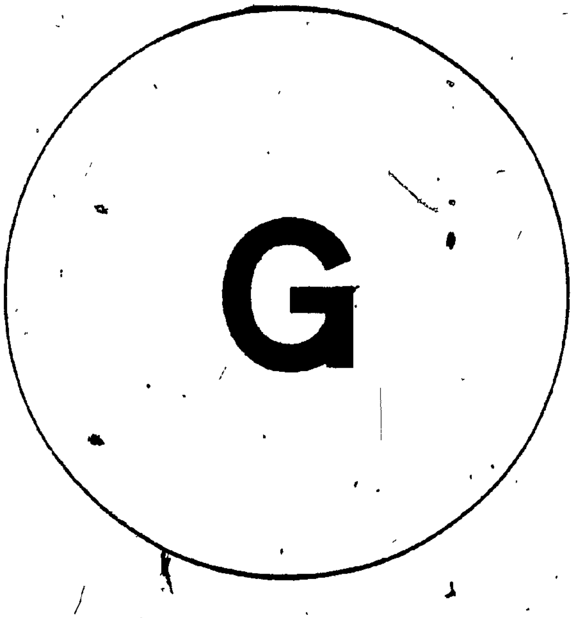
Three-dimensional drawings (3-D figures) - Five of the Shepard and Metzler (1971) drawings and their mirror-images were used (see example in Figure 1). Pairs consisted of "same" drawings of each of the figures at each of the 10 different degrees of angular disparity and "different" drawings at the same degrees of disparity resulting in a total of 100 pairs. It is important to note that these Shepard and Metzler (1971) drawings represent rotations in depth, that is, around the vertical axis.

Figure 1

Examples of stimuli used in the mental rotation task



Three-dimensional line perspective drawings
(Shepard and Metzler, 1971)



Letter stimuli

Procedure:

Two slides of the small letter "a" was used as an example. The subject was allowed to rotate these slides in his hands. Subjects were instructed to press a letter marked "same" when congruence could be achieved and a lever marked "different" when no match was possible. At this point, the experimenter stressed that the mental rotation was only to occur in the plane of the screen. The sequence of events within a trial was as follows: The fixation X was flashed up for two seconds followed immediately by the appearance of the test pair of letters. The letters remained projected on the screen for a maximum of 13 seconds or until the subject made a response at which time the letters would disappear and the next trial initiated. Subjects were assured that 13 seconds would be usually ample enough time to carry out the necessary mental operations and come to a decision. Type of letter, same/different pairs, and angles of disparity were randomly distributed throughout the test trials. Reaction times and errors were recorded. Subjects were given 20 practice trials followed by 80 test trials. Each of the 5 letters were represented in the preliminary trials while only one Shepard and Metzler figure was used in the practice series. The exact same procedure was repeated for the 3-D figures except that it was stressed to the subject that rotation this time was to occur in depth, that is about the vertical axis.

Following this first half of the session which took about an hour, subjects were given a 15 minute break before the memory condition was introduced. Subjects were told that the same series of stimuli, letters and complex shapes, would be re-presented except that this time each member of a pair would be presented separately - one preceding the other. The trial sequence would be: the fixation X appears for two seconds after which it is replaced by one member of the pair, the one in the left portion of the screen. This first stimuli is presented for 400 milliseconds, followed by a 100 millisecond inter-stimulus interval and then the presentation of the second stimulus in the right portion of the screen. The second stimulus remained projected for a maximum of 13 seconds or until the subject terminated the trial by making a response. Subjects were again given 20 practice trials and 80 test trials in each condition. This half of the session also took approximately an hour.

Method Section for Visual Scan

Apparatus and Stimulus Display Set-Up:

The stimulus material was generated by and presented on a PDP 11/34A computer and display. The displays in this task consisted of lists of letters. Each list contained 40 rows and depending on the condition each row either contained 4 or 8 letters. Each of the 10 different conditions had its own set of context letters, from which the lists were constructed, and its own critical target letter. Conditions requiring 4 letters per row had 4 context letters and conditions requiring 8 letters per row had 8 context letters. This way all possible letters appeared in each row. In other words, each row was a random permutation of the context letters. Furthermore, each condition consisted of 16 individual lists. That is, 16 separate lists consisting of 40 permutations each of the same context letters were generated by the computer and stored. These 16 lists differed, however, in one respect. Each list had one critical property located at random in one of the critical rows predetermined to be rows 2, 5, 7, 10, 12, 15, 17, 20, 22, 25, 27, 30, 32, 35, 37, 40. Furthermore, position of the critical property in a row was controlled in order to prevent the adoption of searching pattern bias. In the "present" conditions, the critical property is a specified target letter and this target letter replaces one of the context letters and appears in a different row in each of the lists. In the "absent" conditions, the critical property is the absence of a pre-specified letter in one of the rows in each of the lists. That is, 39 rows have the critical letter embedded in them, and the subject's task is to locate the row in which it is missing. List order within each condition as well as condition order were fixed (the same for all subjects). A trial consisted of having a list displayed in full on the display system which looks something like a television screen and having the subject search for and find the target letter or its absence and press a lever to indicate termination of search. Subjects sat approximately 82 cm away from the screen and a chin rest was used to maintain this distance. The lateral visual angle subtended by the display varied according to the number of letters per row (4 letters = 0.77°; 8 letters =

1.54°; 8 letters plus 2 spaces = 1.89°). The visual angle lengthwise was 13.64°.

Description of the 10 Conditions:

The following is a brief description of the context letters, critical properties, and spatial characteristics of the ten different condition manipulations used in this study in the order in which they were presented to the subjects; examples of the stimuli are given in Table 3.

In condition Four 1 there were four letters per row and subjects were required to locate the target letter (F) in one of these rows. Condition Four 0 also contained four letters per row but this time there was a J in every row except for one. Subjects had to search for the row in which the J was absent. Conditions Eight 1 and Eight 0 were the same as the first two except that in each row there were eight letters. In the first case, subjects were looking for a Y and in the second case, they were looking for the only row that had no B in it. Condition Eight 2 had eight letters per row and two possible target letters (CZ). On each trial, either target letter could be present with equal probability though never do they both appear in the same list. In this case, the subject must be primed to receive two relevant feature combinations. Condition Four 9 was identical to Four 1, subjects were searching for an F in a four-letter per row list, only this time distractor items, two X's appear on both sides of each row. The X's are separated from the context letters by a space. Condi-

Table 3

Description of conditions in the visual scan task

Condition	Description	
1) FOUR 1:	**Present Condition**	
	Context letters –	GKBT
	Target letter –	F
2) FOUR 0:	**Absent Condition**	
	Context letters –	GKBT
	Target letter –	J
3) EIGHT 1:	**Present Condition**	
	Context letters –	APNGKUHD
	Target letter –	Y
4) EIGHT 0:	**Absent Condition**	
	Context letters –	APNGKUHD
	Target letter –	B
5) EIGHT 2:	**Present Condition**	
	Context letters –	DLO JWFPX
	Target letter –	C or Z
6) FOUR 9:	**Present Condition**	
	Context letters –	GKBT
	Target letter –	F
	Outline –	XX(space)– – – –(space)XX
7) EIGHT 9: (space)	**Present Condition**	
	Context letters –	KOZDTBMR
	Target letter –	P
	Outline –	– –(space)– – – – (space)– –
8) EIGHT 9: (no space)	**Present Condition**	
	Context letters –	KOZDTBMR
	Target letter –	P
	Outline –	– –/– – – –/– –
9) EIGHT 8:	**Present Condition**	
	Context letters –	METKWXFI
	Target letter –	D
10) EIGHT 7:	**Present Condition**	
	Context letters –	METKWXFI
	Target letter –	H

tion Eight 9 (space) is set up such that each row is a random permutation of eight letters but the center four letters are separated from the remaining two on either side by a space. The target letter in this "present" condition, can only be located in these center four letters. Hence, this condition differs from the Four 9 condition only in that the distractor items are chosen from the context letters. Eight 9 (no space) is identical to Eight 9 (space) except that there is no space between the center four relevant context letters, where the target may be located, and the surrounding distractor letters. In condition Eight 8 subjects are looking through eight letter rows for a round target letter (D) while all of the context letters are sharp, angular letters. In condition Eight 7, both the target and context letters are sharp.

Procedure:

The subject was told that he must locate a target letter or its absence in a list of letters as quickly as he could. Furthermore, he was told that he must do this by using only one strategy, namely, scan the list from left to right and from top to bottom. Should he miss the critical property on the first scan the subject was instructed to begin again from the top as many times as was necessary in order to locate it. Before beginning each new condition, the experimenter verbally described what the subject should expect in terms of list characteristics and task demands. After that, the specified letter for the condition was displayed at the top left-hand corner of the screen. It remained there throughout the condition. A convention, used by Neisser (1963) and Neisser et al. (1963), to prevent premature responses, was to have subjects press a right hand lever if the critical property appeared in a row which had an asterisk (*) to the right of that row and to press a left hand lever if the critical property appeared in a row which had an asterisk to the left of that row. Hence, incorporated into our permutations program for stimulus generation was a procedure for randomly placing asterisks on either the right or the left hand side of each row. The lists were then visually inspected to ensure that an asterisk did not appear on the same side for more than four consecutive rows. This constraint made the response criteria less obvious. It was explained to the subjects before the beginning of the session that their reaction times were determined as soon as they indicated their detection of the target by specifying the location of the asterisk of the appropriate row. A response caused the display to disappear and the next trial to be initiated. Because of the nature of the task, errors were very infrequent. However, when an error was committed, the trial was re-presented to the subject following the last trial within the same condition. Only correct response reaction times were used in the statistical computations. The experimenter said "ready" before the following display was flashed up on the screen. The first 5 conditions took on the average one hour to complete. The subjects were then given a 15 minute break. The second 5 conditions also took approximately one hour to finish.

No practice trials were given in this test.

Chapter 4

Results and Discussion for the Mental Rotation Task

The group data, across all subjects, is described first in order to evaluate the overall performance of untrained, naive subjects on the various adapted versions of the mental rotation paradigm. Since the main thrust of this study is to reveal individual differences in performance across tasks so that constant factors can be partialled out, no major statistical analysis of the group data is presented. The data is scrutinized for changes in performance across subjects across tasks which might reflect a continuum in task difficulty and for evidence that might ensure that no aspect of any of the tasks prevented subjects from being able to complete the tasks without training. In the light of the evidence forwarded by Hock and Tromley (1978) concerning the lack of relationship for letters between reaction time and the smallest and largest angles of disparity on account of the broad range of perceptual uprightness of alphabetic characters, it was to our best interest, for example, to check to see whether the data from our unpracticed subjects was also altered in this direction, since such an effect detracts from a clear demonstration of the operation of mental rotation.

Figure 2 represents the relationship between reaction time and angular disparity for the pairs classified as "same", across all forty subjects for both the letter/simultaneous and three-dimensional/simultaneous conditions (L/S and 3D/S, respectively). It was constructed by first averaging the times each subject took to make a correct response at each of the ten degrees of angular difference across the four trials each subject received at each of the orientation differences. The overall average reaction times across all subjects together was then calculated from these individual average reaction times. Figure 3, representing the letters/memory and three-dimensional/memory conditions (L/M and 3D/M, respectively), was derived in the same manner.

Consider first what was taken to be the easiest most straightforward task in the mental rotation series, the comparison of pairs of simultaneously presented familiar patterns (i.e., letters) which appeared in various disparate orientations. When the time taken across subjects to respond "same" to congruous letters is plotted as a function of the angular disparity between the two letters, the mean reaction times increase linearly across the ten increasing degrees of angular disparity (Figure 2). This finding, according to Shepard and Metzler's (1971) and Cooper and Shepard's (1973) theoretical argument, satisfies the operational criteria for mental rotation. The degree to which the two variables, mean reaction time and angular disparity, are related is given by the correlation coefficient which, in this case, is $r = .9186$. The fact that the slope for this task is so small, though positive ($m = .0074$), indicates that subjects as a whole can rotate letters at a very rapid rate (approximately 135° per second) due to the

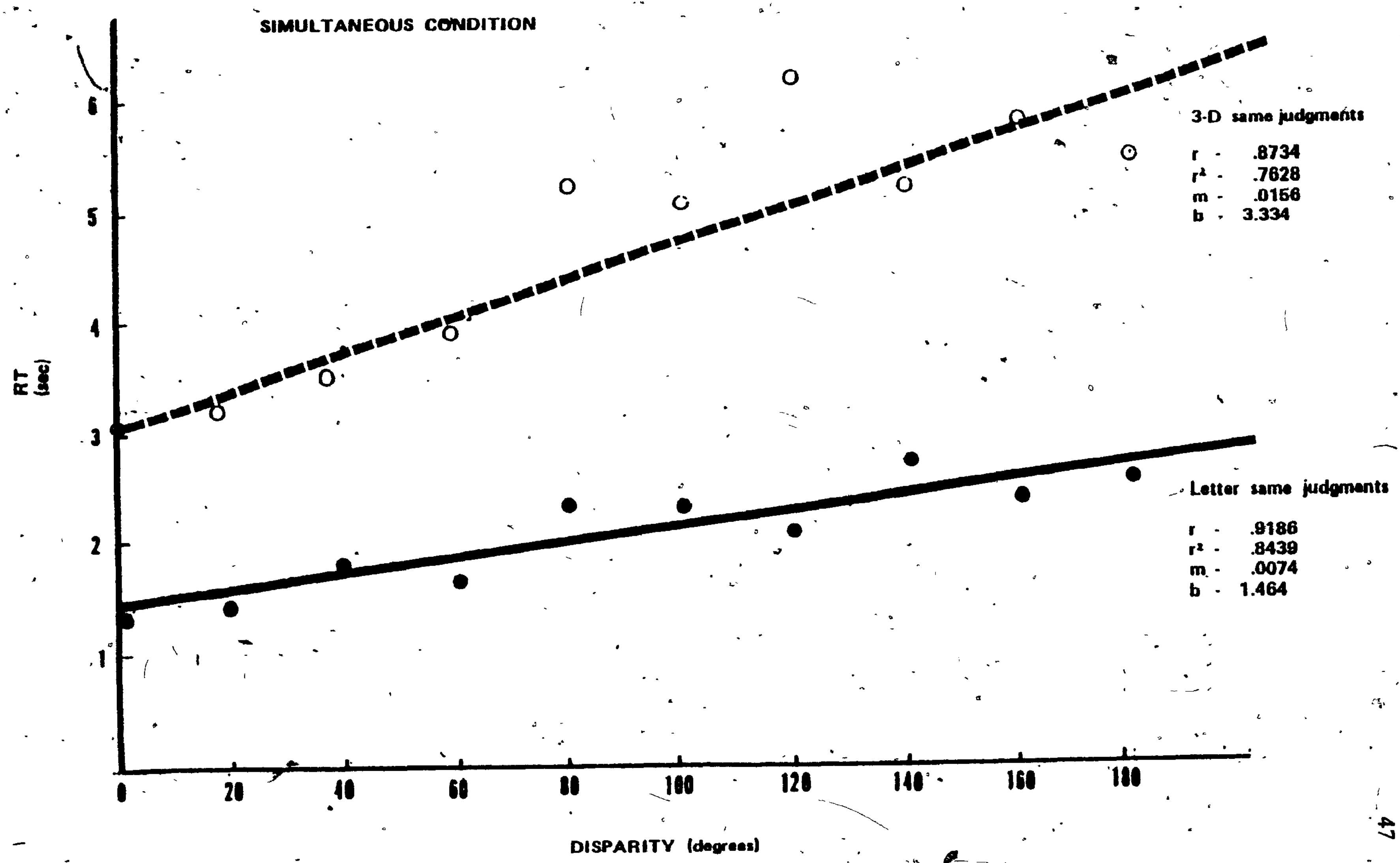


FIGURE 2 - Mean reaction time as a function of angular disparity

extreme familiarity subjects have for the feature combinations of alphabetic characters, as well as to the large range of perceptual uprightness enjoyed by letters. Another indication of the uniformity of performance in this task across subjects is the fact that since the correlation is so high the standard error of estimate is very low. When correlations between reaction time and degree of angular disparity were calculated separately for the two types of "same" stimuli, namely, for normal position pairs and for mirror-image pairs, they turned out to be very similar, as did the values of the slopes and intercepts. For the memory condition, the similarity between the two types of "same" stimuli was also observed.

Table 4 shows the sum across all subjects of errors made in "same" trials and the sum of errors made in "different" trials, at each of the angles of disparity for each of the four experimental conditions. A total error score ("same" plus "different") across all subjects is also given for each of the orientation differences. The overall error rate for the subjects is on the average about 5.87% (4 mistakes per 80 trials, on the average). This fairly low rate labels the task as being easy even for unpracticed subjects. Subjects made equal numbers of errors in "same" pair trials as in "different" pair trials indicating that both decisions could be made with equal accuracy. Furthermore, there is no significant correlation between error scores and angular disparity in either "same" trials (r = .392) or "different" trials (r = .332), demonstrating that decisions based on small rotations and on larger rotations can be made with equal efficiency. Obviously, however, these two types

Table 4

Total errors in each of the four conditions in the mental rotation task

Letters/Simultaneous Condition

Angle:	0	20	40	60	80	100	120	140	160	180
Same errors:	8	3	3	4	16	17	2	9	11	12
Different errors:	12	5	6	13	8	12	10	8	8	16
Total errors:	20	8	9	17	24	29	12	17	19	28

Letters/Memory Condition

Angle:	0	20	40	60	80	100	120	140	160	180
Same errors:	10	4	6	2	12	11	6	10	7	10
Different errors:	6	6	7	7	10	7	11	9	7	6
Total errors:	16	10	13	9	22	18	17	19	14	16

3-D Figures/Simultaneous Condition

Angle:	0	20	40	60	80	100	120	140	160	180
Same errors:	11	11	12	10	25	28	18	35	39	35
Different errors:	26	38	30	31	23	30	48	28	17	33
Total errors:	37	49	42	41	48	58	66	63	56	68

3-D Figures/Memory Condition

Angle:	0	20	40	60	80	100	120	140	160	180
Same errors:	21	24	31	34	46	41	31	36	42	48
Different errors:	57	43	40	48	41	48	50	53	40	43
Total errors:	78	67	71	82	87	89	81	89	82	91

of trials, "same" and "different", involve two different decision processes. Firstly, the function describing reaction time versus angular disparity for "different" trials, can not be adequately plotted because "the angle through which ... (the stimuli) must be rotated to achieve congruence is not defined" (Shepard and Metzler, 1971). That is, "different" judgments are not always arrived at in the same manner since the amount of rotation necessary to detect incongruence may vary. Despite these facts, for letters presented simultaneously, a linear trend exists for "different" pairs as well ($r = .670$; $m = .003$), when the data is analyzed in the same way as for "same" judgments. Reaction times in the "different" trials are slightly longer than in the "same" trials as reflected by the difference in the Y-intercepts of the graphs ($b_{same} = 1.464$; $b_{different} = 2.524$). It should be pointed out, however, that reaction time and Y-intercept are not directly dependent upon each other, and hence, it is not always the case that a difference in one necessarily results in a difference in the other. Though two functions may share a similar Y-intercept value (i.e., similar constant baseline factors), one function may have a faster rising slope than the other, causing the mean reaction time for the former to be longer than for the flatter function. Similarly, two functions may have almost identical mean reaction times, while the Y-intercepts may be quite different.

Because of the irregularity attached to "different" judgments on the whole and their lack of contribution to an understanding or description of mental rotation, measures of performance on "different" trials will not be considered in further analyses. Only error scores on "different" trials will be used, since total error scores across all trials is a consistent measure of overall performance ability.

The next task, which is considered to be at a higher level of difficulty, involves the comparison of pairs of simultaneously presented complex, three-dimensional, abstract and novel shapes. Again, as can be seen in Figure 2, the mean reaction times for subjects to respond "same" is positively and linearly related to angular disparity. The correlation between these two variables is high ($r = .8743$) and hence supports the mental rotation hypothesis. In this case, however, the slope is larger ($m = .0156$), indicating that as a whole subjects have a slower rate of rotation for more complex figures. Along with the increase in slope is an increase in both reaction time and intercept ($b = 3.334$). Overall baseline reaction times, then, were approximately elevated by 1.87 seconds in the three-dimensional task (3D task) in comparison to the letter task. Another indication of the increased difficulty of this 3D task is the rise in error rate from 5.87% to 18.66% (Table 4), an increase significant at the .001 level ($t_{(39)} = -5.983$, $p < .001$). Furthermore, "same" judgments were found to be harder to make accurately as angular disparity increased ($r = .891$, $df = 8$, $p < .05$), whereas "different" judgments showed no systematic relationship with angle of disparity ($r = -.079$, $df = 8$, $p = ns$).

In view of the amount of training received by the subjects in the original Shepard and Metzler (1971) study, namely, 1600 trials across 8 to 10 one hour sessions, the similarity in the data between their subjects and our unpracticed, naive subjects (only 100 trials) shows not only that the phenomenon of mental rotation is fairly robust, but that it also involves rather fixed processing operations. In particular, this statement can be supported by the fact that Shepard and Metzler (1971) reported that the average rate of rotation for their group was around 60° per second, meaning that the average overall slope had a value around m $\doteq$ .0167. It will be recalled that the slope of the function for this condition in this experiment was m = .0156 (about 64° per second). The effect of practice, deemed from Shepard and Metzler's report, appears basically to produce a decrease in overall baseline reaction times (theirs was just above one second whereas ours was b = 3.334 seconds) and in error rate (theirs was only 3.2% whereas ours was 18.66% - about 6.6 mistakes in 80 trials). It should be noted here that the discrepancy in slope between Shepard and Metzler's data and this data may in fact be actually smaller than is observed. This because our subjects, in this condition, had a response bias for saying "same" which ultimately has an effect on the obtained value of the correlation coefficient and the slope. That is, our subjects tended to make more "different" errors ($t_{(39)}$ = -2.394, $p < .05$) on this task, meaning that they were responding "same" more often than not when they were making a premature response (i.e., not completing the full necessary rotation). The implication is that should the subjects be making premature responses in "same" trials and responding "same" more often than not, then not only in this case do they have a higher probability for making a correct decision but they also cause the reaction times to be brought down which in turn causes the correlation coefficient and the slope to be underestimates of the true values for mental rotation.

Reaction times for "different" trials were not correlated with angular disparity (r = .36), slope was small (m = .002), and the intercept value (b = 5.382) was larger than for "same" trials. However, for the same reasons discussed above, there will be no further analysis of the "different" trials.

In general, then, the tasks reported thus far seem to fall well within the range of ability of normal untrained individuals.

Before examining Figure 3, representing the memory conditions, let us consider some of the plausible outcome possibilities. Not only did the memory condition add another dimension to the mental rotation task, thereby increasing the difficulty of the task but it also placed a time constraint on the whole process of mental rotation. Because of this somewhat unique influence, regular indications of increased difficulty such as increased reaction times, intercepts, and slopes as observed in the case of simple versus complex patterns, can not necessarily be expected in the memory condition. Speculations as to possible outcomes are numerous. Since we know that the rate of rotation can vary according to the complexity of the stimuli (letters versus 3D figures), it could also be possible that the extra memory load could force the rotational system to increase its rate in order to compete with the memory constraints on the storage system of the mental representation. Error rate should not change if the system can perform this acceleration without difficulty or loss of information. Slopes would be smaller on account of the faster rate of rotation and intercepts should be smaller if subjects could get off to an early start in the face of the memory limitation. On the other hand, if the rate of rotation can not be stepped up to a sufficient speed because of a sudden usurpation of more processing capacity by the representational system which must maintain an intact image without further visual support, then skewed distributions of error rates towards the larger angle of disparity should result. All other measures, namely, slope, reaction time, and intercept should remain similar to the simultaneous conditions. It could also be that the standard rate of rotation is already fast enough so that the stored memory representation remains sufficiently intact through the operation of rotation. Then, in this case, the two conditions, simultaneous and memory, should look basically alike except maybe for error rate. Finally, if the memory image is not strong enough to endure through rotation at any rate without the supplementation of visual feedback, then there should be no correlation between reaction time and angular disparity, and error rates should reflect guessing.

The letter data for "same" judgments in the memory condition turned out to be a bit of a disappointment because of the small correlation between reaction time and angular differences ($r = .6799$) (Figure 3). Furthermore, points about the best fit line show little deviation and error rates are not significantly different from the letters/simultaneous condition ($t_{(39)} = .572$, p = ns). Taken together these results indicate not only that most subjects found the task easy to do but also that mental rotation was probably not the strategy which the spatial processing system opted to use (probably switched to a verbal-labeling strategy as consistent with subject reports). Because the parameters of this memory task with letters did not, with confidence, elicit the operation of mental rotation in subjects or increase the difficulty of the mental rotation task along a unilateral dimensions, the letters/memory task is concluded not to be a suitable task.

Group data for the 3D/memory condition "same" judgments resulted in an overall high positive correlation between reaction time and angular difference ($r = .9541$). Furthermore, consistent with the possibility that the rotational system is speeded up because of pressure from the memory constraint, were the lowered values of the slope ($m_{memory} = .0081$ from $m_{simultaneous} = .0156$) and the intercept ($b_{memory} = 2.456$ from $b_{simultaneous} = 3.334$). Here too though response bias ($t_{(39)} = -3.09$, $p \angle .01$) to say "same" may be also partially responsible for the small value of m. Error scores, on the other hand, revealed that this task, however, was indeed more difficult than the simultaneous task since the overall error rate became significantly higher ($t_{(39)} = -2.522$, $p \angle .001$). In addition, for "same" trials more errors were made at larger angles of disparity ($r = .777$, $df = 8$, $p \angle .01$), demonstrating the difficulty of the operation. "Different" judgments, on the other hand, showed no systematic relationship with angle of difference ($r = -.216$, $df = 8$, $p = ns$). In further support of the hypothesis of accelerated rotation

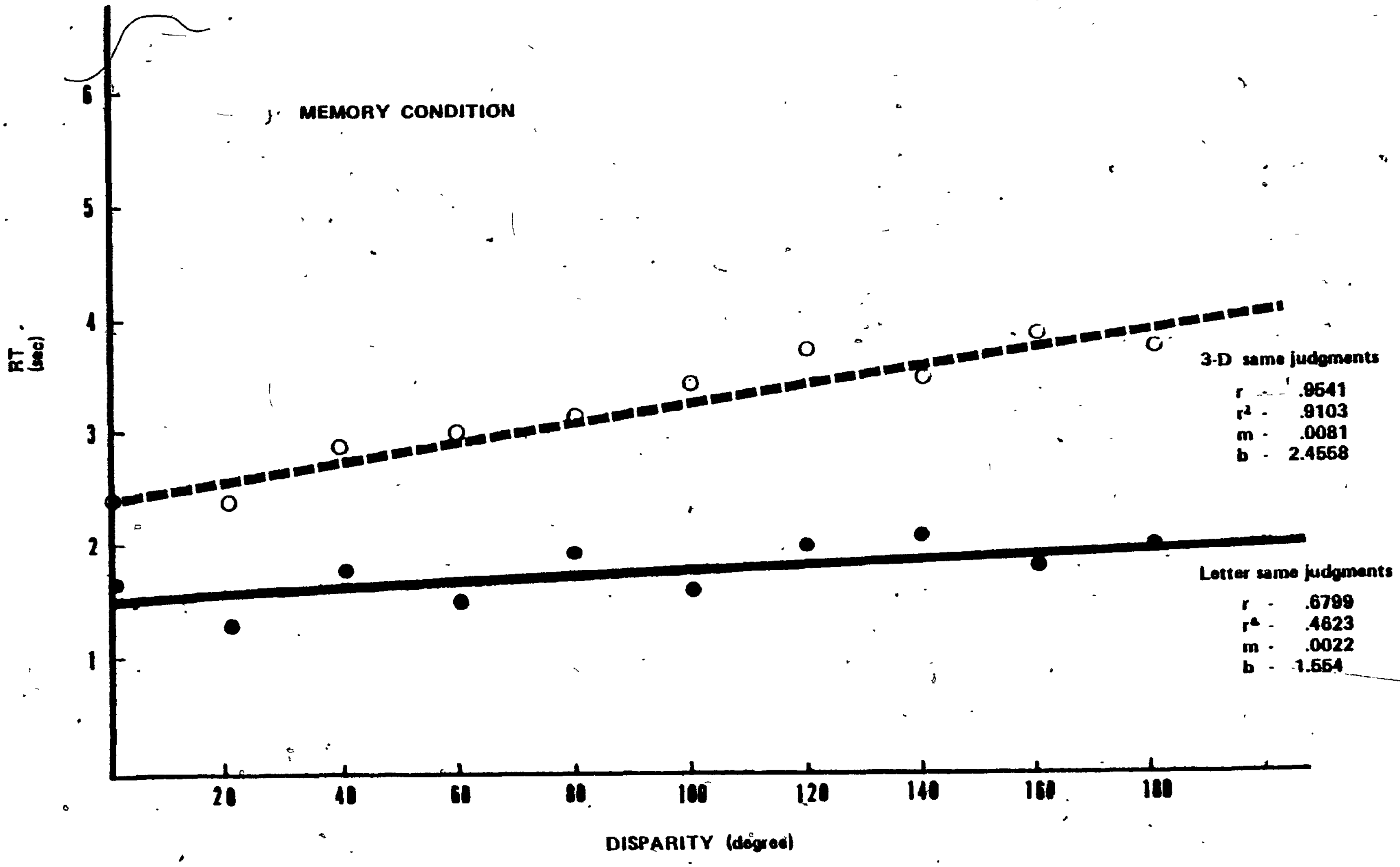


FIGURE 3 - Mean reaction time as a function of angular disparity

rates is the fact that no speed-accuracy trade-off was found to occur in this task, in that, longer reaction times do not correlate with fewer mistakes ($r = -.041$, $df = 8$, $p = ns$).

Though all the measures used, namely, correlation coefficient, slope, intercept, and reaction time are interrelated, only the correlation coefficient provides the necessary indication that mental rotation was the strategy adopted to perform the task. Slope, for instance, could be deceptive since it is possible to have a positive slope and yet have a low correlation between reaction time and angular disparity. On this basis, we proceeded to select a critical value for the correlation coefficient ($r > .632$, $df = 8$, $p < .05$) and to compare this criterion value to each subject's correlation coefficient for each of the four mental rotation conditions. This gave us an indication of the number of subjects who were complying with the requirements made of them, namely, to try and solve the problems by mentally rotating the stimuli. Though evaluations of the absolute performance of each subject in each condition describes the data, we were more interested in examining individual differences in performance as a function of increasing task demands so that constant performance factors could be partialled out and significant differences in processing operations between subjects could be revealed. Across the three condition-comparisons made, namely, letters/simultaneous (L/S) versus letters/memory (L/M), 3D/simultaneous (3D/S) versus 3D/memory (3D/M), and L/S versus 3D/S, there were four possible performance groupings. These groupings were based upon the significance of the correlations, namely, significant/significant (S/S), significant/nonsignificant (S/N), nonsignificant/significant (N/S), and nonsignificant/nonsignificant (N/N). It should be noted that letters/memory versus 3D/memory was not included as a comparison due to the irregularities introduced by the memory parameters. Basically, what the above describes is a series of three contingency tables, presented in Tables 5a, 5b, and 5c. The cell frequencies in these contingency tables provide an index by which the tasks can be evaluated in terms of difficulty and association. Performance measures (r, m, b, error, and reaction times) were then calculated for the performance profile subgroups in order to better characterize individual differences in performance otherwise masked when taken across all subjects together.

Because of the minimal practice our subjects received and the relative difficulty of the tasks, problems in this study were bound to arise concerning the issue of task performance variability. How are subjects who deviate from the path of expected results (i.e., groups S/N, N/S, and N/N) to be accounted for? This issue is clearly demonstrated in the case of letters/memory. Here subjects completed the task with extreme efficiency yet because of the very small correlation between reaction time and angular disparity, it had to be concluded that mental rotation was not the adopted processing strategy. Clearly, the "spatial" ability of the subjects is confirmed yet this task must be judged not to be particularly useful for our purposes. Since though we may want to point out differences in spatial abilities among our subject samples, namely, normal, at- risk,

Table 5

Contingency tables for mental rotation tasks

Table 5a

		Letters / Memory		
		significant	nonsignificant	
Letters / Simultaneous	significant	4	24	28
	nonsignificant	2	10	12
		6	34	40

Table 5b

		3-D Figures / Memory		
		significant	nonsignificant	
3-D Figures / Simultaneous	significant	10	13	23
	nonsignificant	4	13	17
		14	26	40

Table 5c

		3-D Figures / Simultaneous		
		significant	nonsignificant	
Letters / Simultaneous	significant	19	9	28
	nonsignificant	4	8	12
		23	17	40

and diagnosed HD, we want to be able to say something specific about this difference, namely, that its source is, or is not, located within the assemblage of operations involved in mental rotation. Hence, in effect, all tasks or at least the base-line condition should be performed to criterion (i.e., through the use of mental rotation) by all normal subjects. With this in mind, let us look at how well the different mental rotation tasks in this study fare.

Let us first examine the contingency table for the L/S versus L/M conditions (Table 5a). Out of the 40 stubjects, 28 had significant r's (correlations) in the simultaneous condition which means that about 70% of the subjects were performing the task by mentally rotating the letters. However, introduction of the memory condition resulted in a significant change in operational strategy across subjects. Now only 15% of the subjects had significant r's and hence could be said to be using mental rotation consistently to perform the task. This change in performance strategy is reflected in a significant change in the distribution across the contingency table (X^2 = 16.96, df = 1, p $<$.001). It should be noted here that because several chi squares were computed on the same data, the alpha level was corrected to .001. Furthermore, the overall association between two tasks was not significant (X^2 = .08, df = 1, p = ns) indicating that the tasks did not differ along a simple dimension as far as performance was concerned. In addition, a nonsignificant r was not related to poor performance since total error rate for the S/S group is not significantly different from that of the S/N group (even at an uncorrected alpha level which for the t-tests is actually .005) ($t_{(26)}$ = -.514, p = ns) or the N/N group ($t_{(12)}$ = .055, p = ns). These comparisons were made on the data presented in table 6a. However, it could be argued that the subjects in the S/N group may have been having trouble with rotation in the memory condition because both the S/S group and the S/N group show a change from higher to lower slopes across the two conditions, but neither the N/S nor the N/N group show any difference in slope. Whereas the S/N groups may be attempting to perform mental rotation, the N/S and N/N groups may be using some other alternate strategy. If the S/N group can not carry out reliable initial rotations on all trials in the memory condition, then they may be forced to begin the rotation again in some instances. The effect would be erratic reactions which would ultimately result in the low correlations obtained for this group. In this case, error rates would not necessarily be affected.

Examination of the 3D/S to 3D/M contingency (Table 5b) also points to the notion that the task processing requirements inherent in the memory condition seem to be functionally adaptable to alternate processing strategies. In this case, though 57.5% of the subjects had significant r's in the simultaneous condition, 65% of them do not have significant r's in the memory condition. The change in the distribution across the contingency table did not reach significance however (X^2 = 2.37, df = 1, p = ns). On the other hand, the overall chi square was not significant either (X^2 = .945, df = 1, p = ns) suggesting that in fact the two tasks are not associated. Again, as with the letters, the S/S group did not make fewer errors as they went from the simultaneous to the memory task than did the S/N group ($t_{(22)} = -2.018$, $p < .1$) or the N/N group ($t_{(20)} = -.213$, p = ns) even at the uncorrected alpha level. As in the letter condition, it also seems possible in this case as well that the S/N group may be performing mental rotation in the memory condition but not in a steady consistent manner. Again the evidence to support this notion comes from the observation that the profile of measures for the S/N group shows similar trends to that of the S/S group, namely, decrease in slope, intercept, and reaction time. The data being referred to here is presented in Table 6b. The N/S and N/N groups, on the other hand, do not show the same difference trends across the two conditions. Because of the number of t-tests computed for the mental rotation task to compare the various categorized groups of subjects, the alpha level had to be adjusted to .005 and for this reason few of the differences reached significance. However, it should be pointed out that those subjects in the S/S quadrants of the L/S-L/M and 3D/S-3D/M contingency tables showed results consistent with the expected outcomes according to the overall data trends. That is, in both situations there was an observed decrease in slope, reaction time and for the 3D task a decrease in Y-intercept.

The only comparison which showed a change in performance in the direction we had hoped all the manipulations would yield was that between L/S and 3D/S, represented in Table 5c. Though the overall chi square did not reach the corrected level for significance of .001 ($X^2 = 4.097$, df = 1, $p < .05$), this at least showed that

Table 6

Mean correlations, slopes, intercepts, reaction times, and total errors according to types of performance in two mental rotation conditions

Table 6a **Letters/Simultaneous versus Letters/Memory conditions**

Condition	Types of Performance							
	S/S (N = 4)		S/N (N = 24)		N/S (N = 2)		N/N (N=10)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Correlation (r)								
Simultaneous	.725		.815		.510		.395	
Memory	.725		.255		.765		.230	
Slope (m)								
Simultaneous	.013	.007	.008	.005	.005	.002	.003	.003
Memory	.008	.006	.001	.003	.002	.002	.002	.005
Intercept (b)								
Simultaneous	1.596	.722	1.282	.388	1.825	1.486	1.843	.706
Memory	1.298	.642	1.552	.560	1.227	.736	1.739	.620
Mean Reaction Time ($\overline{RT}$)								
Simultaneous	2.79	1.27	2.02	.708	2.2	1.65	2.14	.845
Memory	2.01	1.13	1.80	.664	1.45	.962	1.90	.631
Total Error								
Simultaneous	3.5	1.0	4.42	3.36	.5	.707	6.6	4.58
Memory	8.0	6.78	2.17	2.93	1.0	0	9.2	9.48

Table 6b 3D/Simultaneous versus 3D/Memory

Condition	Types of Performance							
	S/S (N = 10)		S/N (N = 13)		N/S (N = 4)		N/N (N = 13)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	Correlation (r)							
Simultaneous	.801		.769		.365		.335	
Memory	.818		.343		.850		.335	
	Slope (m)							
Simultaneous	.020	.006	.018	.007	.014	.006	.008	.012
Memory	.016	.008	.005	.005	.014	0	.004	.004
	Intercept (b)							
Simultaneous	2.568	1.097	2.876	1.172	3.625	1.552	4.253	2.125
Memory	1.837	.828	2.490	.557	2.387	.935	2.855	1.493
	Mean Reaction Time (RT)							
Simultaneous	4.40	1.60	4.49	1.42	4.92	1.348	5.00	1.59
Memory	3.10	.96	2.89	.83	3.67	1.60	3.26	1.69
	Total Error							
Simultaneous	12.9	7.28	12.0	7.93	15.25	13.96	21.69	25.38
Memory	2.51	10.08	17.43	10.54	20.75	12.28	20.62	17.47

Table 6c **Letters/Simultaneous versus 3D/Simultaneous**

Condition	Types of Performance							
	S/S (N = 19)		S/N (N = 9)		N/S (N = 4)		N/N (N = 8)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	Correlations (r)							
Letters	.830		.800		.360		.450	
3D	.770		.490		.850		.380	
	Slope (m)							
Letters	.009	.005	.010	.006	.004	.002	.003	.003
3D	.020	.007	.012	.008	.017	.004	.007	.013
	Intercept (b)							
Letters	1.212	.380	1.567	.501	1.956	.618	1.781	.884
3D	2.888	1.126	3.657	1.505	2.816	1.056	3.959	2.693
	Mean Reaction Time (RT)							
Letters	1.97	.749	2.464	.925	2.27	.764	2.09	1.02
3D	4.691	1.468	4.763	1.386	4.34	1.064	4.625	1.985
	Total Error							
Letters	1.895	1.487	2.778	2.108	4.00	3.16	2.25	2.71
3D	6.167	3.761	5.90	3.929	3.50	2.887	6.375	4.955

performance under different degrees of pattern complexity was related. Furthermore, the change in performance strategy was not significant ($X^2 = 1.231$, df = 1, p = ns). While 47.5% of the subjects performed significantly across the two tasks, only 20% did not use mental rotation at all and 32.5% switched strategies. The S/S group showed results, found in Table 6c, which followed the overall trend in the data. That is, they showed significant increases in reaction time from the more complex stimuli ($t_{(18)} = -10.843$, $p < .001$), significant increases in intercept (or baseline reaction time) ($t_{(18)} = -7.786$, $p < .001$), significant elevations in slope ($t_{(18)} = -5.5$, $p < .001$) indicating longer rotation rates, and significant rises in error rates ($t_{(18)} = -5.192$, $p < .001$) as would be expected from an increase in difficulty. It is hard to know what is happening in the S/N, N/S, and N/N groups that make them different from the S/S group, since in general, all the results lie in the same direction. All groups, for instance, show tendencies for larger intercepts and longer reaction times. Groups S/S and N/S show trends for increases in slope. Though the performances differ as to the values of the correlation coefficients, it is not clear whether the change in correlations reflects the use of alternate processing strategies or whether it reflects a significant increase in performance variability. None of the measures, not even error rate, can give us a clue as to the validity of one or the other hypothesis.

This leads us to the conclusion that perhaps subjects should be given more practice in the event that they eventually all may be successful in maintaining a reliable and consistent mental rotation strategy. An increase in trials in the L/S and particularly the 3D/S conditions may be compensated for by eliminating the memory conditions. The data suggests that the parameters or characteristics of the memory trials are not selectively conducive to the use of mental rotation to accomplish the task and hence these conditions are not suitable for our purposes, namely, to test spatial abilities including memory for visual patterns, related to the operation of mental rotation. Some other type of task will have to be devised in order to get at the memory aspects of rotation.

The letters/memory condition, in particular, alerted us to the possibility of interference stemming from verbal-labeling. In order to avoid the use of verbal strategies and in the light of the effect on performance of stimulus complexity, it is thought that in future work letters should be replaced by simple yet novel patterns lacking in any distinctive features.

Chapter 5

Results and Discussion for the Visual Scan Task

In the visual scan paradigm, a linear relationship between critical row and reaction time means that a scanning strategy was adopted to perform the task. "Linearity implies that the time taken to scan each item does not change from one end of the list to the other" (Neisser, 1963). The higher the correlation between these two variables, reaction time and target row location, the steadier and more systematic the scanning behavior is purported to be. Task difficulty is reflected in elevations in slope, reaction time, and intercept. Interpretation of results is more straightforward in this task than in mental rotation because alternate strategies from scanning appear to be correlated with poorer results. It should be pointed out that in this task, none of the measures (r, m, b, and RT, that is, correlation, slope, y-intercept, and reaction time, respectively) can be looked at in isolation. High average reaction times may represent an increase in slope, that is, an increase in scanning time per row. Or high mean reaction times may represent an erratic scanning behavior on some of the trials. Qualitatively different types of performance, then, can be depicted by the same statistic. For this reason, all measures are necessary in order to obtain a true picture of performance.

Figure 4 through 8 were constructed by averaging the reaction times across all subjects for each critical row for each of the ten conditions and plotting them against the critical rows. Row length, trial type (present or absent), number of target letters, distractor items, and characteristics of the context letters all had their own effects on the overall data. Though the group results indicate trends, the main emphasis in this study is on individual differences in task performance over and above constant individual factors. For this reason, no statistical tests were conducted on the group data, it is only described to help in the interpretation of tendencies within individuals.

Doubling row length from 4 letters to 8 letters causes processing time to increase, a finding reported by Neisser (1971). As depicted in Figures 4 and 5, slope becomes elevated ($m_{\mathrm{Four}\ 1}$ = .389; $m_{\mathrm{Eight}\ 1}$ = .836; $m_{\mathrm{Four}\ 0}$ = .546; $m_{\mathrm{Eight}\ 0}$ = .778) as does intercept ($b_{\mathrm{Four}\ 1}$ = 7.28; $b_{\mathrm{Eight}\ 1}$ = 10.20; $b_{\mathrm{Four}\ 0}$ = 5.25; $b_{\mathrm{Eight}\ 0}$ = 6.047) as the number of letters increases. The range of reaction times across critical rows for the FOUR (4 letter) conditions is from approximately 5-7 seconds to about 23-26 seconds, whereas the range for EIGHT 1 and EIGHT 0 is between about 8-12 seconds to 36-40 seconds, not quite twice as long, as pointed out by Neisser (1963). Correlations, on the other hand, did not differ that much ($r_{\mathrm{Four}\ 1}$ = .879; $r_{\mathrm{Eight}\ 1}$ = .848; $r_{\mathrm{Four}\ 0}$ = .977; $r_{\mathrm{Eight}\ 0}$ = .970), indicating that despite row length changes, the strategy of the scanning behavior for the two types of lists (present and absent) was not affected by row length.

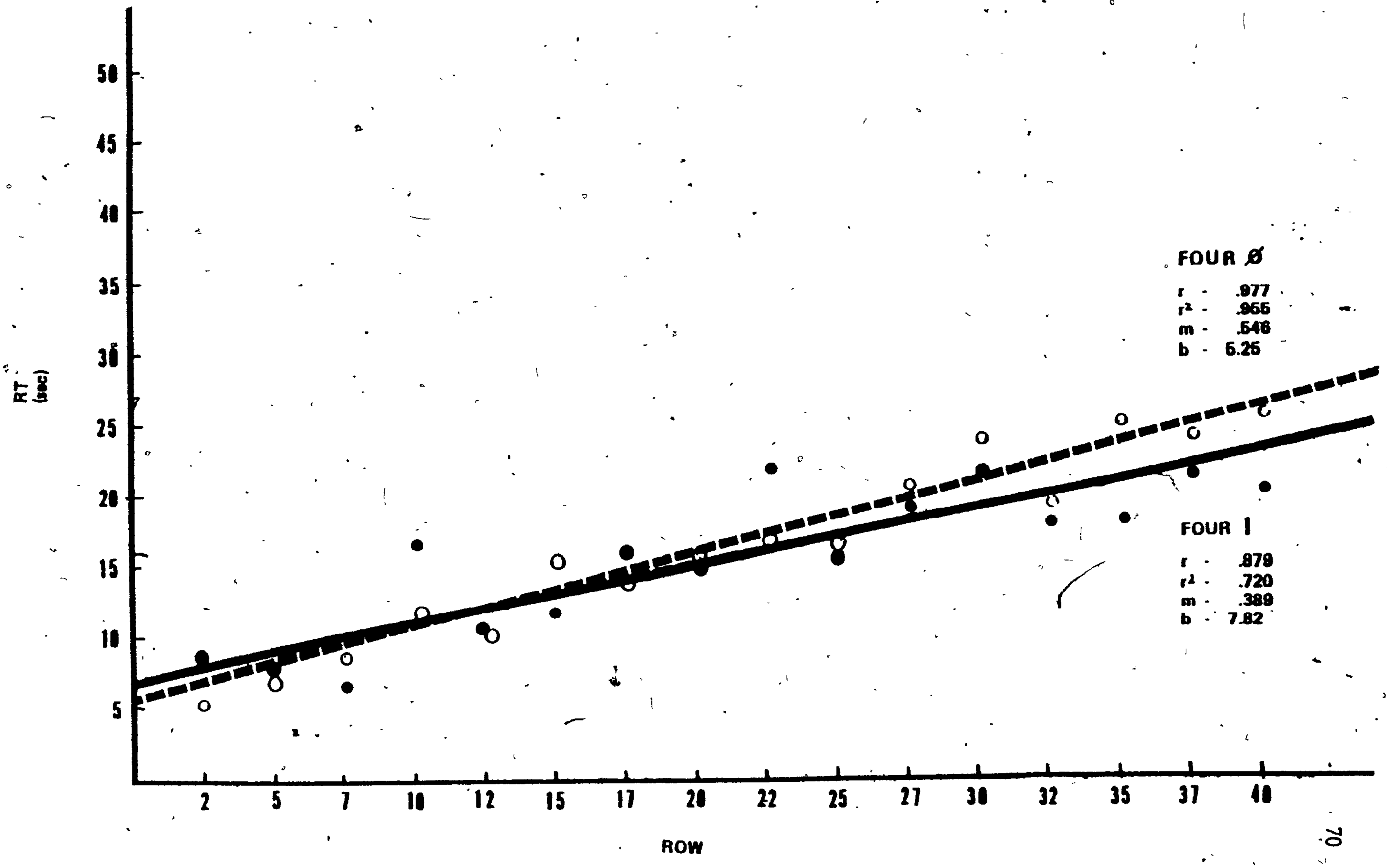


FIGURE 4 - Mean reaction time as a function of critical row for conditions FOUR 1 and FOUR 0

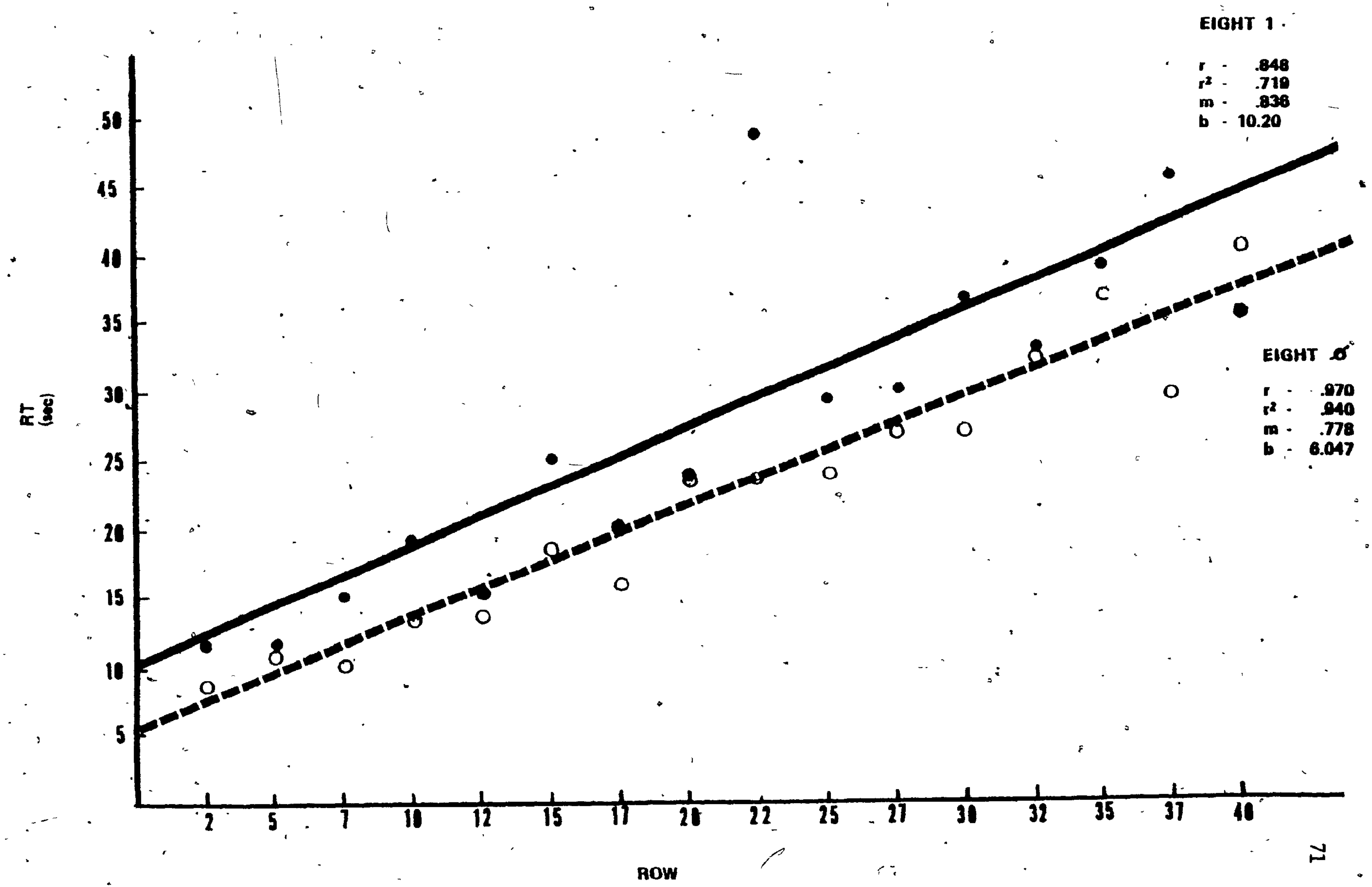


FIGURE 5 - Mean reaction time as a function of critical row for conditions EIGHT 1 and EIGHT 0

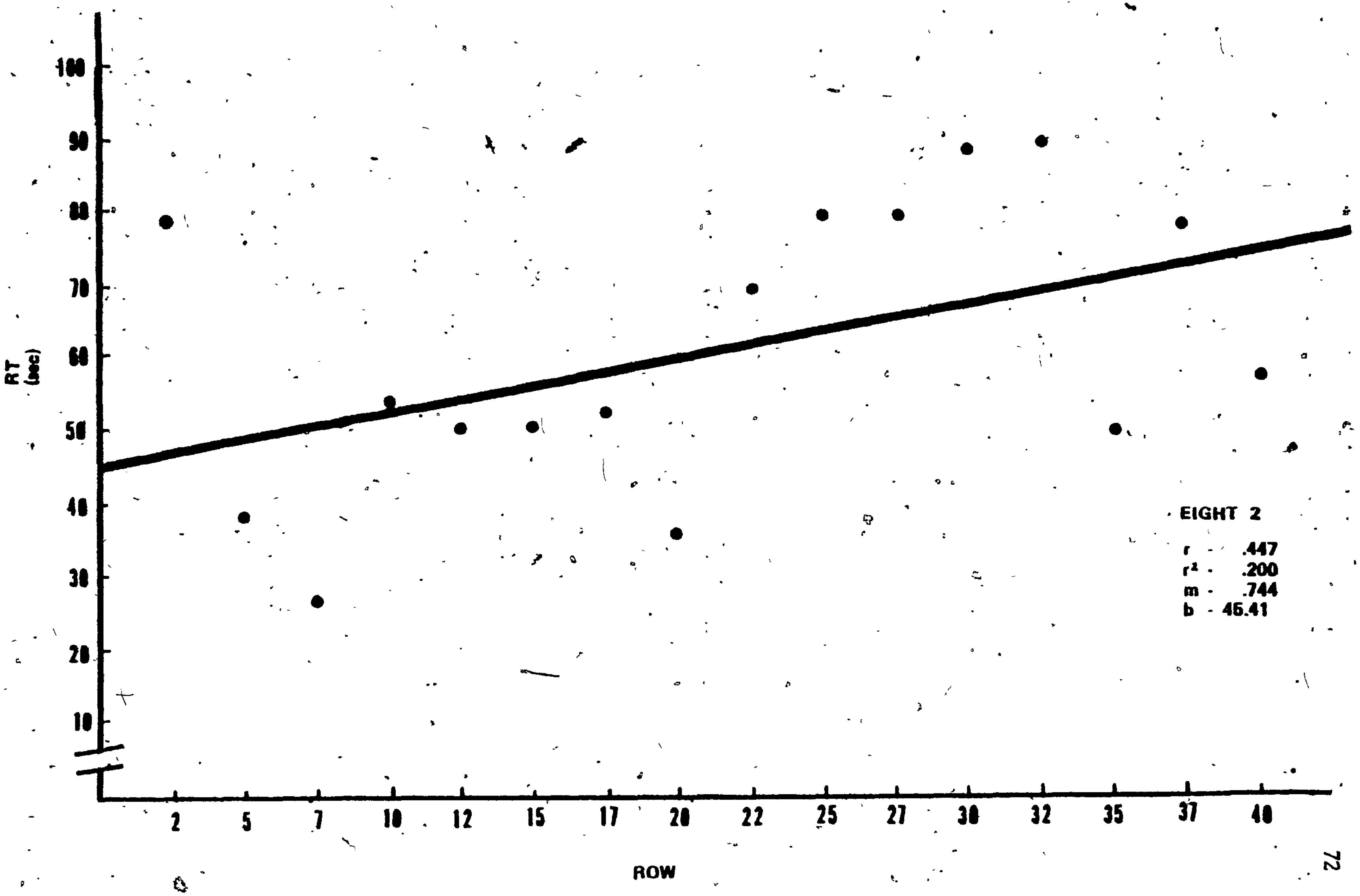


FIGURE 6 - Mean reaction time as a function of critical row for condition EIGHT 2

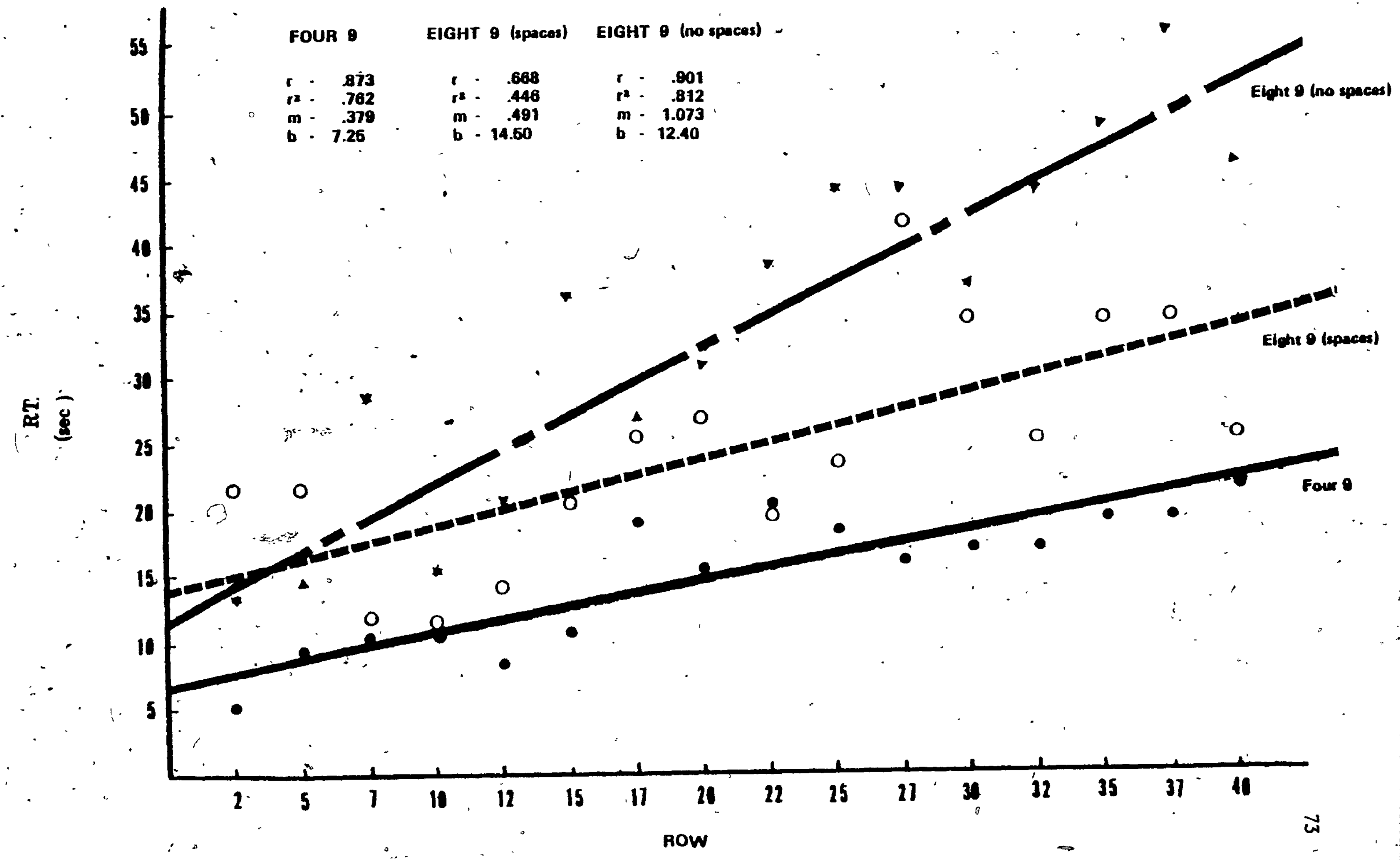


FIGURE 7 - Mean reaction time as a function of critical row for conditions FOUR 9, EIGHT 9 (space), and EIGHT 9 (no space)

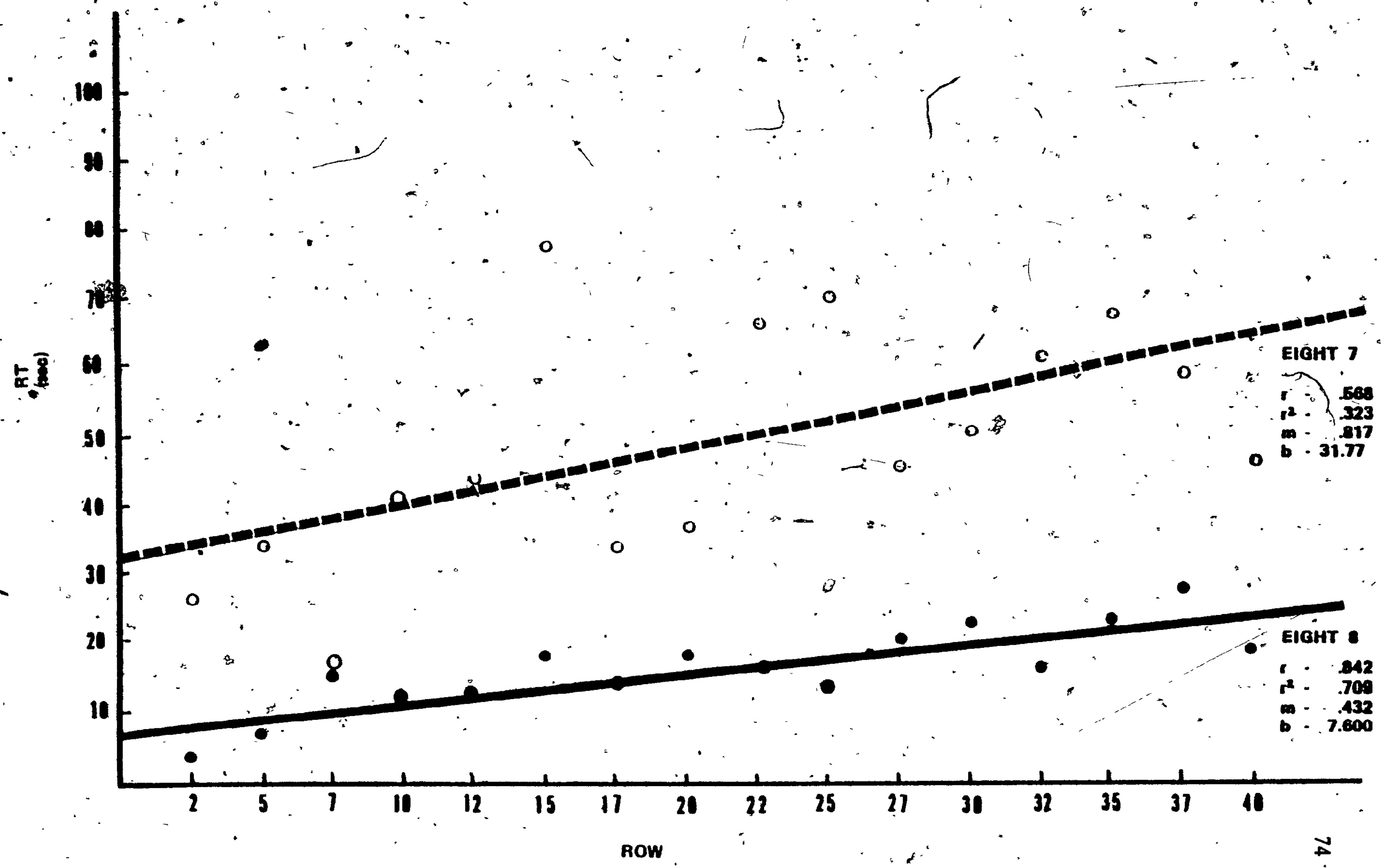


FIGURE 8 - Mean reaction time as a function of critical row for conditions EIGHT 8 and EIGHT 7

Neisser's well-practiced subjects became extremely efficient at performing the "present" conditions over and above the "absent" conditions. Neisser explains this finding by arguing that the effect of priming was most acute in his highly trained subjects, causing the critical property to be picked up and processed in every line in the absent condition. Because of this, the "absent" condition can never exceed the "present" condition in speed even in highly trained subjects. In the present data, this finding of longer processing time in "absent" conditions was only found in the 4 letter conditions, FOUR 1 and FOUR 0 ($m_{\text{Four 1}} = .389$; $m_{\text{Four 0}} = .546$). In the 8 letter conditions, subjects had higher slopes, as a whole, in the EIGHT 1 condition ($m_{\text{Eight 1}} = .836$; $m_{\text{Eight 0}} = .778$). This discrepancy may arise as a result of lack of inadequate practice at the task. Another interesting aspect of "absent" conditions deemed from the data, is the fact that these lists, in particular, induce the adoption of a very systematic scanning strategy among individuals as reflected by the very high correlation coefficients evident in the "absent" conditions ($r_{\text{Four 0}} = .977$; $r_{\text{Eight 0}} = .970$). In general as well, intercepts in the "absent" conditions are lower ($b_{\text{Four 1}} = 7.28$; $b_{\text{Four 0}} = 5.25$; $b_{\text{Eight 1}} = 10.20$; $b_{\text{Eight 0}} = 6.047$) supporting the notion that there is a lower probability in "absent" lists for subjects to miss the target letter than in "present" lists.

EIGHT 2 shows a profile of results, found in Figure 6, typical of unsystematic, erratic search. The low correlation and high intercept indicates unreliable performance ($r = .447$; $b = 45.51$). Though linearity exists, the variability about the best fit line for this trend is very large.

The three distractor conditions (Figure 7) produced very interesting results across subjects. They seem to emphasize the importance of having the scanning response be continuous, regular, unbroken, automatic, for maximum efficiency. It was the condition in which the distractors were context letters but were separated from the center relevant 4 letters (EIGHT 9 space) that caused subjects, taken as a group, to go out of kilter as shown by the relatively low correlation ($r = .668$) and large intercept ($b = 14.5$) for this condition. A description of what might be going on in EIGHT 9 space could be that subjects were trying to avoid scanning through the exterior letters, resulting in a disruption of the fluidity of the scanning behavior. Search becomes more disoriented. The XX distractor condition, FOUR 9, actually yielded almost identical results to FOUR 1 ($r_{\text{Four 1}} = .879$, $r_{\text{Four 9}} = .873$; $m_{\text{Four 1}} = .389$, $m_{\text{Four 9}} = .379$; $b_{\text{Four 1}} = 7.28$, $b_{\text{Four 9}} = 7.25$), and hence can not be said to have induced distraction. The EIGHT 9 (no space) trials showed evidence of a regular search pattern though the distractors affected subjects in such a way as to cause them to have longer scanning times, in that slope was elevated ($m = 1.073$) from the regular EIGHT 1 condition ($m = .836$).

Figure 8 shows clearly the effect that the physical [illegible]racteristics of target and context can have on search behavior. [illegible]sparity in features between target and context letters, as in

EIGHT 8, permits scanning to be speedy and systematic, reflected in the shallow slope (m = .432) and strong correlation (r = .842) in comparison even to EIGHT 1. The increase in scanning speed would be explained by Neisser to arise from the possibility of a more significant priming effect because of the minimal feature overlap between target and context. EIGHT 7, on the other hand, in which the target and context letters share certain feature characteristics had the effect of causing subjects, as a whole, to sacrifice attentional efficiency for scanning speed. That is, the slope (m = .817) is similar to the EIGHT 1 condition but because of the reduction in priming distinctiveness, subjects tended to often miss the target on the first scan. Intercept is augmented on account of the reduction in search accuracy (b = 31.77) and the correlation falls (r = .568).

Though the group data lies basically in the directions reported by Neisser (1963), the overall pattern of results may be misleading with respect to individual performance. Of particular interest is the assessment of scanning strategy across these various conditions for each individual. The data was reorganized to permit the range of individual differences across the different conditions to become more obvious. For this purpose, contingency tables were set up (Tables 7a-7j) in order to make pairwise comparisons between some of the logically related conditions. The tables were constructed in the following manner. Since the correlation coefficient is a good measure of scanning performance, each subject's r for each of the tasks was evaluated as being either

Table 7

Contingency tables for the visual scan tasks

Table 7a

		Four O		
		significant	nonsignificant	
Four 1	significant	18	1	19
	nonsignificant	12	9	21
		30	10	40

Table 7b

		Eight O		
		significant	nonsignificant	
Eight 1	significant	19	1	20
	nonsignificant	16	4	20
		35	5	40

Table 7c

		Eight O		
		significant	nonsignificant	
Four O	significant	29	1	30
	nonsignificant	5	5	10
		34	6	40

Table 7d

		Four 9		
		significant	nonsignificant	
Four 1	significant	13	6	19
	nonsignificant	4	16	20
		17	22	39

Table 7e

		Eight 9 (space)		
		significant	nonsignificant	
Eight 1	significant	9	10	19
	nonsignificant	6	14	20
		15	24	39

Table 7f

		Eight 9 (no space)		
		significant	nonsignificant	
Eight 9 (space)	significant	7	8	15
	nonsignificant	10	14	24
		17	22	39

Table 7g

		Eight 1		
		significant	nonsignificant	
Four 1	significant	11	8	19
	nonsignificant	9	12	21
		20	20	40

Table 7h

		Eight 8		
		significant	nonsignificant	
Eight 1	significant	11	8	19
	nonsignificant	11	9	20
		22	17	39

Table 7i

		Eight 2		
		significant	nonsignificant	
Eight 1	significant	5	15	20
	nonsignificant	3	17	20
		8	32	40

Table 7j

		Eight 7		
		significant	nonsignificant	
Eight 8	significant	8	14	22
	nonsignificant	1	16	17
		9	30	39

significant or nonsignificant according to a predetermined criteria, namely, the .05 level of significance for correlation coefficients for df = 14 (r > .497). Frequencies for the four cells in each of the contingency tables were then obtained by grouping subjects according to their performance patterns (i.e., S/S or significant/significant, S/N or significant/nonsignificant, N/S or nonsignificant/significant, N/N or nonsignificant/nonsignificant). One subject's data could not be used in five of the condition comparisons.

Let us begin with a look at how the same individuals performed under both the FOUR 1 and FOUR 0 conditions. The contingency table (Table 7a) representing this comparison shows a distribution, which under the corrected level of significance ($p < .003$) demonstrates a nonsignificant association chi square ($X^2 = 5.647$, df = 1, $p < .02$) but it was at least in the desired direction for meaningful performance assessment within subjects. Unfortunately, there was quite a strong tendency for change in scanning performance within subjects ($X^2 = 7.692$, df = 1, $p < .007$) even though it did not reach significance under the stricter alpha level adopted. The above means that scanning behavior in one condition is not a good indicator of scanning behavior in the other condition. While only about half of the subjects showed systematic scanning in FOUR 1 (as represented by their significant r's), about 3/4 of the subjects scanned systematically in FOUR 0. This finding is consistent with the group data describing these two conditions. Here again the "absent" condition stands out as being able to induce regular, systematic search in subjects.

Comparison of EIGHT 1 and EIGHT 0 (Table 7b) shows no association between performance across the two tasks (X^2 = .914, df = 1, p = ns) and furthermore, the change in the distribution of significant to nonsignificant is significant (X^2 = 11.529, df = 1, $p < .001$). As in the FOUR letter conditions, EIGHT 1 only had half of the subjects performing systematic search while EIGHT 0 had 35 subjects performing above criterion. Again, this is consistent with group findings which suggest that subjects may need more practice in the "present" conditions in order to develop a more robust search strategy.

Three comparisons (Tables 7g, 7h, and 7c) believed to be straightforward ways of obtaining consistent changes in performance within individuals are those between FOUR 1 and EIGHT 1, EIGHT 1 and EIGHT 8, and FOUR 0 and EIGHT 0. The first two of these comparisons, strangely enough, yielded contingency tables (Tables 7g and 7h) reflecting random distributions. There were no associations (X^2 = .902, df = 1, p = ns and X^2 = .033, df = 1, p = ns, respectively) and no consistent trend regarding change in performance (X^2 = .059, df = 1, p = ns and X^2 = .474, df = 1, p = ns, respectively). Furthermore, only about half of the subjects had significant r's in EIGHT 1. Similarly, EIGHT 1 and EIGHT 8 showed this division among subject performance. Comparison of the "absent" conditions, however, revealed change in performance characteristics in the direction optimal for making valid performance assessments of individuals. That is, there was a trend towards a significant association chi square (X^2 = 6.171, df = 1, $p < .02$), showing that performance traits within individuals was related across the two conditions, and furthermore, there was no significant indication of change in performance ($X^2 = 2.286$, df = 1, p = ns). In this case, 29 subjects performed above criterion in both tasks, only 4 did not reach criterion in either task, and 7 in all underwent a change in scanning behavior.

Comparisons of each individual's performance with one target letter and with two target letters showed the two tasks not to be fundamentally related (Table 7i). In addition, only 5 subjects out of 40 had the ability to engage in systematic scan across the two conditions, leaving 32 subjects unable to adequately perform the EIGHT 2 condition. For this reason, performance on EIGHT 2 can not be compared to performance on any of the other conditions. EIGHT 7 also produced a distribution similar to EIGHT 2 in that 30 of the 40 individuals did not find it possible to engage in systematic search. Only 8 individuals were successful in scanning both EIGHT 7 and EIGHT 8 (Table 7j) in a systematic fashion. These findings showing that the majority of subjects are unable to do EIGHT 2 and EIGHT 7, give support to the overall data which is characterized by great variability. Furthermore, this variability can be said to arise not merely from just a few very poor subjects.

Condition FOUR 9 turned out to produce similar results within individuals to FOUR 1 (Table 7d), a finding also found in the group data. There was significant association between these two tasks ($X^2 = 9.291$, df = 1, $p < .003$) and no significant change in performance ($X^2 = .400$, df = 1, p = ns). However, as with FOUR 1, only about half of the subjects attained significant r's in FOUR 9. Hence, though these two tasks are related in terms of performance, the tasks themselves are not clear-cut in the scanning strategy they provoke. Perhaps, by giving subjects additional practice this effect could be ameliorated and perhaps a slight difference between FOUR 1 and FOUR 9 could be obtained. As it is, however, the two tasks show no gradation in difficulty and hence the end effect is as if FOUR 1 were presented twice, and hence FOUR 9 is redundant.

The two remaining comparisons made with distractor conditions, namely, EIGHT 1 and EIGHT 9 (space), and EIGHT 9 (space) and EIGHT 9 (no space). Tables 7e and 7f present the results which appear to be randomly distributed across each of the contingency tables. Neither association chi squares ($X^2 = 1.242$, df = 1, p = ns and $X^2 = .094$, df = 1, p = ns, respectively) nor the change chi squares ($X^2 = 1.00$, df = 1, p = ns and $X^2 = .222$, df = 1, p = ns, respectively) were significant.

Hence, the only worthwhile comparisons in performance within individuals turned out to be between FOUR 1 - FOUR 0 and particularly between FOUR 0 - EIGHT 0. Perhaps, with more practice, EIGHT 1 versus EIGHT 0 may also become a useful comparison. In other words, FOUR 1, FOUR 0, and EIGHT 0 together were able to reveal consistent individual differences among subjects.

Let us now examine in more detail what the scanning performance per se looks like within each of the performance profile groups (i.e., S/S, S/N, N/S and N/N) across FOUR 1 - FOUR 0 and EIGHT 1 - EIGHT 0 and FOUR 0 - EIGHT 0. Tables 8a, 8b, and 8c present the mean correlations, slopes, intercepts, and reaction times for the subgroups in the three comparisons. Performance of the S/S groups for the FOUR 1 - FOUR 0 and EIGHT 1 - EIGHT 0 comparisons resulted in no significant changes on any of the measures taken, namely, m, b, and RT. Only the slope in the EIGHT comparison revealed a tendency to be higher in the "present" condition ($t_{(18)} = 2.432$, $p < .05$), a finding already mentioned in the discussion of the group data. This trend, opposite to that reported by Neisser (1963), is taken to imply that our subjects were not adequately practiced. The lack of significant change within these groups indicates that a consistent scanning strategy was maintained across both types of lists. The S/N group consists of only one person in both comparisons (FOUR and EIGHT) and in both cases this subject shares a similar performance profile to the S/S group, that is, no significant changes in any of the measures. Furthermore, each of the two subjects had average intercept values in the second condition (FOUR 0 and EIGHT 0, respectively) which way exceeded the intercept value in these conditions for the S/S groups. It appears therefore that both of these subjects were having difficulty with the "absent" lists. On the contrary, subjects in the N/S groups for the two comparisons (FOUR and EIGHT) revealed signs of poor performance on the "present" conditions. The average slopes for both N/S groups were low in comparison to those of the S/S groups, while the intercepts were

Table 8

Mean correlations, slopes, intercepts, and reaction times according to types of performance in two visual scan conditions

Table 8a FOUR 1 versus FOUR 0

Condition	Types of Performance							
	S/S (N = 18)		S/N (N = 1)		N/S (N = 12)		N/N (N = 9)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	Correlation (r)							
Four 1	.750		.624		.240		.165	
Four 0	.925		.406		.935		.240	
	Slope (m)							
Four 1	.586	.292	.735		.269	.261	.090	.305
Four 0	.679	.205	.525		.726	.454	.216	.241
	Intercept (b)							
Four 1	2.875	2.485	3.865		12.555	2.130	12.945	12.981
Four 0	2.456	1.903	15.817		2.130	6.332	12.991	3.945
	Mean Reaction Time (RT)							
Four 1	15.33	5.92	19.30		18.184	8.116	14.893	8.457
Four 0	16.69	4.58	26.85		15.088	2.817	15.593	6.566

Table 8b EIGHT 1 versus EIGHT 0

Condition	Types of Performance							
	S/S (N = 19)		S/N (N = 1)		N/S (N = 16)		N/N (N = 4)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	Correlation (r)							
Eight 1	.790		.980		.278		.020	
Eight 0	.720		.458		.885		.180	
	Slope (m)							
Eight 1	1.148	.529	.731		.652	.590	-.018	.374
Eight 0	.844	.203	.764		.851	.312	.196	.305
	Intercept (b)							
Eight 1	2.280	5.991	3.606		16.004	10.106	29.222	14.049
Eight 0	2.962	2.608	17.185		4.318	3.829	23.949	11.313
	Mean Reaction Time (RT)							
Eight 1	24.129	14.314	31.24		30.42	12.873	28.485	13.144
Eight 0	20.679	4.288	33.22		22.328	4.901	27.995	5.124

Table 8c FOUR 0 versus EIGHT 0

Condition	Types of Performance							
	S/S (N=29)		S/N (N=1)		N/S (N=5)		N/N (N=5)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	Correlation (r)							
Four 0	.936		.980		.366		.138	
Eight 0	.907		.488		.804		.243	
	Slope (m)							
Four 0	.647	.186	.731		.375	.178	.119	.256
Eight 0	.863	.233	.764		.873	.306	.216	.207
	Intercept (b)							
Four 0	2.438	1.830	3.606		11.891	3.448	14.654	4.592
Eight 0	3.142	3.068	17.185		5.432	3.857	20.363	12.608
	Mean Reaction Time (RT)							
Four 0	15.975	4.005	18.964		19.773	5.062	17.159	3.990
Eight 0	21.265	4.322	33.221		23.768	4.852	24.893	8.236

higher. The N/N group showed lack of scanning ability in both the "present" and "absent" conditions for both the FOUR and EIGHT comparisons. Both N/N groups evidenced low slopes and high intercepts in comparison to the S/S groups. In general, however, reaction times across all the groups for both comparisons were fairly consistent which means that subjects in the S/N, N/S, and N/N groups forfeited accuracy for speed.

Finally, the S/S group for the FOUR 0 - EIGHT 0 comparison yielded tendencies towards significance in the expected directions, namely, increased slope ($t_{(28)} = -6.686$, $p < .001$). Intercept, on the other hand was not affected ($t_{(28)} = -1.170$, p = ns). Thus, while a consistent scanning strategy was maintained, processing time per row increased as the number of letters per row was increased. This picture fits the overall data trends as well as the findings observed by Neisser (1963). As in the above two comparisons, the S/N group, again composed of one person in this case, had difficulty with the second condition, namely, EIGHT 0. His average intercept value is much higher than that of the S/S group, indicating unsystematic scanning. Similarly, the N/S group performs poorly on the first condition (FOUR 0) as indicated by their low mean correlation and high average intercept in that condition in comparison to the values of these measures for the S/S group. Finally, the N/N group appears to have difficulty with both of the tasks since their mean slope is low and the mean intercept is high with respect to the S/S group.

It should be mentioned that sex and task ability were not related. There was also no relationship within subjects between competence in the mental rotation task and competence in the visual scan task. That is, knowledge of an individual's performance in one task was not helpful in predicting his performance in the other task. Because of the lack of adequate representation of all age groups within the range covered by the subject sample, no conclusions pertaining to task performance and age could be made.

Chapter 6

Experimental Test Performance and the Luria-Nebraska Neuropsychological Test Battery

Table 9 gives both the range of scores and the median scores all subjects, except for four who were unavailable for testing, for each of the subtests of the Luria-Nebraska Test and for the total score. Figure 9 shows the distribution of total scores for all subjects.

The question addressed in this section of the paper is whether individual differences in performance across the various tasks evident both in the mental rotation and the visual scan paradigms are consistently related to the Luria Vision subtest and Luria Memory subtest which represent an independent, standardized measure of visual and memory functioning. These two subtests were selected on the basis of their face value relationship with the two experimental paradigms and because sufficient variability was obtained between subjects in these scores.

To begin with, it was necessary to choose a measure from the mental rotation task which best represented each subject's overall ability in performing the spatial operations inherent to the experimental task. It was settled that the change in total error scores obtained by comparing error scores from one condition to those from another more difficult condition would be used, since these measures are taken to be indicative of performance successfulness regardless of strategy adopted. In particular, the two scores used were the difference in total errors (that is, the sum of errors made on "same" pairs, plus errors made on "different" pairs) between the 3D simultaneous condition and the 3D/memory condition and between the letters/simultaneous and the 3D/simultaneous conditions. When multiple correlations were computed relating both the vision and memory subtests to the two change in total error scores, both values were significant at the .05 level for the derived critical value of $r_{1.23}$ which is R = .385 (df = 2,40, $p < .05$). The multiple correlation relating change in errors from 3D/simultaneous to 3D/memory to the subtests is $r_{1.23} = .449$ and the multiple correlation between the change in errors from letters/simultaneous to 3D/simultaneous and the subtests is $r_{1.23} = .413$.

With regards to the visual scan task, change in slope from one condition to the next was used as a measure of visual scanning competence and this measure was tested for association with the Luria subtests by a multiple correlation computation. The association between the vision and memory subtest scores and the change in slope with respect to conditions FOUR 1 and FOUR 0 yielded a multiple correlation of $r_{1.23} = .144$ (df = 2,40; p = ns), when actually a negative correlation is expected since the change in slope from FOUR 1 to FOUR 0 is negative. Similarly, when the multiple correlation is computed with respect to the change in slope from FOUR 0 to EIGHT 0, the correlation obtained is again in

Table 9

Luria-Nebraska Neuropsychological Test Battery Scores (Subtest scores and total summary score)

Luria Total
range: 1.5 - 57.7
median: 17.28

Luria Vision
range: 0 - 11
median: 2.125

Luria Memory
range: 0 - 8
median: 1.93

Luria Vision plus Memory
range: 0 - 13
median: 5.16

Luria Motor
range: 0 - 8
median: 2.2

Luria Acoustic
range: 0 - 7
median: 1.75

Luria Tactile
range: 0 - 8
median: 0.4

Luria Arithmetic
range: 0 - 6
median: 0.5

Luria Intellectual
range: 0 - 20
median: 5.1

Luria Expressive
range: 0 - 9
median: 0.86

Luria Writing
range: 0 - 4
median: 0.17

Luria Receptive
range: 0 - 2
median: 0.28

Luria Reading
range: 0 - 3
median: 0.17

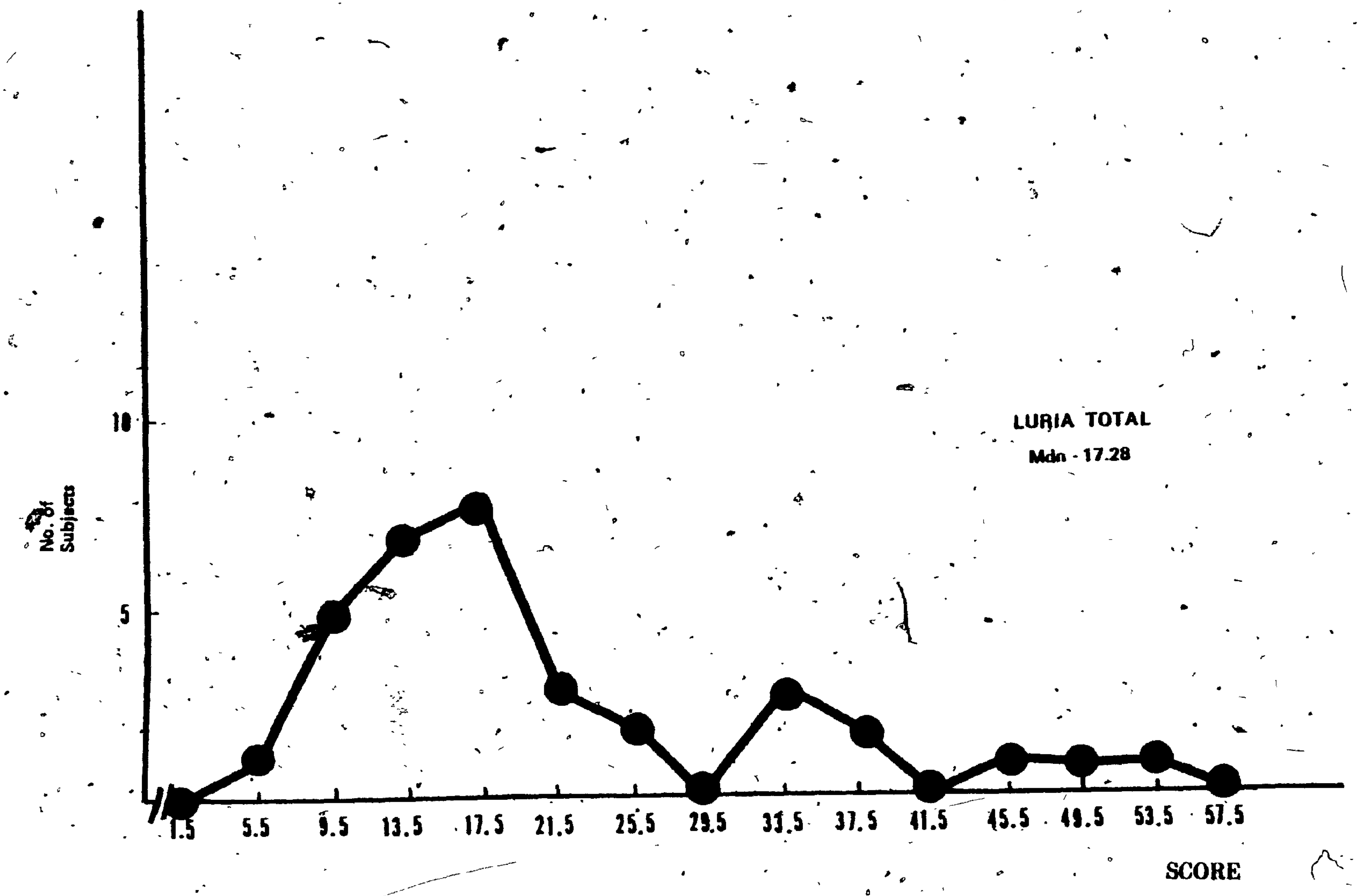


FIGURE 9 - . Frequency distribution for Luria total score

the wrong direction ($r_{1.23}$ = .128, df = 2,40; p = ns) since it should also be in the negative direction.

These findings have two possible interpretations. One is that scanning strategy is not associated with the functions tapped by the Luria-Nebraska Vision and Memory subtest. The other possibility is that, for example, the S/S subjects' performance across the tasks is related to the Luria by some trend, let us say, a negative linear trend, while the remaining subjects making up groups S/N, N/S, and N/N may not be correlated with the Luria on account of more variability within their visual scan measures. The overall outcome, then, upon combining the data is the lack of meaningful relationship.

In order to explore this second hypothesis further, two frequency distributions were set up representing the number of subjects within each of the performance profile groups (S/S, S/N, N/S, N/N) across FOUR 1 - FOUR 0 and then FOUR 0 - EIGHT 0 who obtained joint Vision plus Memory scores above and below the median for the total group joint score. Unfortunately, the cell frequencies were not large enough to warrant the use of chi squares and hence no conclusion could be made with respect to the second hypothesis.

Chapter 7

General Discussion and Conclusions

The purpose of this study was to describe individual differences in performance in a task involving spatial abilities, namely, mental rotation, and in a task involving selective attention, namely, visual scan in untrained subjects. In order to partial out uninteresting constant personal response factors, subjects were tested across a series of conditions, defined on an a priori basis to be of graded difficulty, within each paradigm.

With respect to mental rotation, the conditions which were most successful in allowing us to obtain relevant evidence of consistent individual differences in performance as a function of increasing task difficulty were Letters/Simultaneous and 3D/Simultaneous. It turned out that the memory conditions introduced more performance variability than could be easily explained by an increase in task difficulty from the simultaneous mental rotation conditions. Interpretations of the memory data then can only be speculative, since the results reflect the use of strategies other than mental rotation.

Two suggestions for improvement of the mental rotation paradigm follow from some findings in the data. Firstly, it was brought up in letter conditions that subjects may have taken advantage of verbal labeling. In order to prevent the use of verbal strategies, it is suggested that in future, letter stimuli be replaced by simple yet novel nonsense patterns, lacking any apparent distinctive features.

Secondly, since most, if not all normal subjects should be able to perform at least the baseline task to criterion (namely, mental rotation with simple patterns), then more practice should be given to subjects. In addition, in order to increase the number of subjects performing to criterion in the 3D trials, the 3D task could perhaps be made a little simpler by constructing 3D stimuli which can be rotated in the picture plane instead of in depth. Though Shepard and Metzler's highly trained subjects could perform in both these rotations with equal ease, a difference may be noticed in relatively unpracticed subjects.

In the visual scan paradigm, changes in row length and in type of list, present/absent, were two parameters which yielded consistent individual differences in change in performance. The other conditions representing the other manipulations either produced redundant results or did not yield consistent trends in change in performance within individuals. Conditions apart from FOUR 1, FOUR 0, EIGHT 1, and EIGHT 0 need not be presented in future studies. In order to increase the number of subjects attaining criterion on these four tasks, practice trials should be permitted to subjects to give them a chance to develop a systematic scanning strategy.

In general, then, more trials in the prime conditions in the two paradigms should be administered so that practice effects can be minimized and the probability of meeting criterion in all conditions can be increased. It must be kept in mind, however, that the length of the test session must be as short as possible since the tests will also be administered to neurological patients. Therefore, decisions concerning practice-time to be allotted and conditions to be selected must be made parsimoniously. The restriction in the variability in performance of normal individuals that must be aimed for, is an important concern in the light of the fact that when it comes time to test the patient population of recently diagnosed HD patients and persons at-risk for the disease, we will want to be able to assume with some confidence that normals fall above a certain range in performance, relative to task criterion.

Once normal subjects have been tested under the new improvements proposed, the next step in this research project is to test recently diagnosed-HD individuals on the two paradigms and describe their characteristic range of individual differences across the tasks. At the same time certain control groups should be assessed as well, in order to determine the selectivity of the test measures vis à vis different neurological dysfunctions. For the moment we are contemplating testing recently diagnosed Parkinson's patients because of the fact that both Parkinson's disease and HD stem from basal ganglia pathology (extrapyramidal-motor system), and Korsakoff's syndrome patients and maybe frontal lobe-lesioned patients because of the similarity of their cognitive deficits to that of HD patients.

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