PERFORMANCE ON ELEMENTARY COGNITIVE TASKS IN DOWN SYNDROME
AND FRAGILE X SYNDROME

by

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# Table of Contents

Signature Page ........................................................................................................... 2

List of Tables .............................................................................................................. 6

List of Figures ............................................................................................................. 8

Abstract ..................................................................................................................... 9

Introduction ............................................................................................................... 11

   The System Theory of Intelligence________________________________............... 11

   The Heritability of Intelligence______________________________________________ 19

   The g Factor and Elementary Cognitive Tasks_______________________________ 21

   Chronometric Task Performance by Mentally Retarded Individuals_____ 25

   Overview of Down Syndrome ........................................................................... 28

   Neuroanatomical and Neurofunctional Findings in Down Syndrome ____ 29

   Down Syndrome and Cognition ........................................................................ 31

   Overview of Fragile X Syndrome ..................................................................... 33

   Neuroanatomical and Neurofunctional Findings in Fragile X Syndrome _ 34

   Fragile X and Cognition .................................................................................... 36

   Comparisons Between Down Syndrome and Fragile X Syndrome ____ 39

   Theoretical Justification ..................................................................................... 43

Methods .................................................................................................................... 44

   Subjects ............................................................................................................... 44

   Wechsler Adult Intelligence Scale __________________________________________ 45

   Cognitive Abilities Test _____________________________________________________ 45

   Subject Debriefing ............................................................................................. 47
List of Tables

Table 1: *Summary of differences on cognitive tasks for Down Syndrome and Fragile X Syndrome.*

Table 2: *Previous research comparing Down Syndrome and Fragile X Syndrome on cognitive tasks, including sample sizes.*

Table 3: *WAIS-III subtest descriptions, reliability coefficients, and first factor loadings.*

Table 4: *Post Hoc Power Analysis for ANOVA, p < .05.*

Table 5: *Compromise Power Analysis for ANOVA.*

Table 6: *Post Hoc Power Analysis for Correlation, p < .05.*

Table 7: *Compromise Power Analysis for Correlation.*

Table 8: *Means and standard deviations of age and WAIS-III variables for Down Syndrome and Fragile X Syndrome, with and without outliers.*

Table 9: *Means and standard deviations of selected CAT variables for Down Syndrome and Fragile X Syndrome, with and without outliers.*

Table 10: *Split-half reliability coefficients for select CAT measures.*

Table 11: *Correlations between Full Scale IQ and select CAT measures.*

Table 12: *Factor analysis of WAIS-III subtests, including Arithmetic, unrotated solution.*

Table 13: *Factor analysis of WAIS-III subtests, including Arithmetic, rotated solution.*

Table 14: *Factor analysis of WAIS-III subtests, excluding Arithmetic, unrotated solution.*

Table 15: *Factor analysis of WAIS-III subtests, excluding Arithmetic, rotated solution.*

Table 16: *Rank-order correlations of WAIS-III first factor loadings in selected samples.*
Table 17: Factor analysis of select WAIS-III subtests for Down Syndrome, rotated solution.  

Table 18: Factor analysis of select WAIS-III subtests for Fragile X Syndrome, rotated solution.  

Table 19: First Component from a Factor Analysis of select CAT measures.  

Table 20: Factor analysis of select WAIS-III and CAT variables, rotated.  

Table 21: Factor analysis of select WAIS-III and CAT variables for Down Syndrome.  

Table 22: Factor analysis of select WAIS-III and CAT variables for Fragile X Syndrome.  

Table 23: Structure Matrix and Standardized Canonical Discriminant Function Coefficients for the WAIS-III measures.  

Table 24: Structure Matrix and Standardized Canonical Discriminant Function Coefficients for CAT measures.  

Table 25: Structure Matrix and Standardized Canonical Discriminant Function Coefficients for CAT and selected WAIS-III measures.  

Table 26: Difference scores and correlations for WAIS-III subtests for Down Syndrome and Fragile X Syndrome.  

Table 27: Difference scores and correlations for CAT measures for Down Syndrome and Fragile X Syndrome.
List of Figures

Figure 1: *Detterman’s System Theory of Intelligence* (Detterman, Peterson, & Frey, 2001) 123

Figure 2: *An elementary cognitive task, including a central process F and several potential peripheral processes* (Detterman, Peterson, & Frey, 2001) 124

Figure 3: *CAT Probed Recall and Stimulus Discrimination screen setup.* 125

Figure 4: *CAT Reaction Time screen setup.* 126

Figure 5: *WAIS-III mean subtest performance for FX and DS.* 127

Figure 6: *Estimated Marginal Means of WAIS.* 128

Figure 7: *Estimated Marginal Means of CAT.* 129
Performance on Elementary Cognitive Tasks in Down Syndrome and Fragile X Syndrome

Abstract

by

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The system theory of intelligence (Detterman, 1987) predicts that mental retardation is the result of a deficit in a central component of intelligence. Complex cognitive tasks should show little to no between-syndrome differences, while tasks that tap few central cognitive components, known as elementary cognitive tasks, may show differences. The aim of the current study is to test the system theory of intelligence by identifying differences in elementary cognitive task performance and on WAIS-III subtest performance between two genetic syndromes that cause mild and moderate mental retardation.

Participants were administered the Wechsler Adult Intelligence Scale-III (WAIS-III) and a portion of the Cognitive Abilities Test (CAT), a computer-based assessment measuring performance on a variety of simple cognitive tasks (Detterman, 1988). A discriminant analysis showed that several subtests of the WAIS-III and one of the CAT measures were able to predict group membership. Overall, the WAIS-III did a better job of predicting performance than the CAT.

While the current results do not go against the general predictions of the system theory, they do suggest that complex cognitive tasks are able to discriminate between genetic syndromes, challenging the hypothesis that mental retardation is the result of a
deficit in one or a few central components. Possible causes of between-syndrome differences are discussed.
Performance on Elementary Cognitive Tasks in Down Syndrome and Fragile X Syndrome

Genetic syndromes that cause mental retardation (MR) are of interest to researchers studying cognition and intelligence. Behavior, physiological irregularities, and genetic abnormalities can be correlated to obtain a clearer picture of normal intellectual functioning and to work towards treatments for those with mental retardation. Much research has focused on differences between individuals with MR and non-retarded individuals (MacKay & Bankhead, 1983); only recently have various genetic syndromes been compared to each other (Abbeduto et al., 2003; Bellugi, Lai, Wang, 1997; Hodapp et al., 1992; Powell, Houghton, & Douglas, 1997; Roberts et. al., 2005; Wang & Bellugi, 1994; Welsh & Elliot, 2001). In the current study, a comparison between two genetic syndromes on simple chronometric measures will be used to test a model of intelligence. While there are many studies documenting elementary cognitive task performance in individuals with MR, there are no studies comparing groups of individuals with specific genetic syndromes. The aim of the present study is to test the system theory of intelligence by identifying differences in elementary cognitive task performance between two genetic syndromes that cause mild and moderate MR.

The System Theory of Intelligence

Detterman (1987) proposes that intelligence is a complex system of independent elements that work together (Figure 1). Some of these elements are essential to the functioning of the entire system (central), while others have smaller effects on system functioning (peripheral). In Figure 1 central components are D, E, and F. Though a central component is defined in isolation, behavioral measurement of even a single
central component will depend on sensory and motor responses that can be considered peripheral components (Figure 2). For example, Caruso and Detterman (1983), suggest that a task such as stimulus discrimination includes cognitive components such as analyzing visual information, storing information in memory, retrieving information from memory, making a decision, and making a motor response.

Though central components are not currently specifically defined in the system theory, they are considered central to cognitive functioning. They likely include brain processes that control cognitive behaviors reflected in reaction time, inspection time, and memory (Luo & Petrill, 1999). In Figure 1, central component D might refer to speed of processing, while central component E might represent an aspect of working memory such as the visual-spatial sketchpad. Precise identification of central processes may require techniques like fMRI that can associate brain processes with behavior.

Though cognitive measures such as reaction time may reflect multiple central components, it is likely that they make use of fewer central components than those used by more complex cognitive processes, such as performance on a test of reading comprehension. Most complex cognitive tasks like those included in intelligence tests use all or most central components in a system. A complex cognitive task in Figure 1 might follow the path of A, D, E, F, G.

A complex task such as a subtest of an intelligence test will also employ peripheral components. In Figure 1 peripheral components are A, B, C, G, H, and I. Each of these components is used in some cognitive tasks, but unlike central components they are not as critical to overall system functioning because they are not involved in as many processes. For example, in a task like reaction time peripheral component A might be
defined as a visual orienting response, while peripheral component H might be defined as a motor output such as lifting a finger. As with central components, peripheral components are not currently defined in the theory.

A severe deficit in one central component will diminish performance on every complex cognitive task. The efficiency of the central components determines the level of functioning of the entire system. The system only functions as well as the least efficient central component. When system functioning is measured using complex cognitive tasks that require many central components, little difference is seen in performance on the tasks. All complex cognitive tasks show deficits because they all require the deficient central component (Detterman, 1987; Detterman & Daniel, 1989).

The system theory predicts that individuals with MR have deficits in central components, decreasing the efficiency of the entire system of intelligence. In MR individuals, complex tests of cognitive abilities correlate with each other because of central deficits. If even one central component is deficient, the entire system functions at a lower level (Detterman, 1987). According to the system theory, it is possible that two different genetic disorders will have deficits in different central components and yet not differ behaviorally on complex measures of cognitive ability.

A valuable illustration of the system theory of intelligence, based on hypothetical data, comes from Detterman, Petersen, and Frey (2001). Using the model in Figure 1 and N = 2,500, they generated random normal deviates for each of the basic components, A – I. Each simulation was performed ten times. Each path through the system was considered a cognitive process. This resulted in nine cognitive processes (ADEFG, ADEFH, etc.). The value assigned to a cognitive process represented the efficiency of
that process, and was the minimum value of any of the basic components included in that
cognitive process. For each of the 10 simulations, of 2,500 cases the values of all
cognitive processes in the system were averaged. The average represented IQ, or the
efficiency of the system.

The researchers also calculated average correlations among the cognitive
processes. The average correlation among all cognitive processes was \( r = .65 \). The
correlation of \( .65 \) among cognitive processes showed that it was possible to simulate the
correlation among mental tasks that is a key component of the system theory of general
intelligence. Note that the only assumption in this simulation was the configuration of
the system of intelligence.

When the simulated sample was divided into high- and low-ability groups, the
correlations among the cognitive processes for each group were \( r = .27 \) and \( r = .51 \),
respectively. The simulated low-ability group showed the most similarity across
cognitive processes (Detterman et. al, 2001).

In fact, correlations among mental tests are higher for low IQ than for high IQ
subjects. Detterman and Daniel (1989) analyzed data from 20 MR adults, 20 college
students, and WAIS and WISC standardization samples. Elementary cognitive tasks, such
as learning, match-to-sample, and choice reaction time, correlated more highly among
themselves and with IQ in the lower ability groups then in the high-ability group. WISC-R
and WAIS-R subtests also correlated more highly in the low-ability groups then in the
high-ability group. Presumably, such results mean that individuals with low ability have a
deficit in a central component, which leads to less variation in the performance of the
various elements in the system. Higher ability subjects do not have an overarching
Influence of one individual central component, and their tests show more variation in performance.

In low-ability individuals, different central components may be affected, yet will lead to the same behavioral result. Consequentially, it is difficult to differentiate among specific categories of intellectual deficit through the measurement of complex cognitive processes (Detterman, 1987).

In another hypothetical simulation by Detterman and colleagues (2001), two samples were created. A severe deficit in one central component was created for one, and a severe deficit in a different central component was created for the other. When any of the central components (D, E, F) had a value that was several standard deviations below the average value, all cognitive processes and IQ levels were brought down to the lower level of functioning, regardless of the values assigned to any of the other central or peripheral components. A discriminant analysis using complex cognitive process values was unable to significantly distinguish between the two samples. However, a discriminant analysis using central component values was able to successfully differentiate the samples.

Theoretically, then, groups that have deficits in different central components should show similar levels of functioning on complex cognitive tasks. For example, two groups with different central component deficits may show identical scores on subtests of IQ tests such as the WAIS-III. Complex tasks employ many central and peripheral components, and any central component deficit will weaken task performance. A difference between groups in test performance would only come about when tests that tap fewer central components are used.
It is hypothesized that there is a class of tasks that access a smaller number of central components (Detterman, 1987). These tasks are known as elementary cognitive tasks (ECTs). ECTs are simple tasks. An example of an ECT is a reaction time task, one measure of which is decision time. Decision time is measured by the amount of time it takes a subject to lift his finger off of a home key after a target is illuminated. Decision time theoretically taps a central component such as speed of processing (Luo & Petrill, 1999). ECTs are generally less influenced by variables that may affect scores on more traditional tests of cognitive abilities, such as practice or strategy (see Jensen, 2006).

Ideally, it would be possible to identify a set of ECTs in which each task measures a single central component. In this case, the ECTs identifying each central component would correlate moderately with more complex tasks and would not correlate at all with each other, though it is unlikely that even the most basic cognitive tasks measure just one central component. Figure 2 shows an example of the path an elementary cognitive task might occupy in the system, when the only central component being tapped is component F.

Elementary cognitive tasks such as reaction time, inspection time, and stimulus discrimination tasks are known to correlate moderately with measures of general intelligence (Detterman, 1987; Detterman et. al., 2002; Luo & Petrill, 1999; Loranger et. al., 2002). Theoretically, these tasks are thought to access fewer central components, while traditional IQ tests recruit both peripheral and a greater number of central components.

With respect to the current study, it is possible to make predictions from this theory. First, it is unlikely that two genetic disorders which have different genetic
causation and result in different physical phenotypes could result in identical behavioral and cognitive phenotypes. The most probable prediction would be that the genetic syndromes would have markedly different cognitive profiles. However, according to the system theory of intelligence it is possible for both syndromes to have identical or very similar profiles on complex cognitive tasks. The two syndromes could produce deficits in different central components. As described above, these different central deficits might manifest as identical profiles on measures of complex processes. In this case it would not be possible to discriminate among the syndromes.

The use of cognitive tasks that measure a specific central component would increase the likelihood of discriminating between the groups. Unfortunately, it is not clear that even the most basic of cognitive tasks currently available measure a single central component. Nonetheless, based on the system theory of intelligence it is expected that elementary cognitive tasks include fewer central components that the much more complex tasks included on intelligence tests. Theoretically, an individual with a genetic deficit that causes MR could perform above the level predicted by his or her full scale IQ on an elementary cognitive task that does not include the affected central cognitive component. Therefore, it should be expected that profile differences between two genetic syndromes are more likely to be found for elementary cognitive tasks than for complex measure like subtests of the WAIS-III.

The current study will focus on two genetic syndromes that cause MR. Individuals diagnosed with Down Syndrome (DS) and Fragile X Syndrome (FX) typically show impairments in IQ that are around three standard deviations below the population average (Mazzocco, 2000; Nadel, 2003). The two genetic mutations produce
cognitive outcomes that are quite similar, though the syndromes show great differences in anatomy, health outcomes, and even personality. How do genetic abnormalities that produce differences in anatomy, behavior, and health outcomes lead to such similar cognitive results? It is possible that both syndromes have impairments, but the impairments are substantially different between syndromes. DS and FX individuals end up with low IQ, but they get there by different routes (different cognitive profiles). In this case both the genetic causation is different, and the resulting impairments are different. It is also possible that both syndromes have impairments and the impairments are the same. The genetic causation is different, and has different effects on the brain, but the cognitive profiles of the two groups are very similar. The second possibility is in line with a system theory of intelligence, which predicts that the entire system of intelligence is deficient, even while different central components may be affected.

Thus, Down Syndrome and Fragile X Syndrome present an opportunity to explore cognition in syndromes that have known, and markedly different, genetic abnormalities. Comparing the two genetic syndromes on complex and elementary cognitive tasks can lead to a clearer picture of genetic influence on behavior. It is logical to assume that varying genetic etiologies would produce varying cognitive deficits, and there is research to suggest slight variations in cognitive profile. However, individuals diagnosed with these syndromes show far more similarities than differences, and it is not currently possible to discriminate among syndromes based on tests of cognitive ability (Hodapp et. al., 1992; Powell, Houghton, & Douglas, 1997). In addition to furthering a system theory of intelligence, research on elementary cognitive tasks in populations with genetic
disorders has the potential to aid the search for the genetic basis of central components of cognitive abilities and intelligence.

The Heritability of Intelligence

It is well-established that there is a significant genetic influence on intelligence (see Bouchard, 1997). Family and twin studies across the lifespan generate heritability estimates of close to 50%, but research suggests that heritability increases with age (Chipuer, Rovine, & Plomin, 1990). Heritability estimates range from about 20% in infancy, 40% in children, 60% in adolescents, to about 80% in adults (McGue, M., Bouchard, T. J., Iacono, W. G., & Lykken, D. T., 1993; Pal, Shyam, & Singh, 1997; Plomin, 1986).

Heritability has also been investigated in individuals at the low end of the IQ spectrum. In a study of 148 monozygotic and 135 dizygotic twin pairs aged 5-13, Thompson and colleagues (1993) found no difference in heritability of cognitive ability between low-ability subjects and heritability in a full sample. Though this finding has been replicated several times, other research suggests that individuals scoring in the lowest 5% of twins on cognitive ability tests did show significantly greater heritability of cognitive abilities than a full sample (Cherny, Cardon, Fulker, & DeFries, 1992; Saudino, Plomin, Pedersen, & McClearn, 1994; Spinath, Harlaar, Ronald, & Plomin, 2004; Sundet, Eilertsen, Tambs, & Magnus, 1994). The authors speculate that different genes might affect cognitive development in those individuals with mild mental impairment. It is also possible that the environment has less of an effect on cognitive ability outcomes at the low end of the distribution (Spinath et. al., 2004). Though an increase in heritability in low-ability subjects is contradicted by the Thompson et. al. (1993) study, the authors
suggest that the effect may partially be due to a higher similarity in cognitive ability in both monozygotic and dizygotic twin pairs at low-ability levels as compared to normal ability levels.

Though specific genes associated with intelligence have not yet been identified, research is progressing through the use of DNA pooling. DNA pooling allows researchers to more easily identify genotypic differences between groups by identifying Quantitative Trait Loci (QTLs). QTLs are locations on a chromosome that vary between groups and potentially impact the trait in question. Plomin and Ian (2001) used DNA pooling to compare 147 markers on chromosome 4 and 66 markers on chromosome 22 in samples of high-ability and average-ability children. Though the researchers identified several QTLs, they caution that many more areas and interactions are probably involved in a complex trait such as intelligence (Plomin & Ian, 2001). Evidence has been found for genetic influences on specific cognitive abilities, and it is possible that different cognitive abilities will be impacted by genes in different locations (Brooks, Fulkner, & De Fries, 1989; Cardon et al., 1992; Plomin & Ian, 2001).

The search for QTLs responsible for intelligence has been slow, probably because many QTLs of small effect size are involved in the heritability of intelligence. Plomin, Kennedy, and Craig (2006) suggest one way forward may lie in identifying QTL sets thought to be associated with intelligence. In addition to large twin studies, research using large samples of individuals with genetic disorders may also assist in identification of candidate genes. For example, comparisons between the various genetic deletions that are diagnosable as Williams Syndrome have led to the identification of genes implicated in neuronal development and communication and in visual-spatial abilities (Hirota et al.,
The identification of QTLs and genes responsible for intelligence will greatly impact intelligence research, influencing both the theories driving research and practical application of findings.

The g Factor and Elementary Cognitive Tasks

Most measures of cognitive ability, no matter how diverse, are positively correlated. Though each test measures specific abilities, they also share variance with other cognitive tests. It is possible to determine the amount of shared variance through the use of factor analysis. The common factor that tests of cognitive ability share is referred to as the general factor, or the g-factor (see Jensen, 1998). The general factor is a highly heritable trait. As the g-loading of a task increases, estimates of heritability increase as well (Petrill, 1997). Specific tests differ in the amount of variance that loads on g, but in general a more complex task will have a higher g loading than a less complex task (Jensen, 1998).

Some researchers hypothesize that g is a single process or quality, and that the correlations among various tests of cognitive ability reflect how much of this process is employed by each test (Carroll, 1993). Others hypothesize that g is a reflection of a number of components working together. The correlations among various tests arise because the tests share a number of basic components (Detterman, 1987; Kranzler & Jensen, 1991; Kranzler & Jensen, 1993).

Neurofunctional evidence that g is not represented by a unitary process comes from Colom, Jung and Haier (2006). The authors found that the g factor as measured by the WAIS-R and WAIS-III was correlated with gray matter clusters that were distributed throughout the brain, not centered in a single area. The subtests of the WAIS are
generally quite complex, and the general factor obtained from them presumably taps many components of intelligence. Even tasks that are thought to be quite simple, such as a delayed match-to-sample task, show significant differences in activation patterns during different phases of the task such as encoding and retrieval (Habecka et. al., 2005). Simpler still is a proposed neural network involved in reaction time. The brain areas active during reaction time show some overlap with that of $g$, for example in the middle and medial frontal cortex and inferior parietal cortex (Adam et. al., 2003; Colom et. al., 2006). It is possible that tasks thought to measure a minimal number of central components, such as ECTs, can help to untangle the debate over the processes behind $g$.

Already, much research has focused on the relationship between ECT performance and $g$. A meta-analysis of behavioral genetic research on chronometric tasks concluded that processing speed is moderately heritable, and that as task complexity increases heritability also increases (Beaujean, 2005). Genetic and environmental influence varies across ECTs, suggesting that different ECTs contribute to $g$ in various ways (Petrill et. al., 1995). Though ECTs are known to correlate moderately with measures of general intelligence, they are not conceptualized as general intelligence or as $g$ (Detterman, 1987; Detterman et. al., 2002; Luo & Petrill, 1999; Loranger et. al., 2002).

Several studies have examined ECTs using a battery called the Cognitive Abilities Test, or CAT. The CAT is a battery of computer-based cognitive tests that measure performance on a variety of elementary cognitive tasks (Detterman, 1988). Using a sample of school-aged twins, Petrill and colleagues (1995) found that ECTs such as reaction time (RT), probed recall (PR), and stimulus discrimination (SD) were all significantly correlated with Full Scale IQ as measured by the WISC-R. The highest
correlations were with measures of SD, which ranged from $r = -.36$ to -.45. Overall RT and PR correlations were $r = .28$ and $r = .18$, respectively. In addition, the researchers found that the amount of variance accounted for by environmental or genetic factors was different for different ECTs. SD appeared to be impacted by additive genetic factors, while RT measures appeared to be effected by common environmental factors. Given different correlations with Full Scale IQ and different levels of genetic and environmental causation, it can be argued that the CAT tests measure different and basic cognitive components (Petrill et al., 1995).

Petrill, Luo, Thompson, and Detterman (1996) again used a sample of school-aged twins to explore genetic and environmental influence on ECTs. They suggested a possible factor structure for the several CAT tasks composed of two factors: 1. Speed, consisting of mean decision time RT, mean decision time SD, and PR mean reaction time, and 2. Learning, consisting of learning percent correct, self-paced learning percent correct, and PR % correct. Several tasks from the WISC-R were included in the Learning factor (Arithmetic, Digit Span, and Coding), as they are thought to tap many of the same abilities as the CAT tasks included in the Learning factor.

For the phenotypic factor analysis, the CAT Speed factor had moderate loadings on a general factor (mean decision time SD .37, mean decision time RT .38, PR mean reaction time .32), and higher loadings on a speed factor (mean decision time SD .57, mean decision time RT .59, and PR mean reaction time .49). The Learning factor showed moderate group factor loadings, with higher general factor loadings (with the exception of Coding). Though the Learning factor showed the highest genetic general factor loadings (ranging from .41 to .49), it showed no genetic group factor loadings. The speed
factor had moderate group genetic factor loadings (mean decision time SD .46, mean decision time RT .50, and PR mean reaction time .47) and lower genetic general factor loadings (mean decision time SD .17, mean decision time RT .19, and PR mean reaction time .17). Again, differing sources of genetic variance for different group factors and ECTs indicate that intelligence is not a unitary construct (Petrill et. al., 1996).

Luo and Petrill (1999) used structural equation modeling to look at the relationship between various ECTs as measured by the CAT. In this sample several measures loaded on a Chronometric factor. These included the CAT measures in the Petrill et. al. (1996) Speed factor plus CAT measures of inspection time. In this sample mean decision time RT showed a group factor loading of .509, mean decision time SD showed a group factor loading of .601, and PR mean reaction time for correct responses showed a group factor loading of .441. The data also showed a Learning and Memory factor, which included CAT measures and several additional measures from the WISC-R and the Specific Cognitive Abilities battery. These measures loaded much less on a group factor, while showing moderate to high loadings on a g factor. For example, PR percent correct loaded .148 on a learning and memory factor and .491 on a g-factor. As in Petrill et. al. (1996), the WISC-R subtests Arithmetic (.199), Coding (.130), and Digit Span (.162) were also included in the Learning and Memory factor.

Luo and Petrill (1999) also looked at the relationship between CAT group factors and g. A Learning and Memory factor including only CAT tasks showed a moderate correlation of .386 with psychometric g. The CAT RT factor (including PR mean reaction time, mean decision time RT, and mean decision time SD) correlated only .072 with g, while the CAT general factor (a general factor from all CAT scores) correlated more
highly at $r = 0.662$. The authors point out that the CAT general factor might reflect mental speed, leaving mostly method variance in the CAT RT factor. Research on ECTs as measured by the CAT demonstrates that different ECT group factors and even individual measures have different relationships to general intelligence. This evidence bolsters the argument that $g$ is not represented by a unitary process.

It appears that ECTs as measured by the CAT show measurably different relationships with $g$ and with cognitive tests similar to those included in the WAIS-III. Theoretically, ECTs tap a minimal number of central processes. According to the system theory of intelligence, a group that has a deficit in one central process will show a performance deficit on an ECT that taps that central process. A group that has a deficit in a central process not tapped by the ECT would not show as severe a decrement in performance. However, a comparison between the groups on $g$ or on more complex tasks would reveal no differences. This theory can be investigated by testing two homogeneous groups of mentally retarded individuals on ECTs and a measure of $g$.

Chronometric Task Performance by Mentally Retarded Individuals

Despite the recent focus on comparisons of different etiological groups, researchers comparing unknown etiology MR with non-retarded individuals have yielded a wealth of information about intelligence and cognition. These studies often use undifferentiated groups of MR individuals compared to normal chronological- or mental-age matched groups. This has helped to extend theories of intelligence to include those at the very low end of the distribution of IQ.

Elementary cognitive tasks have been studied extensively in MR and normal-IQ subjects. Many studies have shown that individuals with MR have slower and more
variable reaction times (RT) and inspection times (IT) than normal subjects (Baumeister & Kellas, 1968; Baumeister & Kellas, 1968b; Davis, Sparrow, & Ward, 1991; Lally & Nettelbeck, 1977; Nettelbeck, Kirby, Haymes, & Bills, 1980). Several studies show that although individuals with DS show slower processing than typical populations, basic cognitive underpinnings seem to be similar (Glazebrook et. al., 2005, Goldman et. al., 2005, Welsh & Elliott, 2004). A meta-analysis by Kranzler and Jensen (1989) showed that MR individuals evidence a correlation between IT and IQ that is similar in magnitude to that of normal children and adults.

A study by Lally and Nettelbeck (1977) found no difference in RT between 10 MR individuals and 10 normal controls, but the authors hypothesize that the MR group responded to stimuli at shorter exposure durations using less evidence than normal subjects – they used a predetermined level of caution for all exposure durations and therefore had similar RTs for all exposure durations. When the viewing time was unrestricted, RT for the MR group was much slower than for controls. They did not have to consider the speed element and could focus on the accuracy of their responses, leading to similar findings as previous RT studies using MR. This study points to an important consideration when studying MR individuals. The MR subjects were using a different response strategy (speed as opposed to accuracy) than normal subjects, making comparison between the two groups very difficult. Another study looked at two groups, each composed of 8 MR individuals. One group was instructed to respond accurately and was praised for a RT slower than their initial mean RT, while the second group was told to respond quickly and accurately. The praise group had a slower mean RT than the non-praise group, but there was no corresponding increase in accuracy (Nettelbeck, Kirby,
Haymes, Bills, 1980). According to this research it may be more useful to compare mentally retarded groups to each other rather than to normal individuals on ECTs.

Though several studies have compared groups with various genetic syndromes, none have compared performance across genetic syndromes on elementary cognitive tasks (Abbeduto et al., 2003; Bellugi, Lai, Wang, 1997; Hodapp et al., 1992; Wang & Bellugi, 1994). There have, however, been elementary cognitive task studies comparing individuals with DS and MR individuals of unknown etiology. Though DS shows slower RT than non-retarded subjects, no differences have been found between DS and MR of unknown etiology in simple cognitive ability tasks such as RT, stimulus discrimination, recognition, and probed recall (Gabriel, 2004; MacKay & Bankhead, 1983; Welsh & Elliot, 2001).

According to the system theory of intelligence, it would be unlikely to find differences in ECT performance between a genetically homogeneous group such as DS and between a genetically heterogeneous group such as those with MR of unknown etiology. The deficits exhibited by individuals in the undifferentiated group may have various genetic or environmental causes, and it is unlikely that as a group they will show a uniform deficit in one or more central component. As discussed above, ECTs as measured by the CAT show differing levels of heritability, showing that they are affected by genetics (Petrill et. al., 1995). The current study addresses this issue by comparing two genetically homogeneous groups: Down Syndrome and Fragile X Syndrome.
Overview of Down Syndrome

DS occurs in 1 in 800 live births and is among the most prevalent of the genetic disorders that cause MR. Approximately 95% of cases are accounted for by a third copy of chromosome 21, termed trisomy-21. The other 5% of cases are termed mosaicism (2%) and translocation (3%). Mosaicism occurs when some cells have trisomy-21 and some cells are normal. Translocation occurs when the long arm of an extra chromosome 21 breaks off and attaches to chromosome 14 or 22 (Nadel, 2003; Harvey & Kennedy, 2002).

Individuals with DS have recognizable physical characteristics such as small, flattened heads and facial features, almond shaped eyes, and shortened stature (Harvey et al., 2002). They also show an increased frequency of thyroid dysfunction, congenital heart disease, hearing loss, sleep apnea, and obstructive airway disease (Cohen, 1996; Harvey & Kennedy, 2002; Roizen, 1996).

The majority of DS adults over the age of 35 show the physical markers of Alzheimer’s such as neurofibrillary tangles and amyloid plaques, but only 30% show a pattern of dementia. The proportion of DS that show dementia is higher than the general population and cognitive decline occurs earlier than in non-retarded adults and retarded individuals of unknown etiology (Das, Divis, Alexander, Parrila, Naglieri, 1995; Schapiro, 1988; Zigman, Schupf, Lubin, Silverman, 1987). There is some evidence that DS adults show two stages of cognitive decline – an initial decline in processing skills such as the ability to form long term memories, followed by the appearance of dementia due to the loss of over-learned behaviors (Schapiro, 1988).
Behaviorally, DS individuals are not skilled communicators and may show difficulties with attention (State et al., 1997). Some studies have described an increase in IQ with mosaicism, but it is still not clear what role the type of genetic mutation plays in cognition (Fishler & Koch, 1991). Interestingly, both IQ and adaptive behavior scores in DS are correlated with parental education level (Libb, Myers, Graham, Bell, 1983).

Neuroanatomical and Neurofunctional Findings in Down Syndrome

Morphological differences appear between DS and normal brains as early as six months of age. DS brains are typically smaller and show delays in myelination and less dendritic arborization (Kates, Folley, Lanham, Capone, & Kaufmann, 2002; Nadel, 2003; Pinter et. al., 2001; Raz et. al., 1995; Weis, Weber, Neuhold, & Rett, 1991).

Several consistent morphological abnormalities seem to correspond to the strengths and weaknesses of DS individuals. Abnormal morphology in the temporal lobe may be related to impaired short-term auditory memory and other auditory problems seen in DS (Kates et al., 2002; Raz et al., 1995; Wang, 1996). Reductions in cortical volume in the DS brain have led to a number of hypotheses about the impact on functioning. For example, the prefrontal cortex is smaller in DS. The prefrontal cortex is thought to regulate “executive” functions such as planning and executing sequences, where individuals with DS tend to show deficits (Jernigan et al., 1990; Nadel, 2003). The DS brain also shows a decrease in the size of the cerebellum (Jernigan et al., 1990; Jernigan et al., 1993; Kesslak et al., 1994; Lenhoff et al., 1997; Raz et al., 1995; Weis et al., 1991). While the cerebellum has long been established as a base for motor learning, new data suggests a role in language processing. Individuals with DS typically show a deficit in verbal abilities, though it is unclear if this deficit stems from cognitive deficits or from
structural abnormalities such as an enlarged or protruding tongue (Abbeduto et. al., 2003; Harvey et al., 2002; Wang, 1996).

At least two studies have shown different patterns of activation in DS brains as compared to normal individuals. Horwitz, Schapiro, Grady, and Rapoport (1990) found that DS adults had smaller glucose uptake correlations between frontal and parietal regions and in Broca’s area than normal controls. Ratios of regional to whole-brain metabolism showed unusual interactions between the thalamus and the temporal and occipital lobes. The researchers posit that these circuits could be related to language and attention deficits seen in DS. Another study found an increased cortical glucose metabolic rate in DS, which the authors hypothesize may be due to the general inefficiency of the DS brain (Haier et. al., 1995). Support for decreased efficiency in the DS brain is supported by findings of increased levels of antibodies to gliadin and gluten in DS individuals. Increased levels of antibodies suggest increased levels of peptides in the blood, some of which cross the blood-brain barrier in the form of opioide peptides. These peptides may play a role in synaptic pruning and cell development (Nygaard, Reichelt, & Fagan, 2001).

Individuals with DS show consistent neuroanatomical differences when compared to normal groups. Some abnormalities seem to have clear ties to behavior, such as temporal lobe dysmorphology and impairments in auditory processing (Kates et al., 2002; Raz et al., 1995; Wang, 1996). Other abnormalities seem to have more diffuse effects (Haier et. al., 1995; Nygaard, Reichelt, & Fagan, 2001).
Down Syndrome and Cognition

Despite the large amount of research that has been done on DS individuals, a cognitive profile is still emerging. Though differences in brain structure do not become apparent until about 6 months of age, some research finds that, prior to 6 months of age, DS and normal infants show distinctions in performance on tasks that require recognition of visual stimuli (Fagan, 1975; Nadel, 2003). Many studies have shown weaknesses in learning and memory, with particular difficulty consolidating information into long term memory. Consistent with an increased incidence of hearing loss, DS individuals show a weakness in auditory processing. Individuals with DS also tend to process information at a global level, ignoring detail (Lenhoff et al., 1997; State et al., 1997; Zelazo & Stack, 1997).

In general, verbal skills are less developed than nonverbal skills in DS, with a particular weakness in grammar (Abbeduto et al., 2003; Wang, 1996). Though researchers have long suggested that hearing problems in DS may contribute to problems in communication, studies that control for hearing ability show that cognitive deficits likely play a more prominent role. Welsh and Elliot (2001) tested 13 DS subjects, 14 MR subjects, and 14 non-retarded controls matched for hearing ability. Subjects performed rapid aiming movements under three conditions: a visual cue at the target location, a visual cue removed from target location, or a verbal cue. The DS group had significantly longer movement times than the MR and control groups in the verbal cue condition. The similar RTs of the DS and MR groups suggest that the DS subjects had no deficit in hearing and reacting to sounds. The authors posit that the longer movement times demonstrate that the DS subjects react and then figure out which button they will be
hitting. This is an interesting finding in light of Lally and Nettelbeck (1977), in which the MR group used the response strategy of speed rather than accuracy to show a decreased RT. In the Welsh and Elliot study, the DS group (but not the MR group) showed the same sort of strategy in the condition they found most difficult. Evidence for a specific auditory deficit has also surfaced in ERP studies, where distribution of ERP components during auditory processing was significantly different in 9 DS subjects than in 13 mental age and 11 chronological age matched controls (Lincoln et. al, 1985).

The weakness of auditory short-term memory in DS is fairly well established (Brock & Jarrold, 2005; Jarrold, Baddeley, & Hewes, 2000). Performance on digit-span tasks is consistently lower than that of MR controls (Wang, 1996). Numminen, Service, Ahonen, and Ruoppila (2001) matched 15 DS and 15 unknown- etiology MR controls on non-verbal IQ and tested them on a variety of working memory tasks. The DS group performed significantly more poorly on phonological loop working memory tasks, especially digit span, but no difference was found on visual-spatial sketchpad or central executive tasks. DS individuals tend to perform relatively well on visual-motor tasks and tasks that tap visual-spatial short-term memory, such as the Corsi block-tapping test (Wang et al., 1994).

Individuals with DS tend to show some strengths and weaknesses in cognition. Auditory processing and verbal skills seem to be particular weaknesses for individuals with DS (Abbeduto et. al., 2003; Wang, 1996; Welsh & Elliot, 2001). Auditory working memory tasks, such as digit span, seem to be particularly affected, while visual-motor and visual short-term memory tasks are a relative strength (Numminen et. al., 2001; Wang et. al., 1994).
Overview of Fragile X Syndrome

The most common cause of hereditary MR is Fragile X syndrome (FX). FX is caused by a genetic mutation on the FMR1 gene, located on the X chromosome. The X-linked mutation is typically passed through females, but is most frequently expressed in males. It is estimated that 1 in 2000 males have FX (Dykens, Hodapp, Leckman, 1987). Physical markers of FX include a long face, protruding ears, crossed eyes, and flat feet. Behaviorally, FX individuals may have a learning disability or be mentally retarded, have autistic features, impulsivity, hyperarousal, social anxiety, or engage in self-injurious behavior (Mazzocco, 2000).

FX is caused by an excess of repeats of a trinucleotide element called CGG (cytosine-guanine-guanine). CGG is located in the fragile X mental retardation 1 gene, also called FMR1. The primary areas of FMR1 expression in brain are the nucleus basalis magnocellularis and the hippocampus (Abitol et. al., 1993). Normal individuals have 6-54 CGG repeats. Those with a FX premutation have about 50-200 repeats, and a person with greater than 200 repeats is considered to have the full FX mutation. Repeats over 200 interfere with the functioning of the FMR1 gene, which normally creates FMR protein (FMRP) (Brunberg et. al., 2002; Mazzocco, 2000; Murphy et. al., 1999). FMRP is primarily expressed in cell bodies and postsynaptic regions of neurons and plays a role in brain development and plasticity. FX individuals show a deficit of FMRP, though those with the permutation usually show no abnormalities (Devys, Lutz, Rouyer, Bellocq, & Mandel, 1993). Low levels of FMRP can also decrease the transmission of action potentials in the brain. It is thought that fewer action potentials decrease the efficiency of
neuronal recruitment in response to cognitive demands (Menon, Kwon, Eliez, Taylor, & Reiss, 2000).

Individuals with abnormal CGG repeats show a great range of mental abilities. Those with the premutation usually have a normal IQ, but may show physical features including tremors, ataxia, and impotence. Males with the full mutation are almost always mentally retarded and the phenotype shows less variability in males (Brunberg et al., 2002; Mazzocco, 2000). Females with the full mutation show an array of effects. Females normally have two X chromosomes, and one member of each pair of genes is not active. Because the inactivation is random, the number of normal X chromosomes that produce FMRP varies from female to female and is generally greater than in males (Bennetto, Pennington, Porter, Taylor, & Hagerman, 2001). Loesch and colleagues (2002) found that individuals with low values of FMRP are generally male and those with higher values of FMRP are mostly female. Consistent with that finding, only about half of females with the full mutation have MR, though they still may show lower IQ (Mazzocco, 2000).

Neuroanatomical and Neurofunctional Findings in Fragile X Syndrome

MRI studies reveal dysmorphology in the FX brain. It appears that similar areas are affected in full mutation and premutation individuals, though no correlation has been found between number of repeats and structural abnormalities (Murphy et al., 1999).

Cortical and subcortical structures have shown significant differences from normal brain structure. FX subjects show a decrease in white matter density in the frontal caudate pathways. These pathways play a role in executive functioning and attention, both of which show deficits in FX (Barnea-Goraly et. al., 2003). Significant differences are also found in subcortical structure volumes. FX subjects show enlargement of the
caudate and thalamic nucleus, with the caudate volume larger in males than in females (Eliez et al., 2001; Reiss et al., 1995). Both sexes seem to show an increase in hippocampal volume, and FX individuals have significantly larger ventricles and more cerebrospinal fluid than normal subjects (Brunberg et al., 2002; Eliez et al., 2001; Kates, Abrams, Kaufmann, Breiter, & Reiss, 1997; Murphy et al., 1999; Reiss et al., 1995; Reiss et al., 1991; Reiss, Lee, Freund, 1994).

Several studies have found significant anatomical abnormalities in portions of the cerebellum and brainstem, particularly in posterior cerebellar vermis size (Brunberg et al., 2002; Reiss, Aylward, Freund, Joshi, & Bryan, 1991; Reiss et al., 1995). In FX females, posterior vermis size predicted performance on cognitive measures such as IQ, and the ratio of active X chromosomes with the mutation to active X chromosomes without the mutation predicted posterior vermis size. The authors conclude that posterior vermis volume differences may play a direct role in cognition or they may indicate which period of development is most affected by the FX mutation (Mostofsky et al., 1998).

Recent research has used fMRI to look at activation in the FX brain. The few published studies show fairly consistent results. FX individuals tend to show less activation than controls during difficult tasks, possibly due to ceiling effects (Kwon et al., 2001; Rivera et al., 2002). In studies using 1- and 2-back working memory tasks and in a study of arithmetic, FMRP levels significantly correlated with activation, though IQ did not (Kwon et al., 2001; Menon et al., 2000; Rivera et al., 2002). This is interesting in light of studies that show a correlation between FMRP levels and cognitive measures. It is possible that FMRP mediates brain activation independently of overall IQ.
As compared to average-IQ individuals, FX subjects also show unusual patterns of activation during working memory tasks, particularly in the frontal lobes. Using a modified version of the Stroop task, Tamm, Menon, Johnston, Hessl, and Reiss (2002) used fMRI to study executive functioning and attention in 14 FX females and 14 normal controls. In normal subjects the Stroop task activates the prefrontal cortex. Both groups showed activation of the prefrontal cortex, but only the left hemisphere showed activation in the control group. Controls also had significantly greater activation in the left superior parietal, left orbitofrontal, and right angular gyri. There was a correlation between performance and left orbitofrontal activation in the FX group that was not present in the control group. The left orbitofrontal area is thought to play a role in executive functions such as working memory and attention.

There seem to be consistent, measurable differences between the neuroanatomy of FX and typical individuals. Individuals with FX show less density in white matter tracts, consistent with abnormal activation in the frontal lobes (Barnea-Goraly et. al., 2003). The cerebellum is also affected (Brunberg et al., 2002; Reiss et. al., 1991; Reiss et al., 1995). It is more difficult to make neurofunctional/behavioral links in FX individuals as a group, as levels of FMRP expression seem to play a role in brain activation.

Fragile X Syndrome and Cognition

Genetic variability in FX individuals presents difficulties for researchers attempting to build a cognitive profile. Recent research has focused on the expression of FMRP rather than number of CGG repeats. Number of repeats can be misleading, as the number can be unstable, and in females it is not representative of the number of mutated X chromosomes that are active. Bennetto et al. (2001) found that while the number of
CGG repeats was not related to any neurocognitive variables, the proportion of cells with an active normal FMR1 gene was correlated with FSIQ, PIQ, executive functioning, spatial ability, and visual memory. Loesch and colleagues (2002) studied 144 extended families and found that FMRP expression was correlated with several subtests from the WAIS (Digit Span, Symbol Search, Object Assembly, and Picture Arrangement). The authors hypothesize that attentional skills are strongly affected by the FMRP deficit.

While there is research linking FMRP expression to language, executive functioning, neuronal activation patterns, and behavioral problems, it is unclear how the FMR1 mutation interacts with other physiological and environmental stimuli to produce the FX phenotype (Bailey et. al., 2001; Reiss & Dant, 2003; Rivera et. al., 2002; Sobesky et. al., 1996). Evidence from past research shows deficits in visual-spatial skills, arithmetic, attention, sequential processing, short-term memory and executive functioning. FX individuals tend to show strengths in long-term memory and verbal skills (Loesch et al., 2002; Mazzocco, 2000; State et al., 1997). Further difficulties in measurement come from male and female differences in the syndrome. Hodapp and colleagues (1989) observed that FX males tend to show a decline in IQ, usually around the time of puberty. Mostofsky and colleagues (1998) found that mean parental IQ predicted performance on intelligence tests for FX females, but the strength of prediction was weaker than in normal subjects.

Receptive language skills seem to be preserved in FX when compared to MA-matched controls, though there appear to be sex differences. Abbeduto et al. (2003) found that the receptive language scores of FX females were significantly greater than males, but there was no difference in the magnitude of differences between various tests. The
authors hypothesize that FX females have the same cognitive profile as males, but that females function at a higher level.

Several studies have used the Kaufman Assessment Battery for Children (K-ABC) to assess FX individuals (see description below). These studies have consistently found sequential processing performance to be lower than simultaneous processing or achievement performance in FX, with particular difficulty on the hand movement subtest. This finding is consistent with reports of difficulties with visual-motor coordination in FX. FX individuals perform significantly better than their group mean on the Gestalt Closure subtest, utilizing perceptual closure, inference, and flexibility (Dykens et al., 1987; Hodapp et al., 1992; Hodapp, Dykens, Ort, Zelinsky, 1991).

FX individuals also appear to have significant problems maintaining and manipulating information in memory. Weaknesses have been found in auditory, visual, and motoric short term memory, though verbal memory seems relatively spared (Dykens et al., 1987; Bennetto et al., 1991; Hodapp et al., 1991). Studies using 1- and 2- back working memory tasks have found visual-spatial working memory deficits in FX subjects, even after removing the effects of IQ (Kwon et. al., 2001; Menon et al., 2000).

Many studies of arithmetic abilities have shown significant impairment in FX (Dykens et al., 1987; Hodapp et al., 1992; Hodapp et al., 1991). Rivera and colleagues (2002) asked 16 female FX and 16 CA-matched non-retarded female subjects to view arithmetic equations with either two or three operands. The subjects had to judge if the results were correct or incorrect by pressing a button. The subjects also took the WAIS-III or WISC-III; the Arithmetic, Digit Span, and Coding subtests were used as measures of mathematical ability and working memory. FSIQ was one standard deviation lower for
the FX group. Even after the effects of FSIQ were removed, FX subjects showed a significant decline in performance on the three-operand task as compared to both FX group performance on the two-operand task and the difference in task performance in the control group. The authors suggest that this finding points to a specific deficit in arithmetic processing in FX (Rivera et al., 2002).

As in DS, FX individuals seem to have some specific deficits. Individuals with FX tend to have difficulties with visual-spatial skills, arithmetic, attention, sequential processing, short-term memory and executive functioning (Dykens et al., 1987; Bennetto et al., 1991; Hodapp et al., 1991; Loesch et al., 2002). They show relatively strong performance on tasks tapping long-term memory and verbal skills (Loesch et al., 2002; Mazzocco, 2000; State et al., 1997).

Comparisons Between Down Syndrome and Fragile X Syndrome

Though Down Syndrome and Fragile X Syndrome both cause mental retardation, the genes and genetic mechanisms affected are very different. As described above, DS is most often caused by a trisomy of chromosome 21, which means that extra genetic material is responsible for the symptoms (Nadel, 2003). FX is known as a trinucleotide repeat disorder, where excess genetic material (in this case CGG repeats) can lead to disruption of the manufacture of FMRP. The FMRP deficit is what is thought to lead to the physical, behavioral, and cognitive symptoms associated with FX (Abitol et al., 1993).

One clear example of differences caused by genotype is the physical markers of each disorder. Both DS and FX individuals typically have recognizable outward appearances. In the case of DS, individuals usually have smaller than normal heads and
almond shaped eyes (Harvey et al., 2002). As outlined above, they frequently have health problems such as thyroid dysfunction, congenital heart disease, sleep apnea, and hearing loss (Roizen, 1996). Those with FX Syndrome typically have larger heads, long faces, and wider and longer ears. The FX mutation also causes specific health problems, such as connective tissue problems, frequent otitis media, increased incidence of seizures, mitral valve prolapse, flat feet, and enlarged testicles (Hagerman, 2000).

In addition to outward appearance, DS and FX individuals show neuroanatomical differences. Individuals with DS show proportionately smaller cerebral volumes than those with FX and show different patterns of white and grey matter reductions. For example, parietal white matter is reduced in DS compared to normal controls, while in FX it is spared or even enlarged. Temporal grey matter shows reductions in both DS and FX groups, as does cerebellar volume, though in FX reductions in volume are concentrated in the posterior vermis (Brunberg et al., 2002; Jernigan et al., 1990; Jernigan et al., 1993; Kates et al., 2002; Kesslak et al., 1994; Lenhoff et al., 1997; Raz et al., 1995; Reiss, Aylward, Freund, Joshi, & Bryan, 1991; Reiss et al., 1995; Weis et al., 1991).

Though current neuroanatomical and neurofunctional research is far from conclusive, it is reasonable to assume that differences in brain morphology and activation patterns would lead to differences in behavior (Mostofsky et al., 1998; Tamm et. al., 2002). For example, decreases in white matter density in frontal pathways of individuals with FX may play a role in the deficits in executive functioning and attention in those individuals (Barnea-Goraly et. al., 2003).

Developmentally, children with DS do not show behaviors that are markedly different from normal individuals. Generally they show the same types of behavior, but at
a later age than normal individuals. For example, DS children usually take longer to toilet train than typical children. As teenagers and adults, DS individuals are often described as withdrawing from the world (State et al., 1997). In contrast, FX individuals do show specific patterns of behavior. They are more likely to show autistic-like symptoms or be diagnosed with autism, show sensory defensiveness, or engage in perseverative speech. Those individuals who are higher functioning often have social anxiety, depression, and may show schizotypal behaviors (Mazzocco, 2000).

In addition to behavioral differences, there have been several studies directly comparing DS and FX individuals on cognitive tasks. Hodapp et al. (1992) gave 10 DS males, 10 FX males, and 10 non-specific MR males the Kaufman Assessment Battery for Children (K-ABC). The groups were matched on mental and chronological age. DS and FX groups scored significantly lower on all measures than the non-specific MR group, and all three groups performed more poorly on sequential processing than on simultaneous processing or achievement. No significant difference was found between simultaneous and sequential processing in the DS group. The FX group showed a significant weakness in sequential processing and strength in achievement (a test that measures knowledge and academic skills). Though Hand Movements was the strongest subtest for the DS group, it was the weakest subtest for FX. The Hand Movements subtest is a component of sequential processing which measures the ability to reproduce a sequence of movements. The Gestalt Closure subtest was significantly higher than group means in both the FX and non-specific groups, and was quite high (though not significantly so) in DS. The authors suggest that this may be indicative of a general effect of MR on cognition.
A second study of K-ABC performance in 8 DS and 32 FX subjects yielded similar results (Powell, Houghton, & Douglas, 1997). FX subjects showed a weakness in Sequential Processing, with a significantly lower score on Hand Movements. DS subjects showed significantly higher scores on Hand Movements. Interestingly, DS subjects scored significantly higher on Reading/Decoding then on other Achievement subtests, while FX individuals scored significantly lower in both Reading/Decoding and Arithmetic. This is unusual in light of Hodapp et. al. (1992) and of research that shows a language deficit in DS.

A language deficit for DS subjects has been found in other comparison studies. A study of 25 DS, 19 FX, and 24 nonverbal MA-matched controls looked at receptive language skills such as vocabulary, syntax, and nonverbal cognition. DS individuals scored significantly lower than the FX group on tests measuring use of syntax, and subtest scores indicated that the comprehension of syntax was more difficult than the comprehension of vocabulary. The FX group did not significantly differ from controls on any measure (Abbeduto et al., 2003). Similar results were found in a study of phonological skills in 32 DS males, 50 FX males, and 33 typically developing males matched for mental age. The DS groups showed delayed speech development, including greater deficits in phonological processes than both the typically developing and FX groups (Roberts et. al, 2005). This study appears to show a specific deficit in language for individuals with DS, which may manifest in lower verbal IQ scores on the WAIS-III.

Undeniably, the preceding research has uncovered some differences in cognitive profile between individuals with DS and FX. However, the two groups show overlapping scores on any individual measure, and there is currently no reliable way to differentiate
between them on any one measure (Hodapp et. al., 1992; Powell, Houghton, & Douglas, 1997). I argue that, despite differences in genetic mutations, physical dysmorphology, neuroanatomy, and behavior, the most striking feature of both DS and FX is the substantial and similar impairment in IQ that results from the mutations. Furthermore, I argue that ECT performance may illuminate reliable differences between the two groups where more complex cognitive tasks fail.

Theoretical Justification

If intelligence is a system of independent components that work together, complex tasks that include a greater number of central components should show higher loadings on a general intelligence factor (g) than those that use fewer central components (Detterman, 1987). Because individuals with MR are thought to have deficits in central components, complex cognitive tasks that use a great number of central components should show no difference between genetic syndromes. Tasks that tap very few central components, such as elementary cognitive tasks, should show more variation between the genetic syndromes. Therefore, complex tasks that load more highly on the general factor of intelligence should show fewer differences between the DS and FX Syndrome groups than those tasks that show lower loadings on a general factor, if there are differences.

As reviewed above, studies of cognitive profiles of genetic syndromes have shown differences between DS and FX subjects. These differences, however, are inconsistent and cannot reliably discriminate between syndromes. Existing research on cognitive profiles predicts that individuals with DS will show particular weaknesses on subtests measuring auditory short-term memory, such as Digit Span, and subtests measuring language (Abbeduto et. al., 2003; Numminen et. al., 2001; Wang, 1996). DS
subjects may perform relatively well on tests measuring visual short-term memory (Wang, 1996). Individuals with FX should show deficits in sequential processing, working memory, and arithmetic, and should potentially show strengths on WAIS-III subtests measuring language (Dykens et al., 1987; Hodapp et al., 1992; Hodapp et. al., 1991; Kwon et. al., 2001; Menon et al., 2000; Rivera et. al., 2002).

Methods

While there are several studies documenting chronometric task performance in individuals with MR, there are no studies comparing across groups of individuals with specific genetic syndromes. The aim of this study is to test the system theory of intelligence by identifying differences in ECT performance between two genetic syndromes that cause mild and moderate MR.

Subjects. Participants included a total of 64 individuals: 20 individuals with a previous diagnosis of FX and 44 individuals with a previous diagnosis of DS. Sample size was determined using two criteria – feasibility of subject recruitment and sample size of previous research on FX and DS subjects (Table 2). All participants were 16 years or older. Participants were recruited through county boards of MR, regional parent groups for each syndrome, local school districts, and local work programs. Testing occurred in quiet, private rooms at local workshops, participant’s homes, local schools, and local libraries. Each participant was tested in two sessions in order to ensure individuals perform to their greatest capacity and do not become fatigued. The amount of time between sessions depended on the ability level of the participant. All protocols used in this research were approved by the Case Western Reserve University Institutional
Review Board, and all subjects (and guardians if applicable) gave written informed consent (Appendix A).

Wechsler Adult Intelligence Scale. In the first session, IQ was determined using the Wechsler Adult Intelligence Scale (WAIS-III), administered by the experimenter. The WAIS-III is composed of six Verbal subtests and five Performance subtests. The raw scores obtained on the subtests are combined to produce a Verbal IQ, Performance IQ, and a Full-Scale IQ. To be eligible for participation, all individuals performed at the level of mild (IQ level 50-55 to approximately 70) or moderate MR (IQ level 35-40 to 50-55). The IQ levels used for diagnosis are those specified in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV-TR).

Cognitive Abilities Test. Following completion of the WAIS-III, participants were administered a portion of the Cognitive Abilities Test (CAT) in a separate session. The CAT has been previously used in populations with MR (Detterman et al., 1992; Petrill et al., 2001). No auditory feedback is used in this version of the CAT.

In the current study, participants were administered three CAT tasks in the following order – probed recall (PR), stimulus discrimination (SD), and simple-choice reaction time (RT). Measures from these tasks have been examined in previous research. They show differential heritability, differential loadings on g, and differential relationships with cognitive tasks that are similar to those included in the WAIS-III (Luo & Petrill, 1999; Petrill et. al., 1995 Petrill et. al., 1996). Measures from PR include PR percent correct (PR%) and PR reaction time (PRRT). Measures from SD include SD number of errors (SDERR) and SD decision time (SDDT). RT decision time was also included (RTDT).
All tasks were administered on the same computer, equipped with a touch screen. Performance on each task was recorded by the computer for each participant, and later transferred to a data analysis program. A brief description of each task follows. The complete CAT manual can be found in Appendix B.

**RT:** Using a touch screen, the participant begins by holding down a “home key,” which is a rectangle positioned near the bottom of the screen (Figure 4). An array of numbered windows appears on the screen. Task difficulty can be manipulated by changing the number of windows in the array, from one to eight. One window illuminates per trial. The participant must remove his/her finger from the home key and tap the lighted window on the touch screen. The measurements obtained in the RT task are percent correct and mean decision time. Decision time is the time it took the participant to lift his/her finger from the home key after one of the windows lit. Various measures of accuracy and processing speed are obtained from this task.

**SD:** Again, the participant presses and holds down the home key (Figure 3). Four windows appear on the screen, each displaying a grid with a unique pattern. At the same time a probe stimulus appears in a separate area of the screen. The participant must touch the window that matches the probe stimulus. When the participant removes his/her finger from the home key, all of the windows return to black. As in the reaction time task, the measurements obtained are number of errors and decision time.

**PR:** The participant presses and releases the home key (Figure 3). Four windows appear on the screen and each window lights up in succession. Each window
displays a unique grid pattern for a short period of time. After the fourth window display has darkened, a fifth window, positioned above the array of four windows, displays a pattern. The participant must remember which window displayed the pattern shown in the fifth window and press the window in the array of four that displayed the matching pattern. In this task the measures obtained are memory accuracy and speed.

Subject Debriefing. After completion of the WAIS-III and CAT, the participant testing portion of the study was complete. Each participant was given a debriefing statement that provided a summary of the study, in addition to contact information for the researchers and for the Case Western Reserve University Institutional Review Board (Appendix C).

Analyses. Various analyses will be run to fully explore the CAT and WAIS-III data. All measures will be inspected for outliers, normality of distribution, reliability, and equality of variance across groups. Relationships between demographic variables and cognitive measures will be examined and, if needed, corrected for. Paired t-tests will be used to test for within-group differences in performance on CAT and WAIS-III measures, and ANOVAs will be used to test for between-group differences. Discriminant analyses will be used to determine which measures best discriminate between the groups. The ANOVA and discriminant analyses have the greatest power of the current analyses, and both directly address the proposed hypotheses. Finally, profile analyses will determine if performance differences uncovered by the ANOVAs are caused by actual performance differences on a particular measure or are caused by overall differences in group performance level.
In addition to exploring between-group differences in test performance, group differences in the relationship between each measure and more global measures of functioning (FSIQ and g) will be inspected. Linear and stepwise regression analyses will be run for each group to determine how well FSIQ is predicted by CAT and WAIS-III measures, and to explore group differences in the measures that are the most predictive of FSIQ. Factor analyses run on the entire sample will be used to explore g-loadings of the WAIS-III subtests, with the results of the full sample compared to standardization sample results and to previous results from a low-IQ sample. The CAT factor analyses will be compared to previous ECT factor analyses. Though the power of the analyses is not great, CAT and WAIS-III measures will also be factor analyzed by group to examine between-group differences in loading pattern. A difference score analysis will examine the relationship between g and between-group difference in test performance, testing the hypothesis that the most highly g-loaded tasks will show the least between-group variance.

Results

All analyses were performed using the statistical package SPSS 11.0 for Windows.

Power Analysis. The statistical program Gpower (Faul & Erdfelder, 1992) was used to perform both Post Hoc and Compromise power analyses for ANOVA. In both cases two groups were specified with a total sample size of 60. Table 4 shows post hoc power estimates for small, medium, and large effect sizes, \( p < .05 \). Table 5 shows compromise power analyses using three beta/alpha ratios for small, medium, and large effect sizes.
Subjects in the current research are diagnosed with one of two rare genetic syndromes. A larger number of subjects would be ideal, but geographical and financial constraints placed a limit on recruitment. As shown in Table 2, the current sample size is similar to the sample size in much research comparing FX and DS.

Based on the system theory of intelligence, I expect that there will be between-group differences on ECTs, but no between-group differences on the WAIS-III. Group differences on ECT measures will support the system theory of intelligence: MR can be caused by deficits in different central cognitive components. ECTs are thought to tap a smaller number of central components, while more complex tasks use many central and peripheral components. Between-group differences on ECTs will support the genetic basis of these measures and will strengthen the theory that they tap central cognitive components. The system theory will gain further support if no group differences are found on more complex tasks.

No reliable group differences in subtest performance are expected on the WAIS-III subtests. Though typically I would not be able to accept the null hypothesis, a null result would provide additional evidence for a system theory of intelligence. In the case of differences between the groups on the WAIS-III, I will be able to reject the null. Because the null is expected for the WAIS-III subtests, a small or medium effect size should be used. This will provide a more sensitive test of variation from the null. According to the post hoc analysis, at $f = 0.10$ power is equal to .1187, which is very low. Power at $f = 0.25$ is .4779, still quite low.

Table 5 shows the results of a compromise analysis. Compromise analysis is often used in situations where sample size is restricted (e.g. in clinical populations). In a
compromise analysis the sample size, effect size, and type of analysis are specified. In addition, the ratio \( q = \frac{\beta}{\alpha} \) is specified. This ratio is a measure of the seriousness of type two errors/type one errors. The purpose of a compromise analysis is to determine the best value for the test statistic given the chosen beta/alpha ratio. Despite sample size limitations and the constraints of a small to medium effect size, it may be possible to obtain an acceptably large power level by adjusting alpha (Faul & Erdfelder, 1992).

In the current study the null hypothesis is expected for the WAIS-III subtests. I must be careful of a type-two error, where a false null is not rejected. This means the chosen beta level should be comparatively large, potentially leading to a larger beta/alpha ratio. \( f = 0.25 \) and a beta/alpha ratio of 2 leads to a moderate power level of .6906, a critical F value of 2.0792, and an alpha level of .1547. Given the constraints and aims of the current research, these levels are appropriate.

GPower (Faul & Erdfelder, 1992) was also used to perform Post Hoc and Compromise power analyses for correlations. Table 6 shows post hoc power estimates for small, medium, and large effect sizes, \( p < .05 \). Table 7 shows compromise power analyses using three beta/alpha ratios for small, medium, and large effect sizes. The sample size used in these analyses is 11, as this is a correlation using group means and factor loadings. It is possible that in this case a power analysis will yield inaccurate results, as the sample is comprised of many more data points than are indicated in the power analysis.

According to the post hoc analysis, at \( r = 0.10 \) power is equal to .0908, which is very low. Power at \( r = 0.30 \) is .2484, still quite low. Critical t is equal to 1.8331. Table 7 shows the results of a compromise analysis. Again, I must be careful of a type-two error,
where a false null is not rejected. $r = 0.30$ and a beta/alpha ratio of 2 leads to a low to moderate power level of .5835, a critical $t$ value of 0.8517, and an alpha level of .2082. These levels are not ideal, and correlations between difference scores and g-loadings should be considered exploratory and interpreted with caution.

It should be noted that the following analyses do not report a correction for multiple comparisons, such as a Bonferroni or Holm procedure. While a correction for multiple comparisons would have undoubtedly affected the outcomes of several analyses, in light of the power analyses above it was determined that presenting all results that reached a $p < .05$ level would be appropriate. The current study requires a trade-off between type I and type II error rates, and it is possible to adjust significance cutoffs in either direction.

Preliminary Analyses. 20 individuals with FX were tested. One FX individual was removed from the analysis because WAIS-III scores indicated that the subject was not MR. 44 individuals with DS were tested. Two individuals with DS were removed from the analysis because they were not able to complete the CAT tasks.

DS and FX groups were matched on age and Full Scale IQ (FSIQ) as measured by the WAIS-III. Table 8 shows means and standard deviations for age and WAIS-III variables both before and after removal of univariate outliers. Univariate outliers were defined as scores greater than three standard deviations from the group mean. Table 9 shows means and standard deviations for selected CAT variables both before and after removal of univariate outliers. One outlier was removed from each of the following variables: Performance IQ, Arithmetic, Matrix Reasoning, and Picture Arrangement. Two outliers were removed from PRRT and SDERR, one in each group. Subsequent analyses
were performed both with and without univariate outliers. The removal of outliers slightly altered the analyses, and the following results refer to data with univariate outliers removed. Standardized residual plots, Mahalanobis Distances, and Cook’s Distances were visually inspected for multivariate outliers. Two potential multivariate outliers were identified. Analyses were performed both with and without multivariate outliers. The removal of outliers did not significantly alter the analyses, and the following results refer to data with possible multivariate outliers included.

Correlations were calculated between demographic and cognitive variables to explore possible group differences. Diagnosis significantly correlated with gender ($r = .319, p < .012$) and with Verbal IQ ($r = .281, p < .028$). As discussed above, FX is an X-linked disorder, affecting mostly males. Those females that are affected are often not MR, and therefore were not eligible for the current research. For this reason, the current FX sample is nearly entirely male. FSIQ, Verbal IQ, and Performance IQ did not significantly correlate with gender. FSIQ and Performance IQ also did not significantly correlate with diagnosis.

Age at testing correlated significantly with Verbal IQ in both DS ($r = -.446, p < .002$) and in FX ($r = -.618, p < .005$). The WAIS-III Verbal subtests that correlated with age were similar in both groups. In DS, Information ($r = -.580, p < .001$), Similarities ($r = -.384, p < .016$), and Comprehension ($r = -.457, p < .003$) correlated with age. In FX, Information ($r = -.503, p < .028$) and Similarities ($r = -.528, p < .020$) correlated significantly with age, with Comprehension ($r = -.438, p < .061$) approaching significance. Note that the correlation is negative: as an individual ages, Verbal IQ decreases. The age range of the current sample was 16 to 61. It is possible that
generational differences, such as increased access to education and inclusion of MR individuals in society, have provided more opportunities for interaction, resulting in greater conversational and informational skills in younger individuals (Schalock, Harper, & Genung, 1981).

A multivariate ANOVA revealed a significant multivariate effect of age (F = 3.602, p < .01), and significant between-subjects effects of age on vocabulary (F = 4.678, p < .05), similarities (F = 12.610, p < .01), information (F = 22.240, p < .01), and comprehension (F = 14.423, p < .01). Diagnosis also showed a significant multivariate effect (F = 3.40, p < .01), and between-subject effects on information (F = 4.784, p < .05), comprehension (F = 7.398, p < .01), and digit span (F = 6.337, p < .02). With age entered as a covariate, the corrected model showed between-subject effects for vocabulary (F = 4.090, p < .022), information (F = 14.783, p < .01), comprehension (F = 12.153, p < .01), similarities (F = 7.472, p < .01), and digit span (F = 4.064, p < .023). Because the influence of age on the WAIS-III variables may affect further analyses, age-corrected WAIS-III variables were computed using a least squares fit. Age corrected results are presented along with non-age corrected results for the remaining analyses.

For the CAT measures, age significantly correlated with RTDT (r = .2757, p < .05) and SDDT (r = .3488, p < .01). A multivariate ANOVA showed a significant multivariate effect of age (F = 3.127, p = .016), and between-subject effects of age for both PRRT (F = 4.612, p < .05) and SDDT (F = 12.226, p < .01). Diagnosis also showed a significant multivariate effect (F = 2.50, p < .05), and a between-subject effect on PRRT (F = 8.086, p < .006). With age entered as a covariate, the corrected model returned significant between-subjects effects of PRRT (F = 7.567, p < .01) and SDDT (F
As with the WAIS-III, all CAT measures were corrected for age using a least-squares fit. Age corrected results are presented throughout the remaining analyses where applicable.

WAIS-III Preliminary Analyses. All eleven WAIS-III subtests were used in the initial analyses, in addition to Verbal IQ, Performance IQ, and FSIQ. Each subtest has a population mean of 10 and a standard deviation of 3. As expected, subtest means were substantially below population means, and standard deviations were smaller than population standard deviations (Table 8) (Jones, van Schaik, & Witts, 2006; Wechsler, 1997). Block Design, Digit Symbol, and Arithmetic showed skewness scores that were greater than twice the standard error of skew, indicating that the distributions were significantly skewed. Digit Symbol also returned a kurtosis value that indicated a leptokurtic distribution. The non-normality of the distributions is likely due to the size and range restriction of the sample. All subtest distributions were inspected for floor and ceiling effects. Arithmetic showed significant floor effects, with both DS and FX groups scoring significantly poorer than their own mean group scores on the subtest ($p < .001$). During testing it was noted that only the highest functioning of the current participants could correctly answer more than two or three of the Arithmetic subtest questions. It is possible that the Arithmetic subtest does not discriminate well at the lowest levels of functioning (Wechsler, 1997). As discussed below, subsequent analyses demonstrate that the non-normal distribution of Arithmetic across both groups significantly changed the outcome of the WAIS-III factor analysis, and Arithmetic was excluded from further analysis at the individual subtest level.
WAIS-III reliability coefficients for each subtest, calculated from the WAIS-III standardization sample, are presented in Table 3 (Wechsler, 1997). The reliability estimates are quite high for the subtests. They are also high for FSIQ ($r = .98$), Verbal IQ ($r = .97$), and Performance IQ ($r = .94$) (Wechsler, 1997). Zhu and colleagues (2001) calculated reliability estimates on the WAIS-III for a sample of 108 mentally retarded individuals. Table 3 shows split-half reliability coefficients for each subtest, corrected for the variability of the standardization sample. Digit Symbol was not included in the analysis. In general, corrected coefficients were as high as or higher than the WAIS-III standardization sample, though no significant difference was found between the sets of coefficients (Zhu et. al., 2001). The current study should not be impacted by low reliability on the WAIS-III.

Two WAIS-III subtests, Digit Symbol and Matrix Reasoning, showed significant difference in between-group variance as measured by the Levene Test of Homogeneity of Variances ($p < .05$ for both subtests). An independent samples t-test showed no significant between-group differences for Matrix Reasoning ($t = .518, p = .606$) or Digit Symbol ($t = -1.114, p = .270$). When equal variances were not assumed the t-test remained non-significant ($t = .583, p = .563$ and $t = -.984, p = .334$, respectively).

According to ANOVA results, individuals with DS showed significantly poorer performance on Digit Span, Information, Comprehension, and overall Verbal IQ as compared to FX ($p < .05$) (Table 8). An ANOVA on WAIS-III subtests corrected for age returned nearly identical results (Table 8). The current results are consistent with previous research on verbal ability in DS (Abbeduto et. al., 2003; Wang, 1996; Welsh & Elliot, 2001). The results of paired t-tests showed that individuals with DS perform more
poorly than their own mean WAIS-III performance on Digit Span ($p < .01$), but better than their own mean WAIS-III performance on Block Design and Picture Arrangement ($p < .01$). Poor performance on Digit Span is in line with previous research on DS individuals (Abbeduto et al., 2003; Numminen et al., 2001; Wang, 1996). Both DS and FX individuals performed significantly worse than their own mean performance on Arithmetic, as described above. This finding is in agreement with previous studies of FX performance (Dykens et al., 1987; Hodapp et al., 1992; Hodapp et al., 1991). In addition, the FX group showed a specific strength on the Information subtest ($p < .003$). ANOVA and paired t-test results revealed that WAIS-III subtest performance is in agreement with previous results from DS and FX samples.

Linear regression analyses were run for both DS and FX. The dependent variable was FSIQ and all WAIS-III subtests were entered as independent variables, excluding Arithmetic. These analyses were used to check for between-group differences in subtest slopes and intercepts and in subtest prediction of FSIQ. FSIQ is predicted from the WAIS-III subtests, so the regression equation was expected to be highly significant for each group. However, it is possible that some subtests are better or worse predictors of FSIQ in the different groups. Both original and age corrected data were analyzed, though only original data are reported as the results showed few differences. Both analyses were significant at the $p < .01$ level. For DS $R = .998$, and all predictors were significant at the $p < .01$ level. For FX $R = .999$, and all predictors were significant at the $p < .01$ level except Matrix Reasoning, which did not significantly predict FSIQ in FX ($t = 1.793, p = .111$). Though the factor analyses are described more thoroughly below, it should be noted that the regression results reported here are consistent with results from the WAIS-
III factor analysis for the FX group, in which Matrix Reasoning showed a low loading on the first factor (.295), traditionally thought of as g. Stepwise regression analyses revealed that, while Block Design was most predictive of FSIQ in both DS (R = .857) and FX (R = .892), the subtests that were most predictive of IQ showed between-group differences. In DS, Digit Span (R = .927), Picture Arrangement (R = .950), and Digit Symbol (R = .965) were the most predictive after Block Design. While still significantly predictive of FSIQ, Comprehension and Information were the least predictive of the WAIS-III subtest. In FX, Matrix Reasoning was still not significantly predictive of FSIQ. The most predictive subtests after Block Design were Comprehension (R = .960), Picture Completion (R = .973), and Information (R = .983). The regression analyses show that, while WAIS-III predicts FSIQ in both groups, there are between-group differences in the way that the subtests relate to FSIQ.

Slopes and intercepts were analyzed for between-group differences. Block Design (t = 2.69, p < .01), Digit Span (t = 2.56, p < .025), and Comprehension (t = 2.79, p < .01) showed significant differences in slope, meaning that these subtests have significantly different relationships to FSIQ in FX and DS. Note that both Comprehension and Digit Span show significant differences in between-group performance. No intercepts showed significant between-group differences.

CAT Preliminary Analyses. Data were extracted from the CAT program and moved to SPSS using the procedure outlined in the CAT manual (see Appendix B).

The CAT variables used for analysis were as follows:
Reaction Time – Mean decision time corrected for outliers (RTDT). Mean decision time is the average time to lift the finger from the home key (Figure 4). RTDT was multiplied by -1 to form a positive factor loadings and correlations.

Probed Recall – Mean reaction time all trials (PRRT) and percent correct all trials (PR%). Mean reaction time is the average time it takes to make a response after the probe pattern appears (Figure 3). PRRT was multiplied by -1 to form a positive factor loadings and correlations.

Stimulus Discrimination – Mean decision time corrected for outliers (SDDT), number of errors all trials (SDERR). Mean decision time is the average time to lift the finger from the home key (Figure 3). SDDT and SDERR were multiplied by -1 to form positive factor loadings and correlations.

Participants were administered the CAT tasks in the following order – probed recall (PR), stimulus discrimination (SD), and simple-choice reaction time (RT). ECTs are thought to measure fewer central components, increasing the possibility that DS and FX groups will show differences in performance on central components of intelligence as measured by the CAT tasks. ECTs are differentiated from more complex cognitive tasks by the simplicity of the measures and, theoretically, by the number of components of intelligence thought to be involved in the task as indicated by g-loadings. Measurements from these tasks have been examined in previous research. They show differential heritability, differential loadings on g, and differential relationships with complex cognitive tasks that are similar to those included in the WAIS-III (Luo & Petrill, 1999; Petrill et. al., 1995 Petrill et. al., 1996).
Split-half reliability coefficients were calculated for the CAT measures included above. Table 10 shows that reliability is quite high in the current study, ranging from $r = 0.969$ for RTDT to $r = 0.707$ for PR%. This is in line with previous research on reliability estimates of ECT performance in normal subjects (Hamsher & Benton, 1977; Jensen, 2006; May, Cooper, & Kline, 1986; Petrill et. al., 1995). The current results were not affected by unreliable measures.

One CAT measure, PRRT, showed significant difference in between-group variance as measured be the Levene Test of Homogeneity of Variances ($p < .01$). An independent samples t-test showed a significant between-group difference on PRRT ($t = -2.784, p < .01$) which remained when equal variances were not assumed ($t = -3.696, p < .01$).

Performance on the CAT measures correlated significantly with WAIS-III FSIQ (Table 11). As expected, RTDT, PRRT, SDDT, and SDERR decreased with an increase in IQ. Recall that these variables were multiplied by -1, resulting in positive correlations. As IQ increased, PR% increased, resulting in a significant positive correlation. The resulting correlations are similar to or higher than those found in previous research on the CAT tasks (Luo & Petrill, 1999; Petrill et. al., 1995; Petrill et. al., 1996). The highest correlation was found with SDDT, consistent with previous research (Petrill et. al., 1995). Correlations between age corrected variables are slightly lower, though the pattern of correlations is the same in age corrected and original data (Table 11).

It was predicted that reaction time and decision time measures would be least likely to show between-group differences, due to evidence that they are affected by common environmental factors rather than genetic factors (Luo & Petrill, 1999; Petrill et.
al., 1995; Petrill et. al., 1996). The results of the ANOVA do not support this hypothesis (Table 9). Though RTDT and SDDT do not show between-group differences, PRRT shows significant differences. SDERR was hypothesized to be the ECT most likely to show between-group differences, as SD measures appear to be most impacted by additive genetic factors (Petrill et. al., 1996). This hypothesis also was not supported by the results. An ANOVA using age-corrected CAT data returned similar results (Table 9). Though the current results are not as hypothesized, it should be noted that there is no previous research on the role of genetic and environmental factors in CAT performance in a MR population. Prior samples were composed of normal children, not mentally retarded adults, and previous research did not investigate between-group differences (Luo & Petrill, 1999; Petrill et. al., 1995; Petrill et. al., 1996). The CAT measures have good reliability and correlate with IQ as expected, lending support to the ANOVA results.

Linear regression analyses were run for both DS and FX. The dependent variable was FSIQ and all CAT measures were entered as independent variables. Both original and age corrected data were analyzed, though only original data is reported as the results showed few differences. The DS analysis was significant at the $p < .01$ level, and $R = .723$. Only two predictors reached significance, SDDT ($t = 3.09, p < .01$) and SDERR ($t = 2.44, p < .025$). This finding is consistent with previous research. The FX regression did not reach significance ($p = .170$), and $R = .683$. No CAT variables were significantly predictive of FSIQ. Interestingly, slopes and intercepts showed no significant between-group differences, indicating that the measures have similar relationships with FSIQ, though the relationship is weaker in FX.
Stepwise regression analyses returned similar results for DS. SDDT and SDERR were the only significant predictors of FSIQ ($R = .710$). In the FX group, however, the stepwise analysis returned a slightly different result, with PRRT significantly predicting FSIQ ($R = .558$). This indicated a suppressor variable. Indeed, when each variable was entered in with PRRT, the analysis that included SDDT returned a non-significant t-value for PRRT ($p = .07$). The CAT regression results provide strong support for the idea that the measures, and cognitive components, that predict FSIQ are different in the groups.

WAIS-III Factor Analyses. The factor structure of the WAIS-III has been researched extensively (Arnau & Thompson, 2000; Taub et al., 2004). Arnau and Thompson found a four factor first-order model with a second-order general intelligence factor (or g-factor) best fits the WAIS-III. The first-order factors are Working Memory, Verbal, Perceptual Organization, and Processing Speed. There is some evidence that the four factor structure may not best describe low IQ populations. Using a sample of 105 undifferentiated MR individuals with IQs of 74 or below, Jones, van Schaik, and Witts (2006) found that a principal components analysis, using Oblimin rotation, returned two factor solution. The components were comparable to the WAIS-III verbal and performance subscales.

An exploratory factor analysis was carried out on the subtests of the WAIS-III to determine loadings on the first factor and to explore loading patterns for the full sample. The determinant of the correlation matrix was .009, indicating the matrix can be factored. The Kaiser-Meyer-Olkin measure of sampling adequacy was .757, and the Bartlett's Test of Sphericity was significant at the $p < 0.001$ level. Variables were analyzed using principal components analysis with Oblimin rotation, with missing values excluded.
listwise. The factor structure was found to be irregular as compared to both four- and
two-factor solutions (Arnau & Thompson, 2000; Jones et. al., 2006). Three eigenvalues
over 1.0 were extracted, accounting for 65.53% of the variance. Table 12 shows the
Component Matrix for the unrotated solution, and Table 13 shows the Structure Matrix.
Correlations of less than .4 were not reported, except on the first factor. The unrotated
first factor score correlated with FSIQ from the current sample $r = .988$, $p < .001$. The
rotated first factor score correlated with FSIQ $r = .770$, $p < .001$.

The same analysis was carried out on the WAIS-III subtests, excluding
Arithmetic. As discussed above, Arithmetic shows a floor effect that might significantly
change the outcome of a factor analysis. Though Arithmetic has been shown to load
significantly on both Verbal and Performance factors (Kaufman, Lichtenberger, &
McLean, 2001), in the factor analysis described above, Arithmetic is the only subtest that
loaded on Factor 3 (Table 13). The determinant of the correlation matrix was .01,
indicating the matrix can be factored. The Kaiser-Meyer-Olkin measure of sampling
adequacy was .763, and the Bartlett's Test of Sphericity was significant at the $p < 0.001$
level. Variables were analyzed using principal components analysis with Oblimin
rotation. Two eigenvalues over 1.0 were extracted, accounting for 60.93% of the
variance. Table 14 shows the Component Matrix for the unrotated solution, and Table 15
shows the Structure Matrix. Correlations of less than .4 were not reported, except on the
first factor. Factor scores were saved using the regression method. The unrotated first
factor score correlated with FSIQ from the current sample $r = .989$, $p < .001$. The rotated
first factor score correlated with FSIQ $r = .770$, $p < .001$. All factor analyses were
performed on both age corrected and original data. The age corrected results were very
similar to original results ($\rho = .915, p < .01$), and further interpretation of WAIS-III factor analyses focuses on original data.

It was expected that the results of the factor analysis would be similar to previous findings. The loading pattern of the two-factor rotated solution is similar to published two-factor, rotated results from both the WAIS-III standardization sample and a low-IQ sample (Jones et. al., 2006; Kaufman et. al., 2001). As shown in Table 16, the results of the current rotated factor matrix show rank-order correlations of $\rho = .842 (p < .002)$ with the two-factor principal components, Oblimin-rotated solution from Jones, van Schaik, and Witts (2006). The current findings also correlate $\rho = -.663 (p < .05)$ with the two-factor principal axis, Varimax-rotated solution from the WAIS-III standardization sample (Kaufman et. al., 2001). Table 15 shows full factor loadings for both the first and second factors, compared to the first and second factor loadings for Jones and colleagues (2006). The loading patterns are very similar, and the second factor of both samples shows a rank-order correlation of $\rho = .758 (p < .02)$. The only subtest that shows an unusual loading pattern is Digit Span, with a higher than expected loading on the second factor. Recall that the DS group showed poorer mean performance on Digit Span than both FX and than their own mean subtest performance, and that Digit Span showed a significantly different slope in FX and DS. The unexpected loading of Digit Span is investigated further in group factor analyses described below.

The WAIS-III factor analysis results obtained using principal components analysis with Oblimin rotation with Arithmetic excluded are very similar to previous findings for MR populations (Jones et. al., 2006). In fact, they also correlate highly with standardization sample results from a two-factor solution using principal axis factoring.
and Varimax rotation (Kaufman et. al., 2001). The non-normal distribution of Arithmetic across both groups significantly changed the outcome of the factor analysis, and was excluded from further analyses at the individual subtest level.

The first factor scores from the unrotated, Arithmetic-excluded solution were used as a measure of $g$. Subtest $g$-loadings were used to explore correlations between WAIS-III subtests and between-groups differences. An ANOVA showed that the first factor scores were significantly different between FX and DS ($F = 4.107, p = .047$). Upon examination of the first factor scores, it was noted that one FX individual, while not technically an outlier, had a first factor score greater than two times the standard deviation of the sample. When this individual was removed, the analysis became non-significant ($F = 2.739, p = .104$). In addition, factor scores calculated from age corrected WAIS-III subtests showed no significant between-group difference, even with the FX individual included in the analysis ($F = 3.185, p = .08$).

As shown in Table 14, the first factor loadings in the current sample were lower than the unrotated first factor loadings from a principal component analysis of the WAIS-III standardization sample, and the first factor loading pattern was different (Reddon, de Brito, & Nicholls, 2003). In the current study, the subtests with the highest first factor loadings were Digit Span (.799), Block Design (.716), and Information (.652). In the standardization sample, Digit Span returned one of the lowest first factor loadings, while Vocabulary, Information, and Comprehension showed the highest loadings (Reddon, de Brito, & Nicholls, 2003). The subtest with the lowest first factor loading in the current research, Matrix Reasoning (.301), typically shows high first factor loadings. Spearman’s
Rho was .061 \( (p < .868) \) between the standardization sample first factor loadings and the first factor loadings in the current study (Table 16).

In an effort to determine why the first factor loadings in the current sample were so different from the standardization first factor loadings, several additional analyses were performed. First, those subtests that showed the most skew (Block Design and Digit Symbol) were removed individually and together to see if the analyses returned more normal results. The results showed no correlation with the standardized loadings. Next, the subtests that showed differences in the ANOVA analysis (Information, Comprehension, and Digit Span) were removed individually and together, but none of these analyses returned a significant correlation with the standardized loadings. In addition, the WAIS-III subtests that showed between-group differences in slope (Comprehension, Digit Span, and Block Design) were removed together, but the resulting analysis also showed no significant correlation with Reddon et. al. (2003). Each of the remaining subtests was removed from the analysis individually to determine if one or more subtests were greatly influencing the first-factor loadings. Again, none of the analyses returned results that correlated with the standardization loadings. By removing Digit Symbol, Digit, Span, and Information at the same time, the correlation was increased to \( \rho = .429 \ (p < .397) \). This correlation is not significant and is included to only demonstrate that the irregular loading of the unrotated first factor of the current sample is apparently not due to the influence of one or a few subtests. More likely, the range restriction of the current sample affected the factor analysis results. In addition, it should be noted that there is little research on first-factor loadings of the WAIS-III subtests in low-ability populations. Though the rotated factor solution published by Jones et. al.
(2006) correlates $\rho = .711$ ($p < .05$) with the Reddon results, the mean IQ of the Jones sample was 61.47 ($SD = 6.7$; range = 45-74), while the mean IQ in the current sample was 53.28 ($SD = 4.9$; range = 45-66). As evidenced by the Arithmetic subtest, the WAIS-III may perform differently at very low levels of functioning. In addition, the homogeneous genetic syndromes of the current sample may lead to more patterned performance on particular tasks, as evidenced by the paired t-tests. Due to the irregularities in the unrotated first factor loadings from the current sample, the first factor loadings from Reddon et. al. (2003) were compared to the current first factor results in all remaining analyses requiring WAIS-III subtest g-loadings.

Further exploration of the WAIS-III factor structure was attempted by factor-analyzing WAIS-III scores by diagnoses. Different loading patterns between FX and DS groups may clarify the underlying causes of between-group differences. For example, if a subtest such as Digit Span loaded highly on the Performance IQ factor in DS but not in FX, it could be argued that different central components of intelligence are used more heavily during DS performance of Digit Span than during FX performance. In an effort to more closely adhere to the requirements of factor analysis, six subtests were chosen: three from the Verbal IQ subscale and three from the Performance IQ subscale. The subtests chosen were those that showed the maximum difference between the groups, in order to investigate possible differences in factor structure or first factor loadings. The subtests used in the analysis were Comprehension, Digit Span, Information, Block Design, Picture Completion, and Digit Symbol. Both original and age corrected data were analyzed, though only original data are reported as the results showed few differences.
The following analyses should be considered exploratory in nature, particularly the FX analysis which includes only 19 participants.

The first analysis included DS participants. The determinant of the correlation matrix was .09, the Kaiser-Meyer-Olkin measure of sampling adequacy was .627, and the Bartlett's Test of Sphericity was significant at the $p < 0.001$ level. Variables were analyzed using principal components analysis with Oblimin rotation, missing values excluded listwise. Two eigenvalues over 1.0 were extracted, accounting for 71.09% of the variance. Table 17 shows the Structure Matrix. Correlations of less than .4 were not reported.

The results of the DS factor analysis closely match the results of the full sample WAIS-III factor analysis described above. Note the loading of Digit Span. While the highest Digit Span loading is on the Verbal IQ factor (Component 2), as expected, a moderate loading of .491 is shown on Component 1, the Performance factor. Digit Span also showed an unusually high first factor loading in the full sample, and was one of two WAIS-III subtests that showed significant differences between FX and DS. Recall that the DS group showed significantly poorer Digit Span performance both compared to the FX group and compared to their own mean WAIS-III performance. The DS group, overall, showed rotated loadings that are comparable to the full sample loadings. When the analysis was re-run with all of the WAIS-III subtests included, the DS results correlated $\rho = .939$ ($p < .001$) with the rotated first factor from the current sample, and $\rho = .806$ ($p < .005$) with the rotated first factor from Jones et. al. (2006). As in the full sample, the unrotated DS results showed no correlation with the Reddon first factor loadings ($\rho = -.043$, $p = .907$) (Reddon et. al., 2003).
The second factor analysis included FX participants. It was expected that the Digit Span subtest would show more traditional loadings in the FX sample. The determinant of the correlation matrix was .07, the Kaiser-Meyer-Olkin measure of sampling adequacy was .636, and the Bartlett's Test of Sphericity was significant at the $p < 0.001$ level. Variables were analyzed using principal components analysis with Oblimin rotation, missing values excluded listwise. Two eigenvalues over 1.0 were extracted, accounting for 70.04% of the variance. Table 18 shows the Structure Matrix. Correlations of less than .4 were not reported.

The loading pattern of FX was highly irregular, correlating non-significantly with the DS results ($\rho = -.127, p = .726$) and with the results of the full sample ($\rho = -.164, p = .651$). Comprehension and Digit Symbol were the only two subtests that did not show moderate to high loadings on both factors. As shown in Table 8, the FX and DS groups do not show large differences in subtest means or standard deviations, and it seems unusual that the FX group analysis would return such irregular results. To be sure, the FX factor analysis violates many guidelines on the number of cases needed for factor analysis (Lawley & Maxwell, 1971; Lewis, 1995). For example, Lewis (1995) suggests that an adequate sample size is: number of cases $\geq 5 \times$ number of variables. The FX factor analysis does not meet this criterion. Admittedly, the full sample factor analyses in the current study also fail to meet some published criteria, but the FX group analysis has the added failing of instability. When one variable was removed from the analysis, several of the remaining variables switched from one factor to another, and in some cases the second factor disappeared completely. Guadagnoli and Velicer (1988) warn that instability of results points to a sample size that is too small to give meaningful results.
Unfortunately the irregularity of the FX group analysis makes it difficult to discern if Digit Span shows unusual factor loadings in both groups, and no further interpretation was attempted.

CAT Factor Analyses. An exploratory factor analysis was carried out on the CAT variables to determine loadings on the first factor and to obtain factor scores for further analysis. Several published studies of the CAT have employed hierarchical factor analysis and structural equation modeling to explore the factor structure (Luo & Petrill, 1999; Petrill et. al., 1995; Petrill et. al., 1996). According to Jensen (2006, page 97), a hierarchical factor analysis should be undertaken only if there are enough variables to produce three group factors with three variables per factor. The current study falls well short of this criteria. In order to most closely adhere to the methods of the current study, a principal components analysis was performed. The determinant of the correlation matrix was .331, the Kaiser-Meyer-Olkin measure of sampling adequacy was .747, and the Bartlett's Test of Sphericity was significant at the \( p < 0.01 \) level. Variables were analyzed using principal components analysis, missing values excluded listwise. One eigenvalue over 1.0 was extracted, accounting for 48.92% of the variance. Factor scores were saved using the regression method. The first factor scores saved from the CAT correlated with FSIQ \( r = .676, p < .01 \), and do not show a significant between-group difference. Table 19 shows the Component Matrix. SDDT shows the highest first-factor loading (.812), consistent with the finding that SDDT performance correlates most highly with FSIQ. SDERR shows the lowest loading (.488). Both DS and FX group loadings are similar to the full sample loadings, though only the FX first factor is significantly correlated with the full sample loadings (\( \rho = .90, p < .05 \)). Though the DS loadings are similar in
magnitude, the pattern is slightly different ($\rho = .80, p = .104$). PR% showed the highest loading (.801), though SDDT still shows the highest correlation ($r = .568, p < .001$) with FSIQ in DS.

Age corrected CAT scores show a similar loading pattern to uncorrected measures ($\rho = .900, p < .05$) (Table 19). First-factor loadings are slightly lower, and RTDT replaces SDERR as the measure with the lowest first-factor loading. Age corrected DS first-factor loadings are nearly identical to uncorrected loadings ($\rho = 1.00, p < .01$). Age corrected loadings for FX are very similar to uncorrected loadings ($\rho = .900, p < .05$), though PR% has replaced SDDT as the measure with the highest loading. The loadings of PR% and SDDT were very similar in the uncorrected FX sample, and those measures were the most affected by the age correction. In addition, the first-factor loading of SDERR has increased in the age corrected FX sample, probably accounting for the increase in the full sample loading.

In general, the first-factor loadings of the CAT tasks in the current study are higher than loadings found in previous research using the CAT (Luo & Petrill, 1999; Petrill et. al., 1995; Petrill et. al., 1996). This may partially be due to the use of principal components analysis, which can inflate $g$-loadings (Jensen, 2006). Normally, low loadings on the $g$-factor are thought to indicate an ECT that recruits fewer central components. An ECT that recruits fewer central components is hypothesized to be more likely to show between-group differences, because a deficit in one of the central components would have a greater effect on performance. ECTs that load more highly on $g$ may use more central components, and would be less likely to show between-group differences.
WAIS-III and CAT Factor Analyses. To explore and replicate previously reported associations between CAT and measures similar to the WAIS-III subtests, three additional factor analyses were carried out (Luo & Petrill, 1999; Petrill et. al., 1995 Petrill et. al., 1996). All three analyses included RTDT, PRRT, PR%, SDDT, and SDERR. The WAIS-III subtests included were Digit Span and Digit Symbol-Coding. Ideally, the Arithmetic subtest would be included in the current analyses, but it was excluded as described above. The first analysis calculated factor loadings for all participants. The second included DS only, and the third included FX only. It is important to remember that these analyses should be considered exploratory and results interpreted with caution, particularly given the small sample size of the second and third analyses. In addition, previous results were acquired from samples of normal children, which may not generalize to mentally retarded adults (Luo & Petrill, 1999; Petrill et. al., 1995 Petrill et. al., 1996).

The first analysis included all participants. The determinant of the correlation matrix was .145, the Kaiser-Meyer-Olkin measure of sampling adequacy was .808, and the Bartlett's Test of Sphericity was significant at the $p < 0.01$ level. Variables were analyzed using principal components analysis with Oblimin rotation, missing values excluded listwise. Two eigenvalues over 1.0 were extracted, accounting for 60.77% of the variance. Table 20 shows the Structure Matrix. Correlations of less than .4 were not reported.

Previous research suggested that PR% would load on the same factor as the WAIS-III subtests of Digit Symbol-Coding and Digit Span. PR% showed moderate loadings on both the first and second factors, as did Digit Symbol-Coding (Table 20).
Digit Span showed moderate loading on the first factor. RTDT, SDDT, and PRRT also loaded moderately to highly on the first factor, with SDDT showing the highest loading, but also showing a moderate loading on the second factor. Though it was hypothesized that RTDT, SDDT, and PRRT would load together on a “speed factor,” they did not show any specific loadings apart from the other variables included in the analysis. SDERR showed the highest loading on the second factor. It is possible that the second factor in the current research represents a measure of learning, as hypothesized by Petrill and colleagues (1996). Another possibility is that Factor 2 represents a measure of attention. SDERR and PR% are both measures that reflect, partially, how well an individual attends to the task. In addition, Digit Symbol-Coding is a task that requires sustained attention. An analysis using age corrected data returned only one factor (Table 20), though a comparison of the unrotated first factor loadings from the original data with the first factor loadings from the age corrected data showed a correlation of $\rho = .929$, $p < .01$). In addition, the eigenvalue of the second factor for the age corrected data was .956, while in the original data the second eigenvalue was 1.07. These values reveal little difference in original and age corrected loadings. Though the current analyses show some deviation from the results of previous research, it is important to remember that these analyses use small sample sizes, and that the first factor loadings of the WAIS-III are irregular in the current sample.

The second analysis included only DS participants. The determinant of the correlation matrix was .145, the Kaiser-Meyer-Olkin measure of sampling adequacy was .780, and the Bartlett's Test of Sphericity was significant at the $p < 0.001$ level. Variables were analyzed using principal components analysis with Oblimin rotation, missing values
excluded listwise. Two eigenvalues over 1.0 were extracted, accounting for 59.37% of the variance. Table 21 shows the Structure Matrix. Correlations of less than .4 were not reported. The results of the DS-only analysis are not similar to that of the full sample, and only show a marginally significant correlation of \( \rho = -0.750, p = 0.052 \). Many of the variables show loadings on both factors, with SDERR and Digit Symbol showing the highest first-factor loadings. The results of the age corrected analysis are similar to the original data \( (\rho = 0.857, p = 0.014) \), with the main difference in the loadings of PRRT and PR% (Table 21). Interestingly, neither PRRT nor PR% showed large differences in mean or standard deviation from original to age corrected data in the DS sample (Table 9).

The third analysis included only FX participants. The determinant of the correlation matrix was .025, the Kaiser-Meyer-Olkin measure of sampling adequacy was .715, and the Bartlett's Test of Sphericity was significant at the \( p < 0.001 \) level. Variables were analyzed using principal components analysis with Oblimin rotation, missing values excluded listwise. Two eigenvalues over 1.0 were extracted, accounting for 68.60% of the variance. Table 22 shows the Structure Matrix. Correlations of less than .4 were not reported. The results of the FX-only analysis are in line with results from the full sample, showing a correlation of \( \rho = 0.821 (p < 0.03) \). Interestingly, the first factor loadings of the CAT measures are much higher than those of the WAIS-III subtests. Both Digit Span and Digit Symbol load about equally on the first and second factors, while all of the CAT measures (with the exception of SDERR) show loadings higher than .8 on the first factor. SDERR loads .938 on the second factor. The age corrected analysis correlated highly with the analysis of the original data \( (\rho = 0.893, p = 0.007) \) (Table 22). The greatest
difference appears to be Digit Span, which loads on only the second factor in the age corrected analysis.

The analyses above returned conflicting results and were difficult to interpret. An effort was made to determine which variables were causing the differences in loading between FX and DS. Note in Table 11 that SDERR does not correlate with FSIQ in FX. Removal of SDERR from the DS, FX, and full sample analyses resulted in the extraction of only one factor in each analysis. In addition, correlations between the group and full sample first factors were opposite those of the above analyses, with DS correlating $\rho = .943$ ($p < .01$) and FX correlating $\rho = -.058$ ($p = .913$). When measures that more accurately represent FSIQ for FX are the only variables included in the analysis, the FX first factor shows no correlation with the full sample first factor. Besides the obvious influence of group sample size, it appears that different CAT measures may contribute differentially to FSIQ in the two genetic syndromes. This hypothesis is supported by the results of regression analyses run for each group. If it is the case that the CAT measures show a different relationship to FSIQ in each syndrome, it provides support for the idea that CAT measures are using different cognitive processes, and also supports the system theory of intelligence: performance on ECTs may differ without showing differences in complex measures such as FSIQ.

FSIQ is an observed variable, which is an imperfect representation of the latent variable $g$. Do CAT or WAIS-III measures relate differently to $g$ between the two groups? The first-factor loading of each measure can be conceptualized as a correlation with $g$. Tests for differences in correlations between independent samples were performed to determine if CAT and WAIS-III measures showed between-group
differences in relation to $g$. Both original and age corrected data were analyzed. No set of DS-FX correlations between a given CAT or WAIS-III variable and $g$ showed a significant difference. However, one WAIS-III variable, Comprehension, showed a between-group difference in correlation with FSIQ on both original and age corrected data ($p < .05$ for both analyses). The DS correlation was non-significant ($r = .266$, $p = .093$), while the FX correlation was higher and in agreement with other research on WAIS-III subtests ($r = .727$, $p < .01$) (Wechsler, 1997). Comprehension shows between-group differences in slope, performance, and correlation with FSIQ. It does not show a between-group difference in correlation with $g$, and in fact the DS group does show a significant correlation between Comprehension and $g$. This result may mean that $g$, particularly for the DS sample, is not as highly implicated in Comprehension as more peripheral components.

**WAIS-III Discriminant Analysis.** The main hypotheses of the current study involve differences between FX and DS on WAIS-III and CAT tasks. Discriminant analysis was used to detect differences in performance between the two syndromes. If ECT or complex task performance differs between the groups, a discriminant analysis should be significant. The system theory of intelligence predicts a significant result for ECTs, indicating that it is possible to discriminate between DS and FX based on performance on tasks that use fewer central components of intelligence, such as the CAT. The system theory predicts that the discriminant analysis will not be significant for the WAIS-III, indicating that it is not possible to discriminate between groups on more complex cognitive tasks that include many central components of intelligence.
Due to the large number of variables, two analyses were performed. In both, “Grouping Variable” was Syndrome Identification, and “Independents” were entered together. The first analysis included the WAIS-III subtests. The canonical correlation shows that 65% of the variability in the discriminant scores can be accounted for by the discriminant function. Wilks’ Lambda for the eigenvalue of the discriminant function is significant at $p < .002$, and 77.6% of the cases were correctly classified. According to the structure matrix, Comprehension, Digit Span, and Information have the greatest correlation with the discriminant function (Table 23). This is consistent with Tests of Equality of Group Means: Comprehension, Digit Span, and Information have the smallest Wilks’ Lambda and are all significant at the $p < .05$ level. The Standardized Canonical Discriminant Function Coefficients show that the greatest unique contributions to the discriminant function are provided by Block Design, Digit Span, and Picture Completion. An analysis using age corrected data was not substantially different from the results obtained with the original data.

In the current study the null hypothesis was expected for the WAIS-III subtests. In this case it was important to guard against a type-two error, where a false null is not rejected. If a comparatively large beta level is used, the beta/alpha ratio will be affected. This ratio is a measure of the seriousness of type two errors/type one errors. The results of a compromise analysis showed that $f = 0.25$ and a beta/alpha ratio of 2 leads to a moderate power level of .6906, a critical F value of 2.0792, and an alpha level of .1547. If these levels are used the following subtests reach significance: Verbal IQ, Vocabulary, Block Design, Digit Span, Information, and Comprehension (Table 8). At the compromise analysis significance level two additional WAIS-III subtests reached
significance, with the DS group performing more poorly than the FX group on Vocabulary, but performing better than the FX group on Block Design.

The results from the discriminant analysis and ANOVA indicate that it is possible to discriminate between DS and FX using performance on the WAIS-III subtests of Comprehension, Digit Span, and Information at the $p < .05$ level. This result does not support the system theory of intelligence. If, however, the differences in performance are not related to $g$ and are instead related to some peripheral component of intelligence, these results may be irrelevant to the system theory. This possibility is explored below, in an analysis of WAIS-III subtest $g$-loadings and between-group difference scores.

CAT Discriminant Analysis. The second discriminant analysis included the CAT measures described above. The canonical correlation shows that 47% of the variability in the discriminant scores can be accounted for by the discriminant function. Wilks’ Lambda for the eigenvalue of the discriminant function is significant at the $p < .05$ level, and 70% of the cases were correctly classified. According to the structure matrix, PRRT has the greatest correlation with the discriminant function and the smallest Wilks’ Lambda, significant at the $p < .01$ level (Table 24). The Standardized Canonical Discriminant Function Coefficients show that the greatest unique contributions to the discriminant function are provided by PRRT and PR%. According to ANOVA results, performance on PRRT is significantly slower and more variable in the DS group as compared to the FX group. This was the only CAT variable that showed a significant between-group difference. The age corrected results are nearly identical to the uncorrected results, with the discriminant function accounting for 47% of variability in
scores, classifying 72% of cases correctly, and also showing PRRT as the most
discriminatory of the CAT measures.

Based on previous results, I initially hypothesized that those tasks expected to
load on a “speed factor” (RTDT, PRRT, SDDT) would be less likely to be affected by
genetic diagnosis (Petrill et. al., 1995). It appears, however, that PRRT measures a central
component that is not used by other CAT variables, though it is difficult to determine the
nature of the component. PRRT is a reaction time task, as opposed to a decision time
task. While it is possible that motor functioning is contaminating the current PRRT
results, there is no indication that individuals with DS have impaired motor functioning
as compared to FX. In fact, individuals with DS often perform better than their mean
performance on visual-motor tasks (Hodapp et. al., 1992). The between-group difference
on PRRT provides support for the idea that individual ECTs tap different components of
intelligence, and that it is possible to discriminate between groups using components of
intelligence. The failure of the remaining CAT measures to discriminate between the
groups is due to either a flaw in the system theory, or indicates that the CAT measures
themselves are not adequate representations of single or a very small number of central
components.

WAIS-III and CAT Discriminant Analyses. Finally, a discriminant analysis was
performed which included both WAIS-III and CAT variables. All CAT variables were
included. The WAIS-III variables included were those that were most discriminating in
the WAIS-only discriminant analysis: Comprehension, Digit Span, and Information.
“Grouping Variable” was Syndrome Identification, and “Independents” were entered
together. The canonical correlation shows that 57% of the variability in the discriminant
scores can be accounted for by the discriminant function. Wilks’ Lambda for the
eigenvalue of the discriminant function is significant at $p < .018$, and 83% of the cases
were correctly classified. These results were replicated almost exactly by the age
corrected analysis. According to the structure matrix, Comprehension, PRRT, Digit Span,
and Information have the greatest correlation with the discriminant function (Table 25).
This is consistent with the two previous difference score analyses and with the Tests of
Equality of Group Means: Comprehension, PRRT, Digit Span, and Information have the
smallest Wilks’ Lambda and are all significant at the $p < .05$ level. The Standardized
Canonical Discriminant Function Coefficients show that the greatest unique contribution
to the discriminant function is provided by PRRT. PRRT discriminates between the
groups better than Digit Span and Information, but as a whole the WAIS-III discriminates
between DS and FX more accurately than the CAT. The most discriminating of the
WAIS-III subtests, Comprehension, was able to correctly classify 68% of DS and FX
individuals when entered alone into a discriminant analysis.

WAIS-III Difference Score Analysis. In addition to discriminant analysis,
correlations between WAIS-III difference scores and $g$-loadings were used to clarify
between-group differences. Based on the factor structure of the WAIS-III and on the
system theory of intelligence, those subtests that show the highest $g$-loadings should
include the most central components, and should therefore show the least between-group
differences (Detterman, 1987). This would result in a negative correlation between
subtest $g$-loadings and subtest difference scores. For example, a subtest that traditionally
shows a high $g$-loading is Vocabulary. The system theory of intelligence hypothesizes
that Vocabulary loads highly on $g$ because it uses many central components of
intelligence. A task that uses many central components of intelligence is less likely to show between-group differences in individuals with mental retardation, because it is more likely that the deficient central component will be used during the task. Use of any deficient central component will lower task performance to the level of the deficit central component. Consequentially, no difference in between-group performance would be found even if different central components are deficient. A positive correlation would mean that subtests that load highly on $g$ also show substantial group differences, making it more likely that the two groups show differences in cognitive processes, not only single or a few central components. This would not support the system theory of intelligence.

Groups were matched on FSIQ, a measure that correlates highly with $g$, and the most highly $g$-loaded WAIS-III tasks were expected to show the least between-group variance. This would result in a negative correlation. All of the following results are from original data, as age corrected data showed no substantial differences. As shown in Table 8, performance means for the DS and FX groups were calculated for each WAIS-III subtest using age-corrected subtest scores. The actual difference score was calculated as the absolute value of each DS subtest mean minus each FX subtest mean. Subtest difference scores were correlated with subtest $g$-loadings (Table 26). WAIS-III subtest scores correlated $r = .646$, $(p < .05)$ with group difference scores. However, when the difference scores were added, it was noted that the groups were not exactly equated. The differences scores summed to -.3506. This indicates that there is a difference in overall performance level between the two groups.

To correct for the difference in level, the difference score analysis was run again, this time using z-scores. Z-scores were calculated for each individual, and mean z-scores
calculated for each group, for each subtest. A difference score between the DS and FX groups (the absolute value of DS-FX) was calculated from the z-scores of each subtest and correlated with subtest g-loadings from the current sample \((r = .594, p < .070)\). The correlation decreased and became non-significant. The significant correlation between between-group differences and g-loadings disappears when the difference in overall performance level is removed. This means that when the two groups are on the same performance level, the differences between them can be attributed to factors other than overall \(g\).

A significantly negative correlation would be most strongly supportive of the system theory of intelligence, with the most highly g-loaded tasks showing the least between-group variance. This would indicate that between-group differences are caused by differences in components of intelligence that are not fully represented by \(g\). A non-significant correlation can also be interpreted as supportive of the system theory: between-group differences are not related to only \(g\), but instead may be caused by components of intelligence that are not fully measured by the \(g\)-factor.

The difference scores calculated using the unstandardized WAIS-III subtest scores showed a substantial positive correlation with \(g\). This pattern has been found among racial and ethnic groups (see review in Jensen, 1998), where the largest between-group differences are found on the most heavily g-loaded tests. Conclusions from these studies suggest that differences between these groups are the result of differences in general intelligence, or \(g\). The results of the standardized difference score analysis suggest either that between-group differences for DS and FX are not due to differences in general intelligence, or that existing differences in general intelligence are undetectable in
the behavioral measures used here. The current results also point to another possible issue with the current dataset: it is possible that there are group differences in overall level of performance which must be corrected for by standardizing scores.

CAT Difference Score Analysis. In the same manner as the WAIS-III subtest scores, correlations between difference scores and CAT g-loadings were used to explore the origin of between-group differences. CAT measures were expected to show between-group differences. Theoretically, different CAT measures use different central components of intelligence. The different syndromes are hypothesized to have deficits in different central components. That is, DS might score most poorly on one CAT measure, while FX might score most poorly on some other CAT measure. The more central components a CAT measure uses, the more highly it should correlate with g. The subtests with the highest correlations will be less likely to show group differences, because it will be more likely that deficit central components will be tapped in both groups. The high g-loadings of the current research indicate that the CAT measures may use more central components than originally hoped, and might be less likely to show between-group differences.

Those CAT measures with the highest g-loadings were expected to show the least between-group differences, resulting in a negative correlation. All of the following results are from original data, as age corrected data showed no substantial differences. Z-scores were calculated for each individual, and mean z-scores calculated for each group, for each CAT measure. A difference score between the DS and FX groups (absolute value of DS-FX) was calculated from the z-scores of each measure and correlated with CAT g-loadings (Table 27). As with the WAIS-III, the correlation was non-significant (r = .308,
It appears that between-group differences are not related to the shared variance in the CAT measures represented by $g$. Instead, between-group differences may be related to individual components that make up the CAT measures. ECTs are thought to measure fewer (and more central) components of intelligence, and between-group differences may be related to the central components measured by the individual tasks rather than the shared, diffuse variance represented by $g$.

**WAIS-III Profile Analysis.** Between-group differences have been found on several WAIS-III subtests and on the PRRT subtest of the CAT. An important consideration was brought up by the difference score analysis: possible differences in overall profile level may be causing differences to appear significant when they are not. For example, a pairwise comparison shows that mean WAIS-III subtest scores are significantly different between groups ($t = -2.335, p < .05$). Figure 5 shows WAIS-III mean subtest performance for the two groups. In addition to possible differences in subtest performance, it seems that DS might have a slightly lower overall profile. Profile analysis can correct for differences in profile level, and can determine if observed differences on variables persist even when levels in profile are corrected for.

Data was prepared for the profile analysis by taking the difference between two subtests for each participant, and creating a new variable of those differences. For example, Picture Completion – Vocabulary was used to create a new variable, WAIS1. Vocabulary – Digit Symbol was used to create the new variable WAIS2, and so on. This means that from the 10 subtests of the WAIS-III, nine new variables were created. This computation is the first step in profile analysis, and corrects for differences in profile
level. All of the following analyses refer to original data, as age corrected results were not substantially different.

The new WAIS-III variables were entered into a between-group profile analysis, using the repeated measures analysis in SPSS. The within-subjects variables were the nine levels of the WAIS-III, referred to as WAIS. The between-subjects factor was diagnosis. Box’s Test of Equality of Covariance Matrices was non-significant, indicating that the two groups do not differ in their covariance matrices. Levene’s test of Equality of Error Variances also returned no significant results, showing that the assumption of homogeneity of variance is met. Pillai’s Trace, Wilks’ Lambda, and Hotelling’s Trace are all significant at the $p < .01$ level for both WAIS and for the WAIS*diagnosis interaction, indicating that there are significant multivariate effects. Mauchly’s Test of Sphericity was significant at the $p < .001$ level, indicating that sphericity of the error covariance matrix cannot be assumed and a correction should be employed. The within-subject effect of WAIS was significant at the $p < .001$ level, even when a correction for sphericity was used. The within-subject effect of WAIS*diagnosis did not reach significance when the Greenhouse-Geisser correction for sphericity was used ($p = .069$), though the effect did reach significance without the correction ($p = .023$). In addition, the effect of diagnosis on WAIS did not reach significance as a between-subjects effect, though the observed power was very small (.051). The profile plot (Figure 6) shows the adjusted estimated marginal means of each WAIS variable for DS and FX. WAIS-III subtest performance prediction is not possible from this plot, as the variables do not represent each subtest. However, the crossing of the DS and FX lines indicate that there is an interaction between WAIS-III subtest performance and diagnosis, even when profile level is
corrected for. Observed between-group differences on WAIS-III subtest performance do not appear to be due to differences in level.

CAT Profile Analysis. A pairwise comparison for mean CAT scores shows no significant different between groups ($t = -2.251, p = .08$). However, a profile analysis was performed on the CAT tests to ensure that observed differences in PRRT were not caused by differences in profile level. Data was prepared for the profile analysis in the same manner as the WAIS-III subtest. Four new variables were created, named CAT1 though CAT4. All of the following analyses refer to original data, as age corrected results were not substantially different.

The CAT variables were entered as within-subject variables into a between-group profile analysis, using the repeated measures analysis in SPSS. The between-subjects factor was diagnosis. Box’s Test of Equality of Covariance Matrices was significant ($p < .01$), indicating a between-group difference in covariance matrices, and Levene’s test of Equality of Error Variances returned one significant result ($p < .009$). The inequality of variance could lead to a higher type I error, or false positive rate, though multivariate tests have shown robust results on samples with unequal variances (Finch, 2005). Pillai’s Trace, Wilks’ Lambda, and Hotelling’s Trace were significant at the $p < .01$ level for CAT, and the CAT*diagnosis interaction approached significance at ($p = .053$). This indicates significant differences on CAT tasks, but not a significant CAT*diagnosis interaction. Mauchly’s Test of Sphericity was significant at the $p < .001$ level, indicating that sphericity of the error covariance matrix cannot be assumed and a correction should be employed. The within-subject effect of CAT was significant at the $p < .05$ level, even when a correction for non-sphericity was used. The within-subject effect of
CAT*diagnosis did not reach significance when the Greenhouse-Geisser correction for non-sphericity was used ($p = .390$). An ANOVA of the effect of diagnosis on CAT was highly insignificant ($F = .227, p = .636$), though again the observed power was very small (.075). The profile plot (Figure 7) shows the adjusted estimated marginal means of each CAT variable for DS and FX. The profile plot does indicate an interaction between CAT performance and diagnosis, though this interaction was not significant, or only approached significance, in the above tests.

The CAT profile analysis seems to indicate that, when level of performance is corrected for, there is no significant difference between DS and FX on CAT tasks. That a correction for level would make a significant difference in the CAT profile analysis is surprising, given the high correlation between the CAT measure means by group ($r = .990, p < .01$). The finding of no significant differences on the CAT after removal of differences in profile level, if accurate, does not support the system theory of intelligence.

The WAIS-III shows larger differences in DS and FX performance than the CAT. This result was not predicted by the system theory of intelligence and does not provide support for it. The WAIS-III tasks that discriminate between the groups presumably use many components of intelligence, both central and peripheral, though it can be argued that Digit Span is usually one of the simplest and least g-loaded of the WAIS-III subtests. While the current results do not refute the system theory as a whole, the finding of between-group differences on the WAIS-III subtests argues against the hypothesis that mental retardation stems from a deficit in a few central components, leaving the rest of the system unaffected. It is important to note that between-group differences on the
WAIS-III tasks are not great enough to support the practice of diagnosis or treatment based on cognitive profiles.

Discussion

The current research was designed to test the system theory of intelligence by identifying differences on ECT performance and on WAIS-III subtest performance between Fragile X and Down Syndrome. Due to the number of analyses and results, the discussion will focus on each of the hypotheses.

**Hypothesis 1:** Based on previous research on genetic components of cognitive abilities reliable differences in elementary cognitive task performance are expected.

Detterman (1987) proposes that intelligence is a system of central and peripheral components that work together. It is hypothesized that individuals with mental retardation have deficits in central components, decreasing the efficiency of the entire system of intelligence. According to the system theory, it is possible that two different genetic disorders will have deficits in different central components and yet not differ behaviorally on complex measures of cognitive ability.

ECTs are thought to access a smaller number of central components (Detterman, 1987). Performance on tasks such as those included in the CAT is hypothesized to be more likely to show between-group differences, expressly because fewer central components are used in each measure. The CAT measures used in the current research have shown different g-loadings, different amounts of variance accounted for by genetic factors, and measurably different relationships to more complex cognitive tasks, making it more likely that they tap different central components of intelligence (Luo & Petrill, 1999; Petrill et. al., 1995 Petrill et. al., 1996).
Differences in between-group performance on CAT measures were explored with ANOVA and discriminant analysis. Though the CAT measures appear to be reliable, they tended to load more highly than expected on a first factor and between-group differences were not as predicted. It was expected that SDERR or PR% would be most likely to show between-group differences, due to the small amount of additive genetic variance shown by RTDT, PRRT, and SDDT (Petrill et. al., 1996). In fact PRRT was the only CAT measure to show significant between-group differences, with the DS group showing slower and more variable performance. This single finding fits with the system theory: PRRT accesses a central component that is affected by the genetic mutation that causes DS, but not by the full mutation of FX. The idea that the CAT measures access different components of intelligence is supported by the CAT factor analysis and regression analysis, which show that in each group the CAT measures have different relationships to more complex measures such as FSIQ.

The finding of between-group differences on PRRT was thrown into doubt, however, by the profile analysis. It appears that when level of performance is corrected for, between-group differences on the CAT disappear. This finding is supported by a non-significant between groups ANOVA. The multivariate test for differences shows that the CAT*diagnosis interaction is approaching significance, and the profile plot indicates an interaction. In addition, the means of the CAT measures by group correlate highly and show no significant difference. These conflicting results make it difficult to discern if the between-group difference on PRRT is “real” or merely due to profile level differences. A difference in profile level on the CAT tasks is, in and of itself, an interesting finding. What factors are causing the groups to perform differently on the tasks?
A correlation between the g-loadings of the tasks and a measure of group performance differences was used to examine the origin of differences in performance on the tasks. g is the general factor, created from a factor analysis of many cognitive tests and representing shared variance. If between-group differences on central components of intelligence were significantly related to a diffuse measure of cognitive ability such as g, the relationship would be expected to be negative. As the g-loading of a task increased (meaning a greater number of central components were being accessed), the expectation of between-group differences would decrease. No significant relationship was found, indicating that the differences between the groups are not related to differences in g. Additional support for this idea came from the finding that correlations between the CAT variables and g are not significantly different between the two groups. This finding does not refute the system theory of intelligence, though it can be argued that the low power of this analysis makes it difficult to draw firm conclusions.

Hypothesis 2: The WAIS-III subtests are expected to show little to no group differences, with the most highly g-loaded tasks showing the least between-group variance.

According to the system theory of intelligence it is possible for two different genetic syndromes to have deficits in different central components of intelligence, while still showing identical or very similar profiles on complex cognitive tasks. Complex tasks employ many central and peripheral components, and any central component deficit will weaken task performance. Complex tasks that tap many central components will be more likely to use a component that is deficient; therefore, it should not be possible to discriminate among syndromes using complex tasks such as the subtests of the WAIS-III.
Differences in between-group performance on the WAIS-III were explored with ANOVA and discriminant analysis. Between-group differences and the relationships of those differences to the g-loadings of the measures were not as predicted. The DS group performed significantly poorer than the FX group on the following tasks: Comprehension, Digit Span, and Information. Overall Verbal IQ also showed a deficit in the DS group. The WAIS-III subtests as a whole better discriminated between the groups, and the most discriminating measure, Comprehension, is a complex WAIS-III measure. The measures that showed between-group differences are traditionally highly g-loaded, indicating that they use many central and peripheral processes. These findings appear to be due to more than just differences in profile level, as indicated by the profile analysis. While a finding of between-group differences is not strong evidence against the system theory as a whole, it does not support the hypothesis that mental retardation is the result of a deficit in a single or a few central components.

A correlation between the g-loading of each subtest and a measure of group performance differences was used to examine the origin of between-group differences on the subtests. This relationship was also expected to be negative, so that as the g-loading of a subtest increased, between-group differences would decrease. The difference scores calculated using the unstandardized WAIS-III subtest scores showed a substantial positive correlation with g, but the correlation became non-significant when differences in overall performance level were removed. When the two groups were equated on performance level, the differences between them can be attributed to factors other than overall g. Indeed, the WAIS-III subtest that showed the greatest between-group difference, Comprehension, showed an unexpected relationship with FSIQ in DS, but a
normal relationship with $g$. If the differences between the groups are not related to $g$, they might be irrelevant to the main premise of the system theory. Again, this finding should be considered exploratory due to power constraints.

If differences in WAIS-III subtest performance are not related to differences in general intelligence, what is causing the differences? As described above, the major finding is a deficit in verbal skills in the DS group. It is well known that individuals with DS have structural abnormalities of the tongue and jaw, often making communication more difficult (Ardran, Harker, & Kemp, 1972; Lemperle & Radu, 1980). Though there is some debate as to whether or not the tongue is enlarged, it does seem to have abnormal thrust, possibly due to structural abnormalities of the jaw (Ardran et al., 1972). It is possible that a physical abnormality, present from birth, can create a deficit in performance on tasks that depend on the affected structure. One can imagine a case where a speech deficit, such as articulation difficulty, would affect other aspects of communication over the lifespan. If an individual is very difficult to understand, others will be less likely to interact with that individual, decreasing exposure to vocabulary and opportunities to practice speaking. Over time, these small differences in exposure will compound, and eventually may lead to measurable deficits in performance measures.

Another possibility is that a deficit in auditory short term memory span is affecting verbal skills in DS. Rondal (1997) found that DS individuals with exceptional language skills also had a longer auditory short term memory span. In the current study, Digit Span correlated most highly with Vocabulary ($r = .629$, $p < .001$), and showed moderate correlations with Comprehension and Information. Though no claims of
causation can be made, the auditory short term memory-verbal skill link should also be further investigated in DS.

Conclusions

The current research has possible implications for the system theory of intelligence. Between-group differences on the WAIS-III subtests, while possibly related to peripheral components, seem to indicate that more complex tasks discriminate between groups better than ECTs. While the ANOVA and discriminant analysis results have little bearing on the overall theory, they do not provide support for the hypothesis that mental retardation is the result of a deficit in one or a few components of intelligence. It should be noted, however, that without more exact measures of central components it is difficult to make definitive statements about the composition of $g$. For example, while it appears that the current sample was matched on $g$, there are indications that a larger sample may show significant differences in $g$. Tasks that are better measures of one or a very few central components might reveal exactly which components contribute to the deficit.

A deeper analysis of between-group differences revealed potential differences in the relationship between the cognitive measures and more global measures of functioning such as FSIQ and $g$. These differences show, first, that the tests may be measuring different cognitive components in each group, and second, that different cognitive components contribute different amounts to overall functioning for each syndrome. These findings are supportive of the system theory: central and/or peripheral components show between-group differences in relationship with FSIQ, even as FSIQ (a measure of overall functioning) shows no between-group differences.
Between-group differences in which CAT and WAIS-III measures are most predictive of FSIQ illustrate that the concept of “cognitive profiles” for a given syndrome must be approached with caution. Differences in test-performance should not be considered a full picture of the cognitive profile of a syndrome. Current results indicate that the components of intelligence that most contribute to level of functioning may be different from syndrome to syndrome. In addition, general anatomic differences may interact with environmental factors to produce recognizable patterns of cognitive performance. The potential usefulness of cognitive profiles might be enhanced if researchers pursued a more thorough understanding of the underlying causes of between-group differences.

The comparison of different genetic syndromes of mental retardation is a complex multivariate problem, but one that deserves more research. The same cognitive component contributing differentially to $g$ or FSIQ in various genetic syndromes is an intriguing possibility. A large-scale analysis of various tests of cognition (such as the WAIS-III) in each syndrome could show which components contribute most heavily to functioning in each group and which components are clearly deficient or relatively spared. In addition to furthering research on the structure of intelligence, a more detailed picture of a genetically homogeneous intellect could generate new candidate QTLs for exploration. Though it is difficult to draw definitive conclusions from the current findings, they suggest that more targeted research will uncover group differences that will be relevant to research in several areas.
Future Directions

Several possibilities for further research follow from the current results. Based on the findings of the difference score analysis and on the finding that the DS group shows a lower overall level of $g$, it is possible that DS within-group differences are not related to $g$. Verbal subtests of the WAIS-III showed the greatest deficit in DS. One possible cause of this deficit is structural abnormalities of the tongue. Some DS individuals have undergone a partial glossectomy to decrease the size of the tongue. A glossectomy is normally performed when the individual is young, in the hope that a smaller tongue will improve appearance, articulation and, over time, allow verbal skills to develop unimpeded. The few studies of glossectomy patients have returned conflicting results (Klaiman et. al., 1988; Margar-Bacal, Witzel, & Munro, 1987; Parsons, Iacono, & Rozner, 1987; Wexler et. al., 1986). Importantly, no studies have followed individuals for more than 24 months after surgery, and most do not follow up after six months. An important avenue for further research on the verbal deficit in DS is to test glossectomy patients pre- and post-operatively on a variety of tasks, including FSIQ, vocabulary, comprehension, articulation, and auditory short term memory. Individuals who undergo glossectomies are usually still developing verbal abilities, so a critical component of this research would be the completion of follow up testing over a period of five to ten years to assess long term effects of glossectomy on verbal skills.

A second question that follows from the current research is whether it is possible to identify and measure individual components of intelligence using behavioral measures. While it appears to be possible to decrease the number of components used in a task, behavioral measures may never adequately identify precise contributions of components.
Newer research methods, such as fMRI, can further recognition and classification of components of intelligence. Already, research has shown that simple tasks reveal changes in activation patterns during different phases of the task, perhaps corresponding to even simpler mechanisms (Habecka et. al., 2005). ECTs, especially those that show possible between-group differences, seem like ideal candidates for research on neuroanatomical correlates of components of intelligence.

Summary

The current research tested the system theory of intelligence. Differences between DS and FX groups were found on the WAIS-III subtests of Comprehension, Information, and Digit Span, and possible differences were found on PRRT. In the current sample, individuals with homogenous genetic disorders that result in mental retardation can be identified based on complex cognitive task performance. While the differences may be due to peripheral components, it is difficult to determine if current results would generalize to a larger sample, which may, for example, differ on $g$. In addition, it appears that there are between-group differences in the components of intelligence that most contribute FSIQ and $g$. The current results should be used to guide more targeted investigations of the causes of between-group differences.
### Table 1. Summary of differences on cognitive tasks for Down Syndrome and Fragile X Syndrome.

<table>
<thead>
<tr>
<th>Down Syndrome</th>
<th>Fragile X Syndrome</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strengths:</strong></td>
<td><strong>Strengths:</strong></td>
<td></td>
</tr>
<tr>
<td>Hand Movements (K-ABC)</td>
<td>Achievement (K-ABC)</td>
<td>Burack, et. al., 1999; Hodapp et. al., 1992;</td>
</tr>
<tr>
<td>Gestalt Closure (K-ABC)</td>
<td>Gestalt Closure (K-ABC)</td>
<td>Hodapp et. al., 1992; Loesch et. al., 2002;</td>
</tr>
<tr>
<td>Visual-spatial short term memory</td>
<td>Long term memory</td>
<td>Mazzocco, 2000; State et. al., 1997;</td>
</tr>
<tr>
<td>Visual-motor tasks</td>
<td>Verbal skills</td>
<td>Wang et al., 1994;</td>
</tr>
<tr>
<td></td>
<td>Daily Living Skills</td>
<td></td>
</tr>
<tr>
<td><strong>Weakness:</strong></td>
<td><strong>Weaknesses:</strong></td>
<td></td>
</tr>
<tr>
<td>Verbal skills including syntax, grammar, speech development</td>
<td>Sequential Processing (K-ABC)</td>
<td>Abbeduto et. al., 2003;</td>
</tr>
<tr>
<td>Consolidation of information into long term memory</td>
<td>Hand Movements (K-ABC)</td>
<td>Bennett et. al., 1991;</td>
</tr>
<tr>
<td>Auditory processing</td>
<td>Visual-motor coordination</td>
<td>Brock &amp; Jarrold, 2005;</td>
</tr>
<tr>
<td>Auditory short term memory</td>
<td>Auditory, visual, and motoric short term memory</td>
<td>Burack et. al., 1999;</td>
</tr>
<tr>
<td></td>
<td>Arithmetic abilities</td>
<td>Dykens et. al., 1987;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hodapp et. al., 1991;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hodapp et. al., 1992;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jarrold et. al., 2000;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lincoln et. al., 1985;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Powell et. al., 1997;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Roberts et. al., 2005;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>State et. al., 1997;</td>
</tr>
</tbody>
</table>
Table 2. Previous research comparing Down Syndrome and Fragile X Syndrome on cognitive tasks, including sample sizes.

<table>
<thead>
<tr>
<th>Author</th>
<th>Comparison</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudhalter et. al., 1990</td>
<td>Deviant, repetitive language</td>
<td>9 DS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 FX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 Autism</td>
</tr>
<tr>
<td>Ferrier et. al., 1991</td>
<td>Conversational skills</td>
<td>18 DS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18 FX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18 Autism</td>
</tr>
<tr>
<td>Hodapp et. al., 1992</td>
<td>Kaufman Assessment Battery for Children</td>
<td>10 DS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 FX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 non-specific MR</td>
</tr>
<tr>
<td>Powell et. al., 1997</td>
<td>Kaufman Assessment Battery for Children</td>
<td>8 DS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32 FX</td>
</tr>
<tr>
<td>Burack, et. al., 1999</td>
<td>Kaufman Assessment Battery for Children, Vineland Adaptive Behaviour Scales</td>
<td>17 DS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17 FX</td>
</tr>
<tr>
<td>Abbeduto et. al., 2003</td>
<td>Receptive language skills - vocabulary, syntax, non-verbal cognition</td>
<td>25 DS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19 FX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 MA matched</td>
</tr>
<tr>
<td>Roberts et. al., 2005</td>
<td>Phonological skills</td>
<td>32 DS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50 FX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>33 MA matched</td>
</tr>
<tr>
<td>Abbeduto, et. al., 2006</td>
<td>Referential communication measures</td>
<td>25 DS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18 FX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25 MA matched</td>
</tr>
</tbody>
</table>
Table 3. WAIS-III subtest descriptions, reliability coefficients, and first factor loadings.

<table>
<thead>
<tr>
<th></th>
<th>First-Factor Loading</th>
<th>Reliability Coefficient WAIS-III</th>
<th>Reliability Coefficient Low IQ</th>
<th>Description of Subtest</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Verbal Scale</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vocabulary</td>
<td>.85</td>
<td>.93</td>
<td>.97</td>
<td>The examinee defines words that are presented orally and visually.</td>
</tr>
<tr>
<td>Information</td>
<td>.83</td>
<td>.91</td>
<td>.94</td>
<td>The examinee answers orally presented questions that assess knowledge of events, objects, places, and people.</td>
</tr>
<tr>
<td>Similarities</td>
<td>.82</td>
<td>.86</td>
<td>.97</td>
<td>The examinee explains how two orally presented words are alike.</td>
</tr>
<tr>
<td>Comprehension</td>
<td>.81</td>
<td>.84</td>
<td>.98</td>
<td>The examinee explains solutions to everyday problems in response to orally presented questions.</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>.78</td>
<td>.88</td>
<td>.96</td>
<td>The examinee solves orally presented arithmetic problems.</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.59</td>
<td>.90</td>
<td>.96</td>
<td>The examinee repeats progressively longer number series presented orally. For Digit Span Forward the examinee repeats the numbers in the order presented For Digit Span Backward the examinee repeats the digits in reverse order.</td>
</tr>
<tr>
<td><strong>Performance Scale</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>.75</td>
<td>.90</td>
<td>.94</td>
<td>From a set of five, the examinee chooses the option that best completes a visually presented matrix pattern.</td>
</tr>
<tr>
<td>Block Design</td>
<td>.72</td>
<td>.86</td>
<td>.97</td>
<td>The examinee uses red and white blocks to reproduce a visually presented or modeled pattern.</td>
</tr>
<tr>
<td>Picture Arrangement</td>
<td>.70</td>
<td>.74</td>
<td>.91</td>
<td>A set of printed cards are visually presented in incorrect order. The examinee rearranges the cards so that they tell a story that makes sense.</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>.66</td>
<td>.83</td>
<td>.96</td>
<td>The examinee identifies the missing element of a visually presented drawing.</td>
</tr>
<tr>
<td>Digit Symbol-Coding</td>
<td>.59</td>
<td>.84</td>
<td>-</td>
<td>The examinee uses a key to fill in a series of boxes with particular symbols. Each box is identified by a number, and the key pairs each number with a corresponding symbol.</td>
</tr>
</tbody>
</table>

Table 4. Post Hoc Power Analysis for ANOVA, \( p < .05 \).

<table>
<thead>
<tr>
<th>Effect Size</th>
<th>Small ( f = 0.10 )</th>
<th>Medium ( f = 0.25 )</th>
<th>Large ( f = 0.40 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lambda</td>
<td>.6000</td>
<td>3.75</td>
<td>9.6000</td>
</tr>
<tr>
<td>Power</td>
<td>.1187</td>
<td>.4779</td>
<td>.8614</td>
</tr>
</tbody>
</table>
Table 5. Compromise Power Analysis for ANOVA.

| Effect Size | Small  
|            | f = 0.10 | Medium  
|            | f = 0.25 | Large  
|            | f = 0.40 |
| Beta/Alpha Ratio: 1 | | | |
| Lambda     | 0.6000 | 3.7500 | 9.6000 |
| Alpha      | 0.4393 | 0.2320 | 0.0880 |
| Power      | 0.5607 | 0.7680 | 0.9120 |
| Critical F (1,58) | 0.6065 | 1.4589 | 3.0112 |
| Beta/Alpha Ratio: 2 | | | |
| Lambda     | 0.6000 | 3.7000 | 9.6000 |
| Alpha      | 0.2898 | 0.1547 | 0.0603 |
| Power      | 0.4204 | 0.6906 | 0.8794 |
| Critical F (1,58) | 1.1414 | 2.0792 | 3.6715 |
| Beta/Alpha Ratio: 4 | | | |
| Lambda     | 0.6000 | 3.7500 | 9.6000 |
| Alpha      | 0.1759 | 0.0990 | 0.0402 |
| Power      | 0.2962 | 0.6042 | 0.8390 |
| Critical F (1,58) | 1.8771 | 2.8119 | 4.4031 |
Table 6. Post Hoc Power Analysis for Correlation, $p < .05$.

<table>
<thead>
<tr>
<th>Effect Size</th>
<th>Small $r = 0.10$</th>
<th>Medium $r = 0.30$</th>
<th>Large $r = 0.50$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta</td>
<td>.3333</td>
<td>1.0430</td>
<td>1.9149</td>
</tr>
<tr>
<td>Power</td>
<td>.0908</td>
<td>.2484</td>
<td>.5493</td>
</tr>
</tbody>
</table>
Table 7. Compromise Power Analysis for Correlation.

<table>
<thead>
<tr>
<th>Effect Size</th>
<th>Small r = 0.10</th>
<th>Medium r = 0.30</th>
<th>Large r = 0.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta/Alpha Ratio: 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta</td>
<td>0.3333</td>
<td>1.0430</td>
<td>1.9149</td>
</tr>
<tr>
<td>Alpha</td>
<td>0.4339</td>
<td>0.3024</td>
<td>0.1753</td>
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<tr>
<td>Power</td>
<td>0.5661</td>
<td>0.6976</td>
<td>0.8247</td>
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<tr>
<td>Critical t(9)</td>
<td>1.1714</td>
<td>0.5362</td>
<td>0.9844</td>
</tr>
<tr>
<td>Beta/Alpha Ratio: 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta</td>
<td>0.3333</td>
<td>1.0430</td>
<td>1.9149</td>
</tr>
<tr>
<td>Alpha</td>
<td>0.2926</td>
<td>0.2082</td>
<td>0.1235</td>
</tr>
<tr>
<td>Power</td>
<td>0.4148</td>
<td>0.5835</td>
<td>0.7529</td>
</tr>
<tr>
<td>Critical t(9)</td>
<td>0.5660</td>
<td>0.8517</td>
<td>1.2378</td>
</tr>
<tr>
<td>Beta/Alpha Ratio: 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta</td>
<td>0.3333</td>
<td>1.0430</td>
<td>1.9149</td>
</tr>
<tr>
<td>Alpha</td>
<td>0.1804</td>
<td>0.1347</td>
<td>0.0835</td>
</tr>
<tr>
<td>Power</td>
<td>0.2782</td>
<td>0.4612</td>
<td>0.6659</td>
</tr>
<tr>
<td>Critical t(9)</td>
<td>0.9626</td>
<td>1.1770</td>
<td>1.5032</td>
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</table>
Table 8. Means and standard deviations of age and WAIS-III variables for Down Syndrome and Fragile X Syndrome, with and without outliers.

<table>
<thead>
<tr>
<th></th>
<th>With Outliers</th>
<th>Without Outliers</th>
<th>Age Corrected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DS</td>
<td>FX</td>
<td>DS</td>
</tr>
<tr>
<td>Age</td>
<td>28.53</td>
<td>26.58</td>
<td>-</td>
</tr>
<tr>
<td>Full Scale IQ</td>
<td>52.74</td>
<td>54.47</td>
<td>-</td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>55.76</td>
<td>58.73</td>
<td>-</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>2.05</td>
<td>2.47</td>
<td>-</td>
</tr>
<tr>
<td>Information</td>
<td>3.17</td>
<td>4.00</td>
<td>-</td>
</tr>
<tr>
<td>Similarities</td>
<td>2.95</td>
<td>3.58</td>
<td>-</td>
</tr>
<tr>
<td>Comprehension</td>
<td>2.27</td>
<td>2.89</td>
<td>-</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>1.20</td>
<td>1.26</td>
<td>1.20</td>
</tr>
<tr>
<td>Digit Span</td>
<td>2.00</td>
<td>2.89</td>
<td>-</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>58.02</td>
<td>57.74</td>
<td>57.46</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>3.34</td>
<td>3.00</td>
<td>3.18</td>
</tr>
<tr>
<td>Block Design</td>
<td>3.51</td>
<td>2.89</td>
<td>-</td>
</tr>
<tr>
<td>Picture Arrangement</td>
<td>3.56</td>
<td>3.58</td>
<td>3.51</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>3.10</td>
<td>3.58</td>
<td>-</td>
</tr>
<tr>
<td>Digit Symbol-Coding</td>
<td>2.07</td>
<td>2.42</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 9. Means and standard deviations of selected CAT variables for Down Syndrome and Fragile X Syndrome, with and without outliers.

<table>
<thead>
<tr>
<th></th>
<th>With Outliers</th>
<th>Without Outliers</th>
<th>Age-corrected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DS</td>
<td>FX</td>
<td>DS</td>
</tr>
<tr>
<td>RTDT</td>
<td>0.76</td>
<td>0.296</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>0.296</td>
<td>0.169</td>
<td></td>
</tr>
<tr>
<td>PRRT</td>
<td>4.48</td>
<td>3.708</td>
<td>3.98</td>
</tr>
<tr>
<td></td>
<td>3.708</td>
<td>1.388</td>
<td>2.47</td>
</tr>
<tr>
<td>PR%</td>
<td>.58</td>
<td>.296</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>.55</td>
<td>.293</td>
<td></td>
</tr>
<tr>
<td>SDDT</td>
<td>7.26</td>
<td>3.867</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>5.63</td>
<td>3.491</td>
<td></td>
</tr>
</tbody>
</table>
Table 10. Split-half reliability coefficients for select CAT measures.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Half 1/Half 2 Correlation $^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTDT</td>
<td>.969</td>
</tr>
<tr>
<td>PRRRT</td>
<td>.950</td>
</tr>
<tr>
<td>PR%</td>
<td>.707</td>
</tr>
<tr>
<td>SDDT</td>
<td>.911</td>
</tr>
<tr>
<td>SDERR</td>
<td>.918</td>
</tr>
</tbody>
</table>

$^1$ All correlations significant at the $p < .01$ level.
Table 11. Correlations between Full Scale IQ and select CAT measures.

<table>
<thead>
<tr>
<th></th>
<th>FSIQ Original Data</th>
<th>FSIQ Age Corrected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Full Sample</td>
<td>FX</td>
</tr>
<tr>
<td>RTDT</td>
<td>.400**</td>
<td>.551*</td>
</tr>
<tr>
<td>PRRT</td>
<td>.412**</td>
<td>.600**</td>
</tr>
<tr>
<td>PR%</td>
<td>.470**</td>
<td>.638**</td>
</tr>
<tr>
<td>SDDT</td>
<td>.576**</td>
<td>.552*</td>
</tr>
<tr>
<td>SDERR</td>
<td>.402**</td>
<td>.284</td>
</tr>
</tbody>
</table>

*Correlations significant at the $p < .05$ level.

**Correlations significant at the $p < .01$ level.
Table 12. Factor analysis of WAIS-III subtests, including Arithmetic, unrotated solution.

<table>
<thead>
<tr>
<th>Subtest</th>
<th>Component 1</th>
<th>Component 2</th>
<th>Component 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary</td>
<td>.658</td>
<td>-.426</td>
<td></td>
</tr>
<tr>
<td>Information</td>
<td>.692</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Similarities</td>
<td>.686</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comprehension</td>
<td>.577</td>
<td>-.507</td>
<td></td>
</tr>
<tr>
<td>Arithmetic</td>
<td>.245</td>
<td>.905</td>
<td></td>
</tr>
<tr>
<td>Digit Span</td>
<td>.823</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>.295</td>
<td>.797</td>
<td></td>
</tr>
<tr>
<td>Block Design</td>
<td>.725</td>
<td>.441</td>
<td></td>
</tr>
<tr>
<td>Picture Arrangement</td>
<td>.515</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picture Completion</td>
<td>.495</td>
<td>.512</td>
<td></td>
</tr>
<tr>
<td>Digit Symbol-Coding</td>
<td>.600</td>
<td>.423</td>
<td></td>
</tr>
</tbody>
</table>
Table 13. Factor analysis of WAIS-III subtests, including Arithmetic, rotated solution.

<table>
<thead>
<tr>
<th></th>
<th>Component 1</th>
<th>Component 2</th>
<th>Component 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary</td>
<td>.797</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information</td>
<td>.806</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Similarities</td>
<td>.785</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comprehension</td>
<td>.743</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arithmetic</td>
<td>.201</td>
<td>.957</td>
<td></td>
</tr>
<tr>
<td>Digit Span</td>
<td>.766</td>
<td>.474</td>
<td></td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>-.184</td>
<td>.781</td>
<td></td>
</tr>
<tr>
<td>Block Design</td>
<td>.362</td>
<td>.824</td>
<td></td>
</tr>
<tr>
<td>Picture Arrangement</td>
<td>.245</td>
<td>.640</td>
<td></td>
</tr>
<tr>
<td>Picture Completion</td>
<td>.135</td>
<td>.715</td>
<td></td>
</tr>
<tr>
<td>Digit Symbol-Coding</td>
<td>.306</td>
<td>.717</td>
<td></td>
</tr>
</tbody>
</table>
Table 14. Factor analysis of WAIS-III subtests, excluding Arithmetic, unrotated solution.

<table>
<thead>
<tr>
<th></th>
<th>Component 1</th>
<th>Component 2</th>
<th>First Factor Loadings$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary</td>
<td>.655</td>
<td>-.451</td>
<td>.85</td>
</tr>
<tr>
<td>Information</td>
<td>.695</td>
<td></td>
<td>.83</td>
</tr>
<tr>
<td>Similarities</td>
<td>.672</td>
<td></td>
<td>.82</td>
</tr>
<tr>
<td>Comprehension</td>
<td>.563</td>
<td>-.513</td>
<td>.81</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.822</td>
<td></td>
<td>.59</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>.308</td>
<td>.798</td>
<td>.75</td>
</tr>
<tr>
<td>Block Design</td>
<td>.728</td>
<td>.437</td>
<td>.72</td>
</tr>
<tr>
<td>Picture Arrangement</td>
<td>.530</td>
<td></td>
<td>.70</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>.502</td>
<td>.509</td>
<td>.66</td>
</tr>
<tr>
<td>Digit Symbol-Coding</td>
<td>.614</td>
<td>.400</td>
<td>.59</td>
</tr>
</tbody>
</table>

$^1$ Loadings from the first unrotated principal component for age groups 16-89 (Reddon, de Brito, & Nicholls, 2003).
Table 15. Factor analysis of WAIS-III subtests, excluding Arithmetic, rotated solution.

<table>
<thead>
<tr>
<th></th>
<th>Current Results</th>
<th>Jones et. al., 2006¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Component 1</td>
<td>Component 2</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>.795</td>
<td>.154</td>
</tr>
<tr>
<td>Information</td>
<td>.792</td>
<td>.229</td>
</tr>
<tr>
<td>Similarities</td>
<td>.793</td>
<td>.187</td>
</tr>
<tr>
<td>Comprehension</td>
<td>.753</td>
<td>.045</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.771</td>
<td>.480</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>-.183</td>
<td>.777</td>
</tr>
<tr>
<td>Block Design</td>
<td>.367</td>
<td>.826</td>
</tr>
<tr>
<td>Picture Arrangement</td>
<td>.237</td>
<td>.640</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>.138</td>
<td>.715</td>
</tr>
<tr>
<td>Digit Symbol-Coding</td>
<td>.292</td>
<td>.719</td>
</tr>
</tbody>
</table>

¹ Loadings from the first rotated factor for an undifferentiated MR sample (Jones, van Schaik, & Witts, 2006.)
Table 16. Rank-order correlations of WAIS-III first factor loadings in selected samples.

<table>
<thead>
<tr>
<th></th>
<th>Current Results</th>
<th>Reddon et. al., 2003</th>
<th>Current Results</th>
<th>Kaufman et. al., 2001</th>
<th>Jones et. al., 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unrotated</td>
<td>Unrotated</td>
<td>Rotated</td>
<td>Rotated</td>
<td>Rotated</td>
</tr>
<tr>
<td>Current, Unrotated</td>
<td>1</td>
<td>.061</td>
<td>.697*</td>
<td>-.164</td>
<td>.455</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p = .61</td>
<td>p = .025</td>
<td>p = .650</td>
<td>p = .187</td>
</tr>
<tr>
<td>Standardization, Unrotated</td>
<td>1</td>
<td>.596</td>
<td>-.640*</td>
<td>.711*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>p = .069</td>
<td>p = .046</td>
<td>p = .021</td>
<td></td>
</tr>
<tr>
<td>Current, Rotated</td>
<td></td>
<td></td>
<td>-.663*</td>
<td>.842**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>p = .037</td>
<td>p = .002</td>
<td></td>
</tr>
<tr>
<td>Standardization, Rotated</td>
<td></td>
<td></td>
<td>1</td>
<td>-.699*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>p = .024</td>
<td></td>
</tr>
</tbody>
</table>

1 Loadings from the first unrotated factor for age groups 16-89 (Reddon, de Brito, & Nicholls, 2003).
2 Loadings from the first rotated factor for age groups 16-89 (Kaufman, Lichtenberger, & McLean, 2001).
3 Loadings from the first rotated factor for an undifferentiated MR sample (Jones, van Schaik, & Witts, 2006).
Table 17. Factor analysis of select WAIS-III subtests for Down Syndrome, rotated solution.

<table>
<thead>
<tr>
<th></th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information</td>
<td></td>
<td>.822</td>
</tr>
<tr>
<td>Comprehension</td>
<td></td>
<td>.813</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.577</td>
<td>.702</td>
</tr>
<tr>
<td>Block Design</td>
<td>.895</td>
<td></td>
</tr>
<tr>
<td>Picture Completion</td>
<td>.751</td>
<td></td>
</tr>
<tr>
<td>Digit Symbol-Coding</td>
<td>.845</td>
<td></td>
</tr>
</tbody>
</table>
Table 18. Factor analysis of select WAIS-III subtests for Fragile X, rotated solution.

<table>
<thead>
<tr>
<th></th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information</td>
<td>.715</td>
<td>.508</td>
</tr>
<tr>
<td>Comprehension</td>
<td></td>
<td>.895</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.434</td>
<td>.812</td>
</tr>
<tr>
<td>Block Design</td>
<td>.795</td>
<td>601</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>.646</td>
<td>.517</td>
</tr>
<tr>
<td>Digit Symbol-Coding</td>
<td>.922</td>
<td></td>
</tr>
</tbody>
</table>
Table 19. First Component from a Factor Analysis of select CAT measures.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Original Data</th>
<th>Age-Corrected Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Full Sample</td>
<td>FX</td>
</tr>
<tr>
<td>RTDT</td>
<td>.631</td>
<td>.847</td>
</tr>
<tr>
<td>PRRT</td>
<td>.729</td>
<td>.805</td>
</tr>
<tr>
<td>PR%</td>
<td>.778</td>
<td>.867</td>
</tr>
<tr>
<td>SDDT</td>
<td>.812</td>
<td>.876</td>
</tr>
<tr>
<td>SDERR</td>
<td>.488</td>
<td>.246</td>
</tr>
</tbody>
</table>
Table 20. Factor analysis of select WAIS-III and CAT variables, rotated.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Original Data</th>
<th>Age Corrected Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Component 1</td>
<td>Component 2</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.698</td>
<td>-</td>
</tr>
<tr>
<td>Digit Symbol-Coding</td>
<td>.487</td>
<td>.786</td>
</tr>
<tr>
<td>RTDT</td>
<td>.717</td>
<td>-</td>
</tr>
<tr>
<td>PRRT</td>
<td>.715</td>
<td>-</td>
</tr>
<tr>
<td>PR%</td>
<td>.571</td>
<td>.670</td>
</tr>
<tr>
<td>SDDT</td>
<td>.824</td>
<td>.421</td>
</tr>
<tr>
<td>SDERR</td>
<td>-</td>
<td>.844</td>
</tr>
</tbody>
</table>
Table 21. Factor analysis of select WAIS-III and CAT variables for Down Syndrome.

<table>
<thead>
<tr>
<th></th>
<th>Original Data</th>
<th>Age Corrected Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Component 1</td>
<td>Component 2</td>
</tr>
<tr>
<td></td>
<td>Component 1</td>
<td>Component 2</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.456, .695</td>
<td>.464, .762</td>
</tr>
<tr>
<td>Digit Symbol-Coding</td>
<td>.806, -</td>
<td>.767, .476</td>
</tr>
<tr>
<td>RTDT</td>
<td>-</td>
<td>-.815</td>
</tr>
<tr>
<td>PRRT</td>
<td>.499, .549</td>
<td>.644, -</td>
</tr>
<tr>
<td>PR%</td>
<td>.752, .412</td>
<td>.811, -</td>
</tr>
<tr>
<td>SDDT</td>
<td>.535, .752</td>
<td>.646, .645</td>
</tr>
<tr>
<td>SDERR</td>
<td>.808, -</td>
<td>.742</td>
</tr>
</tbody>
</table>
Table 22. Factor analysis of select WAIS-III and CAT variables for Fragile X Syndrome.

<table>
<thead>
<tr>
<th></th>
<th>Original Data</th>
<th>Age Corrected Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Component 1</td>
<td>Component 2</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.470</td>
<td>.475</td>
</tr>
<tr>
<td>Digit Symbol-Coding</td>
<td>.617</td>
<td>.653</td>
</tr>
<tr>
<td>RTDT</td>
<td>.849</td>
<td>-</td>
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<tr>
<td>PRRT</td>
<td>.813</td>
<td>-</td>
</tr>
<tr>
<td>PR%</td>
<td>.833</td>
<td>.462</td>
</tr>
<tr>
<td>SDDT</td>
<td>.889</td>
<td>-</td>
</tr>
<tr>
<td>SDERR</td>
<td>-</td>
<td>.938</td>
</tr>
</tbody>
</table>
Table 23. Structure Matrix and Standardized Canonical Discriminant Function Coefficients for the WAIS-III measures.

<table>
<thead>
<tr>
<th></th>
<th>Structure Coefficients</th>
<th>Discriminant Function Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary</td>
<td>.247</td>
<td>.018</td>
</tr>
<tr>
<td>Information</td>
<td>.335</td>
<td>.321</td>
</tr>
<tr>
<td>Similarities</td>
<td>.153</td>
<td>.143</td>
</tr>
<tr>
<td>Comprehension</td>
<td>.377</td>
<td>.140</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.361</td>
<td>.819</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>-.076</td>
<td>.341</td>
</tr>
<tr>
<td>Block Design</td>
<td>-.236</td>
<td>-1.502</td>
</tr>
<tr>
<td>Picture Arrangement</td>
<td>.036</td>
<td>-.100</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>.214</td>
<td>.550</td>
</tr>
<tr>
<td>Digit Symbol-Coding</td>
<td>.185</td>
<td>.265</td>
</tr>
</tbody>
</table>
Table 24. Structure Matrix and Standardized Canonical Discriminant Function Coefficients for CAT measures.

<table>
<thead>
<tr>
<th></th>
<th>Structure Coefficients</th>
<th>Discriminant Function Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTDT</td>
<td>.299</td>
<td>.208</td>
</tr>
<tr>
<td>PRRT</td>
<td>.789</td>
<td>1.021</td>
</tr>
<tr>
<td>PR%</td>
<td>.098</td>
<td>.673</td>
</tr>
<tr>
<td>SDDT</td>
<td>.343</td>
<td>.137</td>
</tr>
<tr>
<td>SDERR</td>
<td>-.125</td>
<td>-.154</td>
</tr>
</tbody>
</table>
Table 25. Structure Matrix and Standardized Canonical Discriminant Function Coefficients for CAT and selected WAIS-III measures.

<table>
<thead>
<tr>
<th>Measures</th>
<th>Structure Coefficients</th>
<th>Discriminant Function Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information</td>
<td>.475</td>
<td>.193</td>
</tr>
<tr>
<td>Comprehension</td>
<td>.753</td>
<td>.375</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.525</td>
<td>.366</td>
</tr>
<tr>
<td>RTDT</td>
<td>.253</td>
<td>.071</td>
</tr>
<tr>
<td>PRRT</td>
<td>.651</td>
<td>.668</td>
</tr>
<tr>
<td>PR%</td>
<td>-.051</td>
<td>-.474</td>
</tr>
<tr>
<td>SDDT</td>
<td>.293</td>
<td>-.199</td>
</tr>
<tr>
<td>SDERR</td>
<td>-.092</td>
<td>-.155</td>
</tr>
</tbody>
</table>
Table 26. Difference scores and correlations for WAIS-III subtests for Down Syndrome and Fragile X Syndrome.

|                          | Difference Score, z-scores (|DS-FX|) | Difference Score, WAIS-III (|DS-FX|) |
|--------------------------|--------------------------------|----------------------------------|
| Vocabulary               | 0.47                           | 0.42                             |
| Information              | 0.59                           | 0.83                             |
| Similarities             | 0.34                           | 0.63                             |
| Comprehension            | 0.77                           | 0.62                             |
| Digit Span               | 0.69                           | 0.89                             |
| Matrix Reasoning         | 0.14                           | 0.34                             |
| Block Design             | 0.41                           | 0.62                             |
| Picture Arrangement      | 0.05                           | 0.02                             |
| Picture completion       | 0.34                           | 0.48                             |
| Digit Symbol-Coding      | 0.31                           | 0.35                             |
| g-loading – Difference Score Correlation | .594 | .646* |
| Current study             | $p < .070$                     | $p < .044$                       |
| g-loading – Difference Score Correlation | .165 | .099 |
| Reddon et al., 20031     | $p < .648$                     | $p < .785$                       |

1 Loadings from the first unrotated principal component for age groups 16-89 (Reddon, de Brito, & Nicholls, 2003).
Table 27. Difference scores and correlations for CAT measures for Down Syndrome and Fragile X Syndrome.

|                          | Difference Score, z-scores (|DS-FX|) |
|--------------------------|--------------------------------|
| RTDT                     | .336                           |
| PRRT                     | .813                           |
| PR%                      | .109                           |
| SDDT                     | .429                           |
| SDERR                    | .165                           |
| Correlation with CAT g-loadings | .308  |
|                          | $p < .614$                     |
Figure 1. Detterman’s (2001) System Theory of Intelligence

Three Central Components: D, E, F
Cognitive Processes: ADEFG, ADEFH, ADFEI, BDEFG..., CDEFI
Figure 2. An elementary cognitive task, including a central component F and several potential peripheral components (Detterman, Peterson, & Frey, 2001).
Figure 3. CAT Probed Recall and Stimulus Discrimination screen setup.
Figure 4. CAT Reaction Time screen setup.
Figure 5. WAIS-III mean subtest performance for FX and DS.
Figure 6. Estimated Marginal Means of WAIS.
Figure 7. Estimated Marginal Means of CAT.
References


cognitive ability: A multivariate genetic analysis of twin data. *Personality and
Individual Differences, 11:2*, 141-146.

Brunberg, J. A., Jacquemont, S., Hagerman, R. J., Berry-Kravis, E. M., Grigsby, J.,
Leehey, M. A., Tassone, F., Brown, W. T., Greco, C. M., & Hagerman, P. J.
(2002) Fragile X Permutation Carriers: Characteristic MR Imaging Findings of
Adult Male Patients with Progressive Cerebellar and Cognitive Dysfunction.

Burack, J. A., Shulman, C., Katzir, E., Schaap, T., Brennan, J. M., Iarocci, G., Wilansky,
with fragile X and Down syndrome. *International Journal of Behavioral
Development, 23:2*, 519-531.

Cardon, L. R., Fulkner, D. W., DeFries, J. C., & Plomin, R. (1992) Multivariate genetic
analysis of specific cognitive abilities in the Colorado Adoption Project at age 7.
*Intelligence, 16:3-4*, 383-400.

*Intelligence, 17*, 15-16.


Chipuer, H. M., Rovine, M. J., & Plomin, R. (1990) LISREL modeling:
Genetic and environmental influences on IQ revisited. *Intelligence, 14*,
11–29.


Goldman, K. J., Flanagan, T., Shulman, C., Enns, J. T., & Burack, J. A. (2005) Voluntary Orienting Among Children and Adolescents With Down Syndrome and MA-


Appendix A

INFORMED CONSENT DOCUMENT - GUARDIAN
Differences In Cognitive Abilities Between Various Phenotypes of Genetic Syndromes

Your child is being asked to participate in research looking at differences in abilities between individuals with a variety of syndromes that have genetic causes. The syndromes are Down Syndrome, Fragile X Syndrome, and Williams Syndrome. Your child was asked to participate because of his/her diagnosis. Please read this form and ask any questions that you may have before you agree to allow your child to participate.

Background Information
This study will explore differences in abilities between individuals with a variety of syndromes that have genetic causation, such as Down Syndrome, Williams Syndrome, and Fragile X Syndrome.

Procedures
If your child participates in this study, he/she would be asked to:
1. Complete a test of general cognitive ability (Wechsler Adult Intelligence Scale-III). This test involves several subtests, such as vocabulary, comprehension, and picture completion. It should take about 1 hour to complete.
2. Complete dimensions of the Cognitive Abilities Test (CAT). The CAT is a computer-based test which measures performance on several simple cognitive tasks. Accuracy and response times are recorded by the computer to form a measure of performance on each task. This test should take about two hours to complete.

Your child will be tested in one session if possible, but no more than two sessions, and testing will take two to four hours to complete. Your child is free to stop at anytime and can refuse to answer any questions.

Risks and Benefits to Being in the Study
There are no major risks; however, your child may become bored while participating in this study.

There are no direct benefits of participating in this research. If you or your child would like, we can share the results of these tests with you. The results of these tests should be used for informational purposes only. The tests are not administered by a licensed clinician, and the results cannot be used in situations that require test results certified by a licensed clinician.

Compensation
Your child will receive two $10 Blockbuster or Target gift certificates for participation. If your child wants to stop the session prior to completion of the tests your child will still receive the gift certificates.
**Confidentiality**
The records of this research will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify your child. Research records will be kept in a locked file, and access will be limited to the researchers, the University review board responsible for protecting human participants, and regulatory agencies.

**Voluntary Nature of the Study**
Your child’s participation is voluntary. If your child chooses not to participate, it will not affect his/her current or future relations with the University. The services provided to your child by the Cuyahoga County Board of Mental Retardation/Developmental Disabilities or any other referral source will not stop or change. There is no penalty or loss of benefits for not participating or for stopping participation. If your child chooses to withdraw from the study prior to completion, he/she will still receive a gift certificate.

**Contacts and Questions**
The researchers conducting this study are Katherine A. Koenig and Douglas K. Detterman. You may ask any questions you have now. If you have any questions later, you may contact them at Katherine A. Koenig at (216) 368-6670 or Doug Detterman at (216) 368-2680.

If you would like to talk to someone other than the researcher(s) about; (1) concerns regarding this study, (2) research participant rights, (3) research-related injuries, or (4) other human subjects issues, please contact Case Western Reserve University’s Office of Research Compliance at (216) 368-6925 or write: Case Western Reserve University; Office of Research Compliance; Sears Building 657; Cleveland, OH 44106-7230.

You will be given a copy of this form for your records.

**Statement of Consent**
I have read the above information. I have received answers to the questions I have asked. I consent to my child’s participation in this research. I understand that my child will also read and sign an informed consent document.

Print Name of Participant: _______________________________

Print Name of Guardian: ________________________________

Signature of Parent or Guardian: ________________________  Date: __________

Signature of Person Obtaining Consent: _________________  Date: __________
Appendix B
CAT

Cognitive Abilities Tests

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Department of Psychology
Case Western Reserve University
Cleveland, OH 44106
(216) 368-2680

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# Table of Contents

## CHAPTER 1  SETUP ................................................................. 1
- General Description ......................................................... 2
- Equipment Requirements ...................................................... 3
  - Computer ........................................................................... 3
  - Video Adapter ................................................................. 3
  - Monitor .............................................................................. 4
  - Touch Screen ..................................................................... 4
  - Serial Adapter ................................................................... 4
  - Hard Disk .......................................................................... 5
  - Floppy Diskettes .............................................................. 5
- Diagnosing Equipment Problems ............................................ 5
  - DIAGNOSE ......................................................................... 5
  - Persistent Problems .......................................................... 5
  - If CAT Worked But Doesn't Work Now ................................. 5
- Hard Disk Setup for CAT ...................................................... 6
  - Using INSTALL ..................................................................... 6
  - Customizing the Installation of CAT .................................... 6
- Deleting CAT from a Hard Disk ............................................. 7
- Floppy Disk Setup for CAT .................................................... 7
  - Single Drive System .......................................................... 7
  - Dual Drive System ............................................................. 7

## Chapter 2  Preparations for Running CAT .................................. 9
- MAKEDISK ............................................................................ 10
  - Data Diskette Structure ...................................................... 10
  - File Sizes ............................................................................ 10
  - Running MAKEDISK ........................................................... 11
- Configuring CAT ................................................................. 13
  - ?????TSK.DAT File ............................................................ 14
  - ?????XTRA.DAT File .......................................................... 15
  - Example of ?????XTRA.DAT .............................................. 16
- Environment During Testing ................................................ 16
  - Testee Space ...................................................................... 16
  - Lighting .............................................................................. 16
  - Sound Levels ..................................................................... 16
- Backing Up Data .................................................................. 17
Table of Contents

Using BACKDATA.BAT ................................................................. 17

Chapter 3 Running CAT ................................................................. 19
Beginning CAT ........................................................................ 20
  The Cover ........................................................................ 20
  Error Messages ................................................................ 20
  The Directories ................................................................ 20
  Testee Information ............................................................. 21
  Testee Progress ................................................................ 22
The CAT Menu ........................................................................ 23
  ALL .................................................................................. 25
  SIX .................................................................................... 25
  CHN .................................................................................... 25
  TST .................................................................................... 25
  SA and GR ........................................................................ 25
Running CAT from the Command Line ........................................... 26
The Touch Screen Calibration Screen ........................................... 27
  Keyboard Input .................................................................. 27
  Touch Screen Calibration .................................................... 27
Test Sequence .......................................................................... 28
Normal Ending ......................................................................... 28
How to Stop CAT .................................................................... 28
  F1-F5-Home .................................................................... 28
  Effect on Data .................................................................... 29
  Ctrl-C .............................................................................. 29

Chapter 4 Procedures to Follow When Testing ............................... 31
Instructions to Testees ............................................................... 32
  Written ............................................................................ 32
  Oral .................................................................................. 32
Practice .................................................................................. 32
  Help by the Tester ............................................................. 32
  Additional Practice ........................................................... 32
Making Response ..................................................................... 33
Session Length ........................................................................ 33
  Ten Tests ........................................................................ 33
  Six Tests .......................................................................... 33
  Progressive Matrices ........................................................ 33
Testing Children ..................................................................... 33
Programming Information
Programming Languages
Timing

Chapter 6 Description of Tests

Test Instructions (TI)
  General Description
  Instruction Format
  Output Data File

Learning (LR)
  General Description
  Practice Trials
  Number of Trials
  Blocks
  Timing
  Criteria
  Stimuli
  Screen Layout
  Programming Details
  Input Data File
  Output Data File

Reaction Time (RT)
  General Description
  Practice Trials
  Number of Trials
  Blocks
  Timing
  Criteria
  Stimuli
  Screen Layout
  Programming Details
  Input File
  Output Data File

Relearning (RL)

Sternberg Memory Search Test (ST)
  General Description
  Practice Trials
  Number of Trials
  Blocks
  Timing

iv
Practice Trials ........................................................................... 72
Number of Trials ....................................................................... 73
Timing ......................................................................................... 73
Stimuli ......................................................................................... 73
Screen Layout............................................................................. 73
Input Data File ............................................................................ 73
Output Data File ......................................................................... 73
Tachistoscopic Threshold (TT) .............................................. 74
  General Description ................................................................ 74
  Practice Trials ...................................................................... 74
  Blocks ................................................................................... 74
  Number of Trials .................................................................. 75
  Timing .................................................................................. 75
  Criteria .................................................................................. 75
  Stimuli .................................................................................. 75
  Screen Layout........................................................................ 75
  Programming Details ............................................................ 76
  Input Data File ....................................................................... 76
  Output Data File ................................................................... 76
Tachistoscopic Delay (TD) ....................................................... 77
  General Description ............................................................... 77
  Practice Trials ...................................................................... 77
  Blocks ................................................................................... 77
  Number of Trials .................................................................. 77
  Timing .................................................................................. 78
  Criteria .................................................................................. 78
  Stimuli .................................................................................. 78
  Screen Layout........................................................................ 78
  Programming Details ............................................................ 79
  Input Data File ....................................................................... 79
  Output Data File ................................................................... 79
Progressive Matrices (PM) ....................................................... 80
  General Description ............................................................... 80
  Practice Trials ...................................................................... 80
  Number of trials .................................................................... 80
  Blocks ................................................................................... 80
  Timing .................................................................................. 80
  Criteria .................................................................................. 80
  Stimuli Used .......................................................................... 80
  Screen Layout........................................................................ 81
Table of Contents

Publications .................................................................................................................. 115

Index ........................................................................................................................... 117
CHAPTER 1  SETUP

General Description ....................................................................................... 2
Equipment Requirements .............................................................................. 3
  Computer ..................................................................................................... 3
  Video Adapter ............................................................................................ 3
  Monitor ....................................................................................................... 4
  Touch Screen .............................................................................................. 4
  Serial Adapter ........................................................................................... 4
  Hard Disk ................................................................................................... 5
  Floppy Diskettes ....................................................................................... 5
Diagnosing Equipment Problems ............................................................... 5
  DIAGNOSE ............................................................................................... 5
  Persistent Problems ................................................................................... 5
  If CAT Worked But Doesn't Work Now .................................................... 5
Hard Disk Setup for CAT ............................................................................ 6
  Using INSTALL ......................................................................................... 6
  Customizing the Installation of CAT ......................................................... 6
Deleting CAT from a Hard Disk ................................................................. 7
Floppy Disk Setup for CAT ......................................................................... 7
  Single Drive System .................................................................................. 7
  Dual Drive System ..................................................................................... 7
General Description

The Cognitive Abilities Tests (CAT) is a set of computer-administered tests of basic cognitive abilities. The battery presently consists of 11 tests, 10 of which are measures of basic cognitive abilities, each of which has substantial research to indicate that the task is sensitive to individual differences. Further, individual differences on these tasks are predictive of differences on standardized intelligence tests. The eleventh task is a progressive matrices-type task.

All of the tests are self-administering and require little or no supervision from the administrator. All are based on the same stimuli and use the same kinds of responses. Administration of the battery of tests is also automated. Little or no intervention should be necessary from the tester.

When the battery is completed, preliminary statistical analysis is conducted by CAT and the data are reported in summary form for each task. These data can be used directly in analyses using SPSS. Trial-by-trial raw data are also available if needed.

Basic Description of Tests

The eleven tests are:

Learning (LR) - In this test, testees are required to learn sets of stimuli of from 3 to 9 items each. The test yields measures of learning rate.

Relearning (RL) - Testees relearn the same sets they originally learned in LR. Measures of savings in learning are obtained by comparing performance on this test to performance on LR.

Reaction Time (RT) - Testees are required to respond as quickly as possible to the onset of a stimulus. The test becomes increasingly complex by the addition of alternatives that must be attended to. Several measures of speed and accuracy are obtained from this test.

Stimulus Discrimination (SD) - This is a modified match to sample test. The testee matches a probe to one of six alternatives. This test yields measures of stimulus encoding and search processes.

Probe Recall (PR) - Six stimuli are presented sequentially in 'windows' on the screen for 1 second each. The testee's task is to remember where each stimulus was presented and to indicate in which position a match to a probe stimulus appeared. Various parameters of memory accuracy and speed are obtained.

Self-Paced Probe Recall (SP) - This test is similar to PR except that the testee can study each stimulus item for as long as desired. Along with measures of memory speed and accuracy, measures of strategy use are obtained.
Recognition Memory (RC) - A forced-choice recognition test uses stimuli from previously presented tests. Measures of memory speed and accuracy are obtained.

Sternberg Memory Search (ST) - Memorized sets of stimuli are tested by presenting stimuli which either are or are not in the memorized set. Measures of memory speed and accuracy are obtained for four different set sizes.

Tachistoscopic Threshold (TT) - Two stimuli are presented for a very brief duration and then are covered with a mask. Testees are required to judge if the stimuli are the same or different. If the decision is wrong, the next presentation is for a longer interval. Over a series of trials, a threshold for determining same and different is obtained.

Tachistoscopic Delay (TD) - This test is the same as TT except that a testee must judge if there is a longer or shorter delay between the offset of the first stimulus and the onset of the second.

Progressive Matrices (PM) - This is a more complex test than the other ten. It is modeled after progressive matrices-type tests. The testee must decide which item from a set of alternatives best fits into a missing position of a matrix of items whose rows and columns obey a rule.

Equipment Requirements

Certain equipment is necessary to run CAT. Other equipment is optional but will produce better results if used.

Computer

CAT runs only on IBM AT computers and compatibles. CAT has run on every IBM compatible it has been tested on. Since BIOS calls, the source of most incompatibilities, are kept to a minimum there should be few problems due to computer incompatibility.

CAT will not run on PC or XT type of computers because of hardware capabilities available on the AT which are not present on the XT or PC.

The speed at which the computer runs (6 megahertz, 12 megahertz, etc) makes no difference to CAT except that the amount of time the testee waits between tests and trials within tests will be minimized at faster speeds. All critical timing is done by the program using the system clock and should be constant despite computer speed.

Video Adapter

CAT requires an IBM Enhanced Graphics Adapter (EGA) or compatible. Video Mode 16 (640 X 350, 4 colors) is used for all test presentations. The EGA must have 256K of memory since page switching is used for several of the tests. Most EGA's now come with 256K of memory. CAT absolutely will not run
without an EGA adapter or compatible. If CAT appears to be working, but screen output is garbled, the problem is almost certainly the video controller (it is not an EGA) or the monitor.

**Monitor**

The monitor should be an EGA color monitor though CAT will work with a monochrome EGA monitor. A Mitsubishi EGA color monitor or NEC Multisync monitor work well and fit the touch screen mentioned below. The monitor must be EGA compatible and capable of displaying a resolution of 640 pixels X 350 pixels.

**Touch Screen**

A touch screen is highly recommended as the best response device. A touch screen suitable for use with CAT can be obtained from Edmark (P.O. Box 3093, Bellevue, WA 98009, Tel(800) 426-0856) for about $300. The touch screen attaches to the front bezel of most standard monitors. Some parallax results because the touch screen is some distance (several inches) from the monitor screen. But CAT uses large touch areas so this parallax should not be a serious problem. A more expensive integrated unit in which the touch screen is fit directly to a video monitor can be obtained from Ellinor Peripherals Limited (Arkwright Road, Reading, RG2 0LU, ENGLAND, Tel. 44-734-314066). Both of these touch screens are of the same design and should perform identically.

If a touch screen is used it is recommended that the monitor be mounted at 30 degrees from horizontal at about 26 inches from floor level. This reduces testee fatigue.

If a touch screen is not attached to the computer, CAT can be run using the keyboard as the input device. If the keyboard is used as the input device, the monitor should be mounted vertically at approximately eye level (about 40 inches from floor level). The keyboard should be placed directly in front of the monitor.

**Serial Adapter**

The touch screen must be connected to a serial adapter port. This port must be configured as COM1: or COM2:. Most AT computers come with at least one serial port and have either a 9-pin male or female connector or a 25-pin male connector. Consult your computer's owner's manual for further information. If there are no serial adapters on your computer, obtain a serial adapter card that plugs into one of the expansion slots.

When using the serial port with the touch screen, the mode command need not be used to configure the serial port (i.e., set the baud rate, stop bits, data bits, etc.). CAT configures the port. However, if you use a serial printer after using CAT on the same serial port, that port must be reconfigured to the printers requirements before using it.
Hard Disk
A hard disk is highly recommended for running CAT although it is not essential. If a hard disk is available, it is used for storing the program and related files. Data are always written to the floppy diskette except in extreme emergencies. Emergencies may occur if the floppy diskette is removed or if the disk drive or disk drive controller malfunction. In such emergencies, the data are written to the default directory which is the CAT directory on the hard disk, if a hard disk is present.

Floppy Diskettes
If a hard disk is installed, only one floppy diskette of any type (1.2 megabyte, 720K, or 360K) is required. If no hard disk is installed, then at least one diskette larger than 360K or two 360K diskettes are required. The diskette(s) must provide sufficient space for the CAT program and files and for a directory to write data output for each test completed. Program and data for one testee require a total of about 700K.

Diagnosing Equipment Problems
There should be few equipment problems with CAT so long as the above hardware configuration is available. If CAT should fail to work as expected, the following instructions should be helpful.

DIAGNOSE
Diagnose is a program that will check on the configuration of your computer and report incompatibilities. No special hardware configuration is necessary to run this program. See how to run CAT using the Menu as explained in Chapter 3.

Persistent Problems
If Diagnose works and does not report a problem but CAT still doesn't work, please let me know (Doug Detterman, 216-368-2680).

If CAT Worked But Doesn't Work Now
If CAT was working, but then stopped working or works erratically, one of the following may be the cause:
Is the hard disk or diskette full? At the root directory, type DIR. There should be at least 200,000 bytes available for CAT to work correctly.
Is the monitor turned on?
Is the touch screen plugged into the correct serial port?
Is the touch screen power supply plugged in?
Is the hard disk or diskette containing CAT OK? At the DOS prompt for the disk device where CAT is stored type CHKDSK. This is a DOS program which checks disks for problems.

**Hard Disk Setup for CAT**

**Using INSTALL**
The easiest way to install CAT is to use the installation batch file on the root directory of the distribution diskette. Insert the distribution diskette in Drive A: and type:

```
>A:\INSTALL
```

This will install CAT on Drive C: in a directory named \CAT. You may change the input disk drive, the disk drive to install CAT on or the root directory name in which CAT is installed. The full command to install CAT on Drive E: in a directory named \MYCAT from a diskette in Drive B: is (backslashes and colons are required):

```
>INSTALL \MYCAT B: E:
```

The INSTALL batch file runs CAT in self-test mode after it is installed. It is highly recommended that the self-test be completed to ensure that CAT works properly.

**Customizing the Installation of CAT**
Insert the CAT diskette in Drive A:. Use the following procedure or a modification of it to install CAT from the distribution diskette:

```
>C:
>CD\n>MD CAT
>CD CAT
>COPY A:\CAT\*.*  C:\CAT\*.*
>MD TOOLS
>CD TOOLS
>COPY A:\CAT\TOOLS\*.*  C:\CAT\TOOLS\*.*
>MD DATA
>CD DATA
>COPY A:\CAT\TOOLS\DATA\*.*  C:\CAT\TOOLS\DATA\*.*
```
This procedure may be modified so that only the portions of CAT that will be used are installed. For example, if no touch screen is used all ??INSTITW.TXT files may be omitted. If keyboard mode will never be used, all ??INST.TXT files may be omitted. Files in the TOOLS and DATA directory need not be installed for CAT to run correctly. The TOOLS directory contains utilities used in running CAT. The DATA contains data files used in examples of the program, DTTOSPS and can be used as a directory to collect DT files from data diskettes for further analysis.

Deleting CAT from a Hard Disk

To erase all CAT files and directories, use the DELCAT.BAT found in the tools directory. The following commands will delete CAT from Drive E:

```
>COPY E:\CAT\TOOLS\DELCAT.BAT E:\*.*
>DELCAT E:
```

Be certain to copy the batch file to the root directory from the \CAT\TOOLS directory before executing it. If DELCAT is executed while it is still in the TOOLS directory, it will be deleted along with the other files in the TOOLS directory and execution will end.

Floppy Disk Setup for CAT

There are two ways to run CAT using only floppy disk drives. If the system has only a single drive (larger than 360K), then both the CAT program information and the data directory will be on a single drive. If the system has two diskette drives, then program information will be on one disk drive and the data directory on the other.

Single Drive System

Format a diskette as specified in the next chapter in the section Makedisk. Be sure to allow about 360K for the CAT files. Make a directory on the data disk called 'CAT'. Copy all files from the distribution diskette into that directory.

You will need to follow this procedure for each diskette used to record testee data.

Dual Drive System

Format a DOS system diskette following instructions in the DOS manual. Make a directory called 'CAT'. Copy all files from the distribution diskette onto this directory. This diskette can now be used for all future testing.
directory diskettes, as described in the next chapter, will have to be made for testees.
Chapter 2 Preparations for Running CAT

MAKEDISK.................................................................................................................. 10
  Data Diskette Structure.......................................................................................... 10
  File Sizes............................................................................................................. 10
  Running MAKEDISK............................................................................................. 11
Configuring CAT....................................................................................................... 13
  ?????TSK.DAT File.............................................................................................. 14
  ?????XTRA.DAT File............................................................................................ 15
  Example of ?????XTRA.DAT ............................................................................... 16
Environment During Testing ............................................................................... 16
  Testee Space........................................................................................................ 16
  Lighting............................................................................................................... 16
  Sound Levels....................................................................................................... 16
Backing Up Data..................................................................................................... 17
  Using BACKDATA.BAT...................................................................................... 17
MAKEDISK

CAT insists that specially formatted diskettes be used to record testee data. In the current version of CAT, this data disk must be inserted in Drive A:. The data disk may also include the CAT directory containing the program files. Data diskettes may be made using the program, MAKEDISK.

Data Diskette Structure

The data diskettes have a special structure. The volume label of the diskette indicates a two letter code for the test series, a two letter code for the revision of CAT, and a 7 number sequence indicating the testee numbers contained on the diskette. An example of an acceptable volume label is TWAA0200109. The code for the test series is TW. The revision of CAT is AA and the diskette is for testee numbers 2001 to 2009.

The diskette also contains a directory for each testee. In the previous example there would be nine directories. The name of the directory identifies the testee whose data the directory will contain. In the previous example, the first directory would be TWAA02.001, the second would be TWAA02.002, the third TWAA02.003, etc.

The data diskettes can be made using the program, Makedisk. Before using the program, you must decide how many persons you are going to be testing and how much disk storage space will be required for each person's data. The amount of disk space required per person will determine how many testee's data will fit on a single disk.

File Sizes

The amount of disk storage space required for each person tested will depend on which tests they are tested on. The total amount of space required is equal to the sum of the file space required for each test plus two times the size of the DT file.

<table>
<thead>
<tr>
<th>File</th>
<th>Max. File Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN</td>
<td>840</td>
</tr>
<tr>
<td>LR</td>
<td>13,390</td>
</tr>
<tr>
<td>RT</td>
<td>8,415</td>
</tr>
<tr>
<td>RL</td>
<td>13,390</td>
</tr>
<tr>
<td>ST</td>
<td>13,183</td>
</tr>
<tr>
<td>PR</td>
<td>4,402</td>
</tr>
<tr>
<td>BK</td>
<td>0</td>
</tr>
<tr>
<td>SP</td>
<td>11,335</td>
</tr>
<tr>
<td>SD</td>
<td>23,323</td>
</tr>
<tr>
<td>RC</td>
<td>1,631</td>
</tr>
<tr>
<td>TT</td>
<td>23,080</td>
</tr>
</tbody>
</table>
TD 23,080
PM 2,630
DT 26,752
DT (in main directory) 26,752
Total 192,203

Use the table of file sizes to compute the approximate maximum size of file space to allow for each testee. Divide this size into the amount of storage space per diskette and the result will be the number of testee's data that will fit on a single diskette. It is better to have too few testees on a diskette than too many.

Before running Makedisk, make sure to have the required number of blank disks on hand. If 40 testee's are to be included in the series, and 4 testees data will fit on each diskette, you will need 10 blank diskettes (Number of testees / Number of diskettes per disk = Number of Disks). The disks may be either formatted or unformatted.

Running MAKEDISK

To run Makedisk, do the following:

```
>CD CAT\TOOLS
>MAKEDISK
```

Follow the prompts provided by MAKEDISK.

**Diskette drive A or B = = = > >**

Enter either A or B to indicate which diskette drive is to be used to make the data diskettes.

**Should all disks be formatted as you go [Y]es or N)o = = = > >**

Answer Y or N. If the answer is yes, diskettes will be formatted as they are inserted. If the answer is no, diskettes used must have been previously formatted. If formatted diskettes are used, they should contain no files or directories Nothing is removed from the diskette so all existing directories and files will be on the diskette after using makedisk.

**Enter a two-character code to identify the series = = = > >**

Enter two alphanumeric characters which will identify this series of testees. All testees in the series will receive the same battery of tests. These first two code letters are completely arbitrary and should be chosen by the tester to easily identify the testee series. They must be characters which are legal in DOS file names. In general, they should be the letters, A to Z or the numbers, 0 to 9.

**Enter a one-character code to identify the CAT version = = = > >**

The current version of CAT is A. This letter should always be A to identify the version of CAT used.

**Enter a one-character code to identify the generation = = = > >**
This refers to the current generation of CAT which is A. This generation letter must be included in the input data file name. Cat will not run unless this generation letter agrees with the letter in the input data file.

Is the code ??AA? [Y]es or N)o] = = = >>

This refers to the four letters identifying the series, generation and version. (Note that ?? is replaced by the code letters entered at series prompt.) Enter Y or N. If N is entered, the series of prompts is repeated. A Y response indicates that the code is correct.

First testee identification number (Enter) = = = >>

Type the number of the first participant and then press the Enter key.

Last testee identification number (Enter) = = = >>

Type the number of the last testee and then press the Enter key.

Number of testees per disk (Enter) = = = >>

Type the number of testees whose data will be stored on each disk (as calculated above) then press the Enter key.

Following this prompt you will be asked to verify the participant information. The prompt will appear similar to the following:

There will be 5 diskettes, with the last diskette having 4 testees.
Testee numbers will begin with 1 and go to 20. [Y]es or N)o] = = = >>

A Y confirms the information entered and a N repeats the prompts to allow corrections.

After all information has been entered correctly and the last prompt is answered with a Y, the screen will clear and the prompt will say (assuming Drive A: was selected):

Insert the next diskette in Drive A:

Insert a diskette and press any key to continue. If you specified that all disks should be formatted by the program, formatting will begin. Formatting is done by the DOS format program which must be on a search path specified by the DOS Path command (e.g., Path = C:;\DOS if FORMAT.COM is in the DOS directory). MAKEDISK actually executes this program. Therefore, this portion of MAKEDISK operates just like the DOS format command on your computer. You will see the following prompt, centered on the screen:

About to format diskette. Answer no to "Another?" prompt.

This prompt is to remind you that you should only format one diskette at a time even though you will be given a chance to format more than one diskette. When you are asked if you wish to format another diskette you should answer no. The next prompts are from the DOS format command:

Insert new diskette for drive A:
and strike ENTER when ready

The diskette should be already be in Drive A: so simply press Enter. The disk drive light should now light up and the disk drive will begin formatting the
diskette. This can take several minutes. When formatting is complete, the following prompt, or a similar one, will appear:

**Format complete**

- **1213952 bytes total disk space**
- **0 bytes in bad sectors**
- **1213952 bytes available on disk**

**Format another (Y/N)?**

If there are bad sectors on the diskette, you may not wish to use it in which case you would insert another diskette and answer yes. Otherwise, answer no. Do not format more than one diskette. If you are making more than one diskette, you will be given a chance to format the others later.

In the next step, MAKEDISK labels the diskette and adds the appropriate subdirectories. A screen display indicates what the program is doing. If formatting was not requested, this screen will be seen immediately following information entry. When MAKEDISK finishes with the diskette, the following prompt will appear:

**Insert the next diskette in Drive A:**

Repeat the above steps until all diskettes are finished.

---

**Configuring CAT**

CAT can be configured to behave differently for each testee series specified by the code letters on the data diskette. This is accomplished by using special files that are only active for the testees having those code letters. The special files control the administration of tests to the testee. They do not control the order in which the specific tests are given, but only the tests that will be given to a particular series of testees.

As an example, suppose there are two testee series designated by code sequences ABAA and CDAA (See explanation of MAKEDISK above to understand code letters). It would be possible to make up two separate special files, called ABAATS.DAT and CDAATS.DAT. The ABAA testees could then be given one set of tests and the CDAA testees a completely different set.

Which of the ???TSK.DAT files is used is determined by the data diskette in drive a: at the time CAT is run. When a testee identification string is selected on the directory screen, a ???TSK.DAT file is searched for in the CAT directory. (The ??? is replaced by the identification code, generation and version letters from the testee identification string.) For any single testee, there may be only one ???TSK.DAT file but there may be a separate ???TSK.DAT file for each series of testees.

The special files are kept in the CAT directory and CAT looks for one each time anyone is tested. If it finds a special file, that file controls the testing. If no file is found, CAT assumes all tests (the eleven cognitive tests plus TI- initial
instructions and BK - break) currently in the battery may be given. The testee can then be given the entire battery or any combination of tests chosen.

**????TSK.DAT File**

To construct a ????TSK.DAT file follow these rules:

1. The first line of the file must be the number of tests to be given (including TI and BK).

2. Each of the next lines must be a two-letter test code (in capital letters) as the code appears in the menu (see below). There should be as many lines of two-letter codes as the number of tests specified on the first line. The total number of lines in the ????TSK.DAT will equal the number of code letters plus one.

3. The file must be named with the first four letters of the name being the testee code letters as specified in MAKEDISK (first two letters for test series; next two letters for CAT version and generation). The remainder of the file name must be TSK.DAT. Thus, an appropriate file name would be ????TSK.DAT where the four question marks are replaced by the appropriate test series, version, and generation letters.

4. The file must be in the same directory as CAT. It must be a pure ASCII file created by Edlin or some other editor that can save files without special format characters (unformatted). Microsoft Word can be used so long as the file is saved unformatted.

The following is an example of a ????TSK.DAT file created using the DOS editor, Edlin:

```
>edlin TWAATSK.DAT
New file
*1I
  1:* 6
  2:*LR
  3:*RT
  4:*PR
  5:*SP
  6:*SD
  7:*TT
  8:*^Z (type F6)
*E
```

Information in bold letters is typed by the user. Each line ends with Enter. After typing this information, a file named TWAATSK.DAT would exist in the current directory. Copy this file to the CAT directory. Thereafter, all testees in the testee series TWAA (as indicated by the data diskette) would receive only the six tests specified in the ????TSK.DAT file, LR, RT, PR, SP, SD, and TT.

Other examples of ????TSK.DAT files might be:
ABAATSK.DAT (file name)

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
</tr>
<tr>
<td>SD</td>
</tr>
<tr>
<td>RT</td>
</tr>
</tbody>
</table>

DDAATSK.DAT (file name)

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
<tr>
<td>TI</td>
</tr>
<tr>
<td>PM</td>
</tr>
<tr>
<td>BK</td>
</tr>
<tr>
<td>TT</td>
</tr>
</tbody>
</table>

The first file indicates that testees in series ABAA would receive only SD and RT while those in DDAA would receive TI, PM, BK, and TT.

????XTRA.DAT File

Another way to customize the use of CAT is with ????XTRA.DAT files. The DT files generated by CAT contain summary statistics from each of the tests administered in the CAT battery. It may be desirable to add information to the DT file for later analysis so all data on a single testee, including scores from other batteries, can be found in one file. The ????XTRA.DAT file is designed for this purpose. The ????XTRA.DAT file will not add the data to the DT file but will provide the space to add information at a later time using an editor or word processor.

The ????XTRA.DAT file is structured exactly like the DT file. To create one, use the following rules:

1. Each line of the file should have three separate entries. The first entry should be the number 999,000. This is the missing data code and will be replaced by the actual data at a later time. This number should be preceded by two blank spaces and followed by two blank spaces.

2. The second entry is a variable name of no more than 8 characters in capital letters. The variable name should be followed by three blank spaces. Care should be taken that the variable name is not the same as one produced by CAT. CAT uses strict conventions to name variables. All variable names begin with the first two letters of the test the data are from. To avoid duplicate names, do not make the first two letters the same as any of the test code letters (TI, LR, RT, RL, ST, PR, BK, SP, SD, RC, TT, TD, and PM).

3. The last entry is the variable label which is an extended description of the variable no longer than 40 characters. It follows the label and may be in both upper and lower case letters. The line should end with a carriage return.
4. Make an unformatted ASCII file with as many lines as needed for extra variables using Rules 1 - 3 above.

5. Name the file with the four code letters of the testee series it applies to and with the ending XTRA.DAT. For example, ABAAXTRA.DAT.

6. Place the file in the same directory as the CAT program. Every time a testee in specified series completes testing, the contents of the ????XTRA.DAT will be appended to the testee's DT file.

7. Use a word processor to add the appropriate data to the DT file as it becomes available.

Example of ????XTRA.DAT
TWAAAXTRA.DAT (file name)

| 999.000 | IQWDR | WAIS-R Digit span Raw score |
| 999.000 | IQWIR | WAIS-R Information Raw score |
| 999.000 | IQPR__1 | PPVT Raw score Odd items |
| 999.000 | IQPR__2 | PPVT Raw score Even items |

Environment During Testing

Testee Space
Each testee should have a cubicle to themselves. Although cheating is not a concern, distraction of the testee can be a problem if others are nearby. The monitor should be mounted, as discussed under equipment, either vertically if keyboard mode is being used or 30 degrees from horizontal if a touch screen is the response device. The testee's eyes should be approximately 24 inches from the monitor screen.

Lighting
CAT is currently given with the room lighting very low. The video monitor is adjusted to moderate levels of brightness and contrast. A method to specify more exactly the monitor and room lighting conditions is being designed.

Sound Levels
CAT has been given in an environment of low to moderate ambient noise. The beeps and buzzes used as feedback by CAT have not seemed to interfere with testing even when as many as 30 testees participated in cubicles in the same room.
Backing Up Data

CAT makes only one copy of data collected on the data disk. Data are not copied to the hard disk or any other device. **It is strongly suggested that all data files be copied by the tester onto a backup diskette as soon as they are collected.**

Using BACKDATA.BAT

A batch file is provided which backs up a given directory on to a diskette having an identical directory. This batch file is designed for copying files between two identical data diskettes made with MADEISK. One of the diskettes is designated as the backup diskette and the other the original or source diskette. The original diskette is used when a testee takes the battery. To protect against loss of data, files from the original diskette are copied to the backup diskette.

To use BACKDATA, insert the original diskette in Drive A:. A second drive must be available to use as a scratch file. The default is Drive C: To copy the files in directory TWAA00.001, type the following:

```
>BACKDATA TWKA00.001
```

Do as instructed by the prompts. Since the data files on the original diskette are made read-only there is very little danger of accidental deletion. After the files have been copied to a temporary directory on Drive C:, you will be prompted to replace the original diskette with the backup diskette. The files will then be copied from the temporary directory on Drive C: to the backup diskette. The test files will also be made read-only on the backup diskette.

You may alter the source drive and the drive on which the temporary directory is written. To use Drive B: as the source and write the temporary directory to Drive D:, use the following command:

```
>BACKDATA TWAA00.001 B: D:
```

Note that both the original and backup diskette will be inserted in Drive B:. 
Chapter 3 Running CAT

Beginning CAT ........................................................................................................... 20
  The Cover ........................................................................................................... 20
  Error Messages .................................................................................................. 20
  The Directories ................................................................................................... 20
  Testee Information .............................................................................................. 21
  Testee Progress .................................................................................................. 22

The CAT Menu ........................................................................................................ 23
  ALL ...................................................................................................................... 25
  SIX ..................................................................................................................... 25
  CHN ..................................................................................................................... 25
  TST ...................................................................................................................... 25
  SA and GR .......................................................................................................... 25

Running CAT from the Command Line .................................................................. 26

The Touch Screen Calibration Screen ..................................................................... 27
  Keyboard Input .................................................................................................... 27
  Touch Screen Calibration ................................................................................... 27

Test Sequence ......................................................................................................... 28

Normal Ending ....................................................................................................... 28

How to Stop CAT ................................................................................................... 28
  F1-F5-Home ....................................................................................................... 28
  Effect on Data .................................................................................................... 29
  Ctrl-C ................................................................................................................... 29
Beginning CAT

Before running CAT, data diskettes must be available. These diskettes can be made using the program, MAKEDISK, as described in Chapter 2. CAT must be on the hard disk or in one of the floppy drives (on the data diskette, if necessary). In the following description, it is assumed that the CAT program is in a directory called CAT. Use the following procedure to run CAT.

1. Insert the data diskette in Drive A:
2. Change to the disk that contains the CAT program.
3. Type CAT and press the Enter key.

If the CAT program is on hard disk (C:) the commands used would be:

```
>C:
>CD CAT
>CAT
```

The Cover

The cover is a colorful display giving basic information about CAT. The important thing for the tester to note is the date and time displayed in the upper middle of the screen. If the date and time are incorrect, exit by pressing the Esc key. Set the date and time using the appropriate DOS commands and then restart CAT.

It is important that the date and time be correct since CAT uses them to keep track of the testee's progress throughout the battery. If properly set, they should not need to be changed except to reflect changes in daylight savings time. If the time is correct, press Enter to continue.

Error Messages

CAT checks to make sure the required data disk is in Drive A:. A number of errors can occur. There may be no diskette inserted. The diskette may not be formatted or it may be write-protected. If an error occurs, a red screen appears accompanied by a beeping sound. Directions are given on the screen for correcting the error.

The Directories

The next screen which appears is on a blue background. (All blue screens are directions to the tester and should be responded to by the tester. Testee screens
have a black background.) The first blue screen provides a summary of the directories on the diskette and what files are in each directory.

At the top of the screen is the volume label. Below it are listed files in the root directory. Each directory name is then listed followed by a list of the first two letters of each file in the directory. Files listed in light blue are archival while files written in pink (underlined below) are read-only and cannot be edited. The screen will appear similar to the following:

```
A:\ Volume label is TWAA0000108
   DT DT
   A:\ TWAA00.001 IN SD DT
   A:\ TWAA00.002 IN LR RT PR SP SD TT DT
   A:\ TWAA00.003
   A:\ TWAA00.004
   A:\ TWAA00.005
   A:\ TWAA00.006
   A:\ TWAA00.007
   A:\ TWAA00.008
Enter identification number between 00001 and 00008
Number (ENTER for first empty directory)? ===>
```

Enter a number in the specified range for the current data disk and press the Enter key. This will select the numbered directory as the data directory for use by the current testee. This directory will be used for data output and information files.

To select the next available testee number for a new testee in the test series, press the Enter key without typing a number. The first empty data directory will be selected by CAT.

If an illegal number is selected, the error will be indicated and a new selection can be made. Otherwise, the testee identification number will be displayed. Press Esc to start over or any other key to go on. The prompt will appear as:

```
Identification: TWAA00.003
   Any key to continue, <ESC> to change
```

**Testee Information**

The testee information screen provides a way of recording information about the testee such as name, address, telephone social security number, birthday, etc. Fill out the information. You will be given a chance at the end to go back and correct any errors. The testee information screen appears as follows:
If data are already entered on the testee information screen, pressing Enter before typing anything else will save the information already recorded. Only incorrect or incomplete fields need be changed. Any field on the screen can be changed by typing over the information that is already there.

If the testee information has been partially completed in a previous session, the tester will be prompted to provide the remaining information on all subsequent sessions until all spaces contain an entry. Testee personal information is not included in the DT file. Identification number of the information file is the only link between testee personal information and test data.

The testee information screen may be revised as many times as desired by pressing Esc at the prompt. To accept the screen as displayed, press the Enter key.

**Testee Progress**

The testee progress screen displays a list of tests to be given to the testee and provides a summary of progress for each test. For completed tests, the date and time the test was started and the time it was finished are displayed. Also shown is the number of previous attempts. This is an example of a testee progress screen:
A test begun but aborted before completion will be indicated with the date and time started and the word "Aborted" (as in RT above). Note that even though the data from an aborted test are saved, they are not analyzed because they are incomplete. The statistical analysis portion of CAT ignores incomplete files.

The list of tests displayed is obtained from the ????TSK.DAT file if one exists. If there is not a ????TSK.DAT file, all possible tests (including TI and BK) are listed. Tests listed on the testee progress screen may or may not be administered as determined by the tester. Because a test is listed on the progress screen does not mean that it will automatically be administered.

If the testee progress screen indicates that the testee has completed a particular test, that testee cannot be given that test again even if the data file for that test is removed from the directory. CAT will not allow completed tests to be readministered.

No tester response is necessary for the testee information screen. If Esc is pressed, CAT begins again with the directory screen. This is a useful feature if a testee has finished part of a battery of tests but the tester has forgotten the testee number. The testee information screen and testee progress screens can be displayed until the correct testee directory is located.

If all information on previous screens has been appropriately entered, pressing Enter will produce the CAT menu.

The CAT Menu

The CAT menu is used to specify which tests are to be given in the current session and in what order the tests are to be given. The menu appears as follows:
Cognitive Abilities Tests

Select from following choices in administration order:
TI - Test Instructions
LR - Learning
RT - Reaction Time
RL - Relearning
ST - Sternberg Memory Search
PR - Probed Memory
BK - Break
SP - Self-Paced Probed Memory
SD - Stimulus Discrimination
RC - Recognition Memory
TT - Tachistoscopic Threshold
TD - Tachistoscopic Delay
PM - Progressive Matrices
ALL - Take the entire battery
SIX - Take LR, RT, PR, SP, SD, and TT
CHN - Take all tests beginning with test specified
TST - Self-test, demonstration mode
DIA - Diagnostic tests for computer problems

Enter Choices:

One or several choices may be entered at the prompt. All two letter choices are tests that will be administered in the order entered. As an example:

Enter Choices: TI LR RT

would present TI (preliminary instructions) followed by LR (learning) followed by RT (reaction time) in that order. On the other hand:

Enter Choices: RT LR

would present RT first and then LR. The simplest way to have CAT administer tests is to type them in the order they are to be administered.

When entering commands from the menu, they may be in upper or lower case letters. Each command must be separated by at least one space or a comma. If a "????TSK.DAT" file is in use only tests included in that file will be run by CAT. Even though LR was entered as a choice in the above example, it would not be administered if the appropriate "????TSK.DAT" file did not contain LR. No test will be administered twice. CAT prevents the readministration of any test previously completed.
ALL

The command, ALL, is equivalent to entering all 13 two-letter test commands at the menu prompt. If ALL is typed, all components of the battery will be administered. The order of administration will be the order the tests appear in the CAT menu. CAT will not readminister a test that has been previously completed even if ALL is specified.

If a ???TSK.DAT file is in effect, only the tests listed in the file which have not been completed will be administered. Therefore, ALL can almost always be used as the only necessary command when a ???TSK.DAT file is used. All of the files in the ???TSK.DAT file will be administered in the standard order. If multiple sessions are required, ALL can still be used because previously completed tests will not be readministered.

SIX

SIX administers the six tests of the short battery, LR, RT, PR, SP, SD, and TT. The six tests are administered in standard administration order. TI and BK are also administered.

CHN

CHN stands for chain. It indicates that CAT should chain from a specified test, administering all tests to the end of the battery. This command must be used in conjunction with one of the two-letter test choices as follows:

```
| Enter choices:  PR  CHN |
```

In this case, all tests beginning with PR on would be administered - PR, BK, SP, SD, etc. to the end of the list.

TST

TST may be used with any of the previous commands. When appended to any list of commands, the tests are given in self-test mode. That is, the computer takes the test itself. During testing, a small hand is visible on the computer screen making the same responses a testee would make. This mode is useful for demonstration and testing equipment to make sure CAT runs properly.

In TST mode, CAT works exactly as if a testee were taking the test. Data files are generated and are analyzed. Care should be taken not to confuse a testee's results with output obtained using the TST option.

SA and GR

Two options not listed on the menu are SA and GR. If either is typed it has the same effect: the end screen is displayed. These commands allow the tester to
use CAT to statistically analyze (SA) or graph (GR) data without administering any of the tests. See Normal Ending below for further information.

Running CAT from the Command Line

Instead of using the menu and entering CAT commands at the 'Enter choices:' prompt, CAT commands can be entered directly on the command line. Using the command line does not alter the order or presentation of the directory, information, or testee information screens. But if the command line is used, the menu will not appear.

In order to enter commands directly on the command line change to the CAT directory, type 'CAT' followed by the commands. For example:

```
>CD CAT
>CAT ALL TST
```

CAT will execute all tests in self-test mode (after the information and progress screens are presented). As another example:

```
>CD CAT
>CAT LR SP RT
```

would execute LR, SP and RT in that order. Note that all rules concerning the ????TSK.DAT file still apply. If the ????TSK.DAT file exists, only those tests listed in the file will be executed. Commands to execute other tests will be ignored.

The command line operates exactly like the menu. Entering commands on the command line has the same effect as entering them at the menu prompt.

If a command is entered on the command line, the menu will not appear. It is also possible to include the commands above in a batch file to customize presentation. For example, the following batch file might be named MYCAT.BAT:

```
ECHO OFF
CD CAT
CAT LR SP RT TT PR TD BK ST RC PM RL SD
```

If this batch file were kept in the CAT directory it would be executed by typing MYCAT. CAT would execute all the tests in the rearranged order specified by the command line. This same batch file could be used even if multiple sessions were required to complete testing because completed tests are not readministered by CAT. Tests on the command line that had already been finished would be ignored.
A batch file should be used if tests are to be given in an order different than the standard administration order. A TSK.DAT file should be used when the tests are to be given in standard administration order. The batch file does not limit the testee progress screen to the tests listed on the command line.

**The Touch Screen Calibration Screen**

After the menu, if the menu was used or after the testee progress screen if the command line was used instead of the menu, the touch screen calibration screen appears. The calibration screen will always appear even if no touch screen is attached to the computer.

**Keyboard Input**

To use keyboard input, press Esc when the calibration screen appears. CAT will now use keyboard input even if a touch screen is connected to the computer. Using keyboard input requires that testees make all responses on the computer keyboard using the space bar and the number keys (1 through 9). Two changes in the tests will occur automatically. Response positions have numbers above them and the instructions are appropriately modified. Other than these two changes all tests are identical to the touch screen version.

If no touch screen is connected to the computer, the only response possible to the calibration screen is to press Esc.

**Touch Screen Calibration**

The touch screen is automatically selected as the input device unless Esc is pressed. Before the touch screen is used it must be carefully calibrated by touching each crosshair exactly in the center as it appears. A crosshair will appear first in the upper right corner and then the lower left corner.

The purpose of calibration is to match the touch screen positions to the computer monitor positions. If calibration is not done carefully it is possible that the sensitive touch areas will be misaligned with the screen display. The testee may have to touch to the right or left of the displayed response position to get a response to register. The only cure for this situation is to stop CAT and begin again this time being sure the calibration is correct.

Calibration of the touch screen is so important for reliable testing that it is essential that it be done by the tester and not left to the testee. The blue screen is a reminder that the tester should do the calibration. Immediately following the touch screen calibration screen, testing begins.
Test Sequence

Each test follows the same basic sequence: 1) A 'please wait' sign appears on the screen while CAT reads the necessary files and sets up the test. 2) Instructions appear on the screen. 3) A series of practice trials are given. 4) A screen indicating the end of practice trials appears. 5) The test is given. 6) A 'please wait' sign appears while the test data are being written to a file.

CAT presents all tests in this way until the tests it was instructed to give on the command line or at the menu prompt are finished. At the end of each test, the raw data is written to a file. **It is extremely important that the data diskette not be removed from the disk drive during testing.** If CAT cannot use the data diskette for any reason it writes the data for a test to the default directory where the CAT program is located. If the CAT program is on the data diskette, data may be lost.

Normal Ending

After all tests have been administered by CAT, a black screen appears with the following centered message:

```
This is the end of this session. 
Please call the person in charge.
```

Only certain keys will have any effect on this screen. 'S' will cause preliminary statistical analyses to be carried out and the results placed in the DT file. 'G' causes the results to be graphed if a DT file exists. 'B' causes both statistical analysis and graphing to be carried out. 'Q' or 'E' cause the program to end immediately without statistical analyses or graphing being done.

How to Stop CAT

Stopping CAT depends on where in the program you wish to stop. During the administration of all tests, the keyboard is disabled even when it is the response device. Only the space bar and appropriate number keys have any effect in keyboard mode. This means that the Ctrl-Alt-Del combination of keys does not have its usual effect of rebooting the computer. This was done purposely so testees would not, accidently or otherwise, stop the test.

F1-F5-Home

If a test is in progress, it may be stopped by pressing the F1-F5-Home keys all at once. It may take a few seconds for this key combination to be successful. It will only work during times when CAT is expecting a testee response of some type.
This combination of keys works for both keyboard and touch screen modes of operation. Pressing this combination of keys causes a return to the directory in which CAT is located.

**Effect on Data**

When a test is aborted using the F1-F5-Home keys, the data are saved in a file. The second line of the file includes the words 'Terminated abnormally'. Though the data are saved, they are not analyzed. The testee progress screen will indicate that the test was aborted and it will be possible to readminister the test. However, when the test is readministered the test data file from the aborted effort is lost. If the partial data from aborted files is to be kept, the file name should be changed. CAT keeps track of the number of previous administrations of each test so even if the data files are lost, the testee information file will indicate how many times the test was attempted.

**Ctrl-C**

If any of the blue screens for tester response are being presented, CAT can usually be stopped by pressing Ctrl-C or Ctrl-Break. All processing stops immediately so it is possible to produce incorrectly written files or other errors using this method of stopping CAT.
# Chapter 4 Procedures to Follow When Testing

Instructions to Testees.................................................................32
  Written......................................................................................32
  Oral.........................................................................................32
Practice .......................................................................................32
  Help by the Tester......................................................................32
  Additional Practice.................................................................32
Making Response.........................................................................33
Session Length............................................................................33
  Ten Tests..................................................................................33
  Six Tests...................................................................................33
  Progressive Matrices ..............................................................33
Testing Children........................................................................33
Debriefing..................................................................................33
  Purpose of Testing....................................................................34
  Graph.......................................................................................34
Instructions to Testees

The basic goal of the instructions is to have the testee understand what the test requires as completely as possible. Instructions for each test consist of three parts. The first part is written instructions presented on the screen. The second part is the tester's clarification of those instructions and the third part is a set of practice trials. Generally, testees will have the most trouble understanding instructions for the first test they take because everything is new to them.

Written

The written instructions are limited to one screen of information. The instructions are different for touch screen and keyboard mode of operation but the differences only pertain to the way responses are made. Testee's under 12 years of age or who read at less than a sixth grade reading level should have the instructions read to them.

Oral

After the instructions have been read, the testee should be given a chance to ask questions of the tester. The tester should watch as the testee completes the practice trials. If necessary, the tester should answer any questions that arise. The goal of the instructions and practice trials is to have the testee understand the test as fully as possible.

Practice

Each test includes a practice period. Some tests use as much as half the test time for practice. Others only provide a few trials of practice. As with instructions, the purpose of these practice trials is to help the testee understand the test.

Help by the Tester

Help by the tester is perfectly appropriate during the practice trials even to the point of guiding the testees hand to make the correct response.

Additional Practice

It is not possible to provide testees with additional practice. However, if it is clear that the testee does not understand the test, the tester should supervise the early trials until it is clear the testee understands what is expected on the test.
Making Response

It is important to stress to testees that all responses should be made with the index finger of the preferred hand. If they get tired, it is acceptable to switch hands or fingers but under no circumstances should a testee be allowed to use two hands to make responses.

Session Length

Whenever possible the test battery should be given in one session. It is possible to provide a programmed break using BK. For younger subjects or disabled subjects it may be necessary to split the battery into two separate sessions to avoid excessive fatigue and to ensure the testees attention and full cooperation.

Ten Tests

If the ten basic tests are given, the battery requires a maximum time of approximately 2.5 to 3 hours to complete for average adult testees. This time includes a short break in the middle.

Six Tests

The shortened six test version of the battery requires a maximum of about 1.5 hours to complete for average adult testees. Younger children require about 2 hours (maximum) to complete the tests.

Progressive Matrices

This test takes about 30 minutes for an average adult testee to complete.

Testing Children

Some special considerations have been found necessary when testing children 12 years of age and under. A supervisor should be present at all times during testing. The supervisor's job is to help the children with the written instructions, to answer questions, and to make sure that boredom or fatigue do not affect the test results. One supervisor for every four children being tested has proved to be an adequate ratio.

Debriefing

Following testing, the tester should explain to all testees why the tests were given and what they measure.
Purpose of Testing

The following is a sample explanation that might be given the testee after finishing the battery: These tests are tests of basic cognitive abilities. They are designed to measure basic mental processes like memory, learning, very short-term memory, visual processing and speed of reaction. It is hoped that these tests will help in understanding the basic cognitive processes you use in more complicated skills like those taught in school.

Graph

The graph program can also be shown to the subject. When the end screen appears, if the tester types 'B', the data in the DT file will be analyzed and a graph will appear on the screen. (The graph program is currently not functional.) Testees can see their performance in relation to a set of normative data.
Chapter 5  General Information About Tests

Instruction Files...........................................................................................................37
Input Data File .............................................................................................................37
  Task Code..................................................................................................................38
  Parameter Line..........................................................................................................38
  Data Documentation.................................................................................................39
  Screen Coordinates.................................................................................................39
  Data Lines..................................................................................................................39
  Chain To Line............................................................................................................40
Stimulus Items ............................................................................................................40
  Dimensions of Monitor Screen................................................................................40
  Dimensions of Stimuli.............................................................................................40
  Representation of Stimuli.......................................................................................41
  Binary Representation............................................................................................41
  Hexadecimal Representation.....................................................................................41
  Decimal Representation...........................................................................................42
  Two's Complement...................................................................................................42
Making Responses ......................................................................................................43
  Differences between Keyboard and Touch Screen Responses..........................43
  Press Bar Response..................................................................................................43
  Position Response ..................................................................................................44
  Same-Different Response .......................................................................................44
  Summary of Required Responses by Test ...............................................................44
Feedback .....................................................................................................................45
  Correct Response (Beep 1).......................................................................................45
  Incorrect Response (Buzz)......................................................................................45
  Release Bar (Beep 2)...............................................................................................45
  Press Bar (Beep 3)....................................................................................................45
  Visual Feedback........................................................................................................45
Data Output File .........................................................................................................46
  Output File Names...................................................................................................46
  Output File Content.................................................................................................46
This chapter describes the general characteristics of all tests. It also provides technical information that may be needed if the tests are modified or further analyses are required from raw data.

**Instruction Files**

Each test (except BK) has an instruction file that is copied directly to the screen. There are actually two instruction files, one for keyboard mode (??INST.TXT) and one for touch screen mode (??INSTTW.TXT). The ?? should be replaced by the two-letter code for each task to yield the file name for the instruction file, e.g., RT, PR, etc.

Each instruction file is straight ASCII text entered in any text editor and saved unformatted. The end of each screen is marked by the word 'END' in capital letters starting in the first column of the line following the screen text. There may only be one screen of information given before the practice trials and one screen given after.

Instructions are presented as yellow letters on a black screen.

**Input Data File**

Each test has an associated data file which is structured in a particular way and contains information specific to the task. The file must be in the CAT directory. It is named ??DATA_A.TXT where the ?? indicate the two letter task code. The 'A' refers to the CAT generation letter in the testee identification string. This letter must be the same as the fourth letter entered in the MADEISK program to identify CAT generation.

The following is an example of a input data file, LRDATA_A.TXT:

```
LR
40 9 5 9 -14 40 9
COLUMN 1 = NUMBER OF ITEMS (3..9).
COLUMN 2 = CORRECT POSITION.
COLUMN 3 = SUBJECTS RESPONSE.
COLUMN 4 = LATENCY OF RESPONSE.
COLUMN 5 = TRIAL TIME.
```
Task Code
The first line of the file is the two letter code specifying the task. This must agree with the task name.

Parameter Line
The second line of the file is the parameter line. This line specifies seven numbers that specify the remainder of the file. These seven numbers specify the following:

1. This number specifies the number of trials to be carried out. It should match the sixth number.
2. This number is the number of stimulus positions used.
3. This number specifies the number of data documentation lines. These lines are added to the end of the data output file for this test. The data documentation lines follow the parameter line. In the above example there are 5 data documentation lines beginning with COLUMN 1 = NUMBER OF ITEMS (3..9) to COLUMN 5 = TRIAL TIME.
4. This is the number of positions on the screen less 1. In the above example, there are 10 screen coordinates. Actual screen coordinates follow after data documentation lines.

5. The fifth number represents the starting trial number. If the number is negative, the trials less than or equal to zero are practice trials or lines of some special information such as stimulus values. In the above example, the first trial is -14. This means there are 15 lines before the actual data lines.

6. The sixth number indicates the index of the last line of the data file that are to be read in. CAT reads from -14 to 40 in the example above.

7. This number specifies the number of columns of input data that are in the file. In the example above, there are 9 columns of data.

**Data Documentation**

The data documentation lines are different for each file. They follow the parameter line immediately. The data documentation lines are appended to each output file to document the data. They should not be changed since data output cannot be changed.

**Screen Coordinates**

The screen coordinates are listed in X, Y order where X is the horizontal screen axis and Y is the vertical screen axis. X ranges from 1 to 640 pixels while Y ranges from 1 to 350 pixels. Position 0 (the first coordinate listed) is usually the position of the upper left hand corner of the bar at the bottom of the screen. The other positions represent the upper left hand corner of stimulus window positions or response windows.

In the example above, the screen coordinate in position 0 represents the probe window at the top of the screen. The next seven coordinates represent 7 windows. Two other windows appear as positions 9 and 10. As can be seen, these last two positions have a different Y coordinate (228) than the previous 7 positions (Y = 140).

In keyboard mode, the numbers which appear above the windows are positioned based on the screen coordinates. Sufficient room must be allowed for numbers above the window if screen coordinates are changed.

Each stimulus is 64 pixels wide by 56 pixels high. At least 16 pixels are left between each stimulus window to allow sufficient touch screen sensitivity. It may be noted that tests with very similar screen configurations have substantially different screen coordinates. This has been done purposely to avoid excessive wear to any one area of the touch screen.

**Data Lines**

The data lines of each file follow the screen coordinates. Up through screen coordinates all input data files have the same general form. Data line structure differs from file to file. In the example above, the first five lines contain stimulus
values which specify the items to be learned in each block of learning trials. This is followed by 10 practice trials. Each line indicates which positions on the screen are to be used and the order in which the positions are to be tested. The 5 stimulus lines and the 10 practice trials represent lines -14 to 0. These are followed by 40 lines in the same format as the practice trials with 10 trials each for 3, 5, 7 and 9 item lists.

Individual tests (Chapter 6) should be consulted for information concerning the data line structure.

Chain To Line
The last line of the data file contains the code letter of the test which normally is given after the current test. This line is not necessary but preserves the order of test administration.

Stimulus Items
All tests use the same stimulus items. These items consist of a 4 X 4 matrix of squares. Each square may be either filled or unfilled. Because there are 16 squares each of which may have two possible conditions, there are a total of \(2^{16} = 65,536\) stimuli.

These stimuli were selected for a number of reasons. The entire population of stimuli can be easily enumerated. They are easily quantified. A number of quantifiable parameters have been identified which predict how easily testees can identify and remember the stimuli. Each stimulus can be represented as a single number, a real advantage for the computer. The stimuli in the population have a wide enough range in difficulty to serve nearly any purpose. A most important reason these stimuli were chosen is that they are free of obvious language and so can be used with testees not able to read or understand English unlike most verbal stimuli.

Dimensions of Monitor Screen
When dimensions are given in pixels (one dot on the screen is a pixel) they are unambiguous. All monitors used with CAT will be 640 pixels wide by 350 pixels high. However, all monitors do not present the same viewing area or have the same height to width active screen area ratio. All physical measurements of distance and size were made on a NEC Multisync monitor which had an active viewing area of 9.75 inches by 7.88 inches. Each pixel is 0.0225 (7.88/350) inches high and 0.0152 (9.75/640) inches wide.

Dimensions of Stimuli
Each stimulus is composed of a 4 X 4 matrix of boxes which are 14 pixels high and 16 pixels wide. The entire stimulus is 64 pixels wide and 56 pixels high. The outside border is green and the inside lines making each cell of the matrix are
gray. When the cell is filled, blue is used as the fill color. Every effort was made to leave at least 16 pixels between stimuli.

Each full matrix measures 1.26 inches (3.2 cm) high by .97 inches (31/32 inches, 2.46 cm) wide. These measured sizes agree with computed sizes (56 pixels high * 0.0225 inches high per pixel = 1.2600 and 64 pixels wide * 0.0152 inches wide per pixel = 0.9728).

Average viewing distance for the stimuli is approximately 53 cm. (53/2.54 = 20.87 inches). At this viewing distance each stimulus item has a .is.stimuli:visual angle; of 3.2 degrees in height and 2.7 degrees wide.

All stimulus items have a green border with gray interior lines. Filled squares in the matrix are displayed in blue. The background for stimuli is always black.

Representation of Stimuli

The stimuli used by CAT can be represented in a number of ways. All of these ways amount to translating the stimulus into a single numerical value. In the following discussion, all numbers have the least significant bit as the right-most bit. The stimulus matrix, on the other hand, has the least significant bit in the upper left hand corner and the most significant bit in the lower right hand corner of the matrix.

Binary Representation

Perhaps the easiest way to represent the stimuli employed by CAT is as 15 bit binary numbers. Each cell could be represented as a cell having a state of 0 (empty) or 1 (filled). Then each stimulus would be represented by a 16 bit string of 0's and 1's:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1111000000000000</td>
<td>[3]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stimulus 1 would have the bottom right hand corner (the most significant bit) filled. Stimulus 2 would have the upper left hand corner filled and Stimulus 3 would have the lower row of the matrix filled. The problem with binary numbers is that they are long and clumsy to use.

Hexadecimal Representation

A somewhat less clumsy numbering system is hexadecimal. In this number system, each digit may range from 0 to 15. Numbers above nine are represented by letters (10 = A; 11 = B; 12 = C; 13 = D; 14 = E; 15 = F).

Using hexadecimal numbers it is possible to represent each row of the matrix as a separate digit in a four-digit number. Think of each cell in a row of the stimulus as having the following values:

<table>
<thead>
<tr>
<th>Cell Value</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>
If a particular cell in the row is filled, add the value to the total but if the cell is unfilled, add 0. If all cells were filled, the row would have the value 15 or F in hexadecimal. If none of the cells were filled, it would have the value 0. Every combination of filled and unfilled cells has a unique hexadecimal number. For example, A ( = 10 decimal) would indicate that cells 2 and 4 were filled.

By using four hexadecimal digits, it is possible to represent any stimulus used by CAT. The binary stimuli above can be represented in hexadecimal: Stimulus 1 = 8000; Stimulus 2 = 0001; and Stimulus 3 = F000. A stimulus with all cells filled would be FFFF and one with no cells filled would be 0000. Because hexadecimal numbers contain letters they are not easy for computers to work with.

**Decimal Representation**

The kind of numbers most computer deal with most easily are decimal numbers. Just as each stimulus matrix can be translated into binary and hexadecimal, it can be translated into decimal. The 'trick', just like in hexadecimal, is to assign a unique power of two to each cell in the stimulus matrix so that each sum of numbers represents a unique stimulus. That is what was done in the following matrix:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>32</td>
<td>64</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>256</td>
<td>512</td>
<td>1024</td>
<td>2048</td>
<td></td>
</tr>
<tr>
<td>4096</td>
<td>8192</td>
<td>16384</td>
<td>32768</td>
<td></td>
</tr>
</tbody>
</table>

If a cell in the stimulus matrix is filled, add the number in the corresponding cell above. If the cell is empty, add zero. Each stimulus used by CAT can then be represented as a single decimal number between 0 and 65,535. A value of zero means all cells are empty and a value of 65,535 means all cells are filled.

**Two's Complement**

The way computers store numbers makes it easier to store stimulus values in what is called two complement form. What this effectively means is that any number over 32,767 (2^15) is stored as a negative number using the following formula:

\[
\text{Two's Complement} = \text{Decimal Number} - 65,536
\]
To get the two's complement, subtract 65,536 from any number greater than 32,767. Applying this formula to the decimal value representing all cells filled (65,536) yields -1. Under this system, a stimulus with all squares filled is represented by -1. If only the lower right hand corner of the stimulus item were filled, the stimulus would have a decimal value of 32,768 which would mean it has a two's complement value of -32,768 (= 32,768 - 65,536). In fact, two's complement numbers range from -32,768 to 32,767.

All stimuli used by CAT are represented in two's complement form. Any stimulus number can be decoded by finding the numbers from the above matrix which will add up to the number. If the stimulus number is negative, add 65,536 to it and work with the result.

In the following discussion, an empty stimulus matrix is used to mark positions in many tasks. This stimulus is often referred to as an empty window because it looks like the panes of a window. When a stimulus is presented in the empty window, the window is sometimes said to be 'lit up'.

Making Responses

CAT requires only three types of responses from testees. They must be able to touch the bar to start the trial, respond to a particular position or item, or choose between same and different (present or absent) alternatives.

Differences between Keyboard and Touch Screen Responses

In the following descriptions, the tests will be discussed as if they were presented using a touch screen, the preferred method of presentation. However, all of what is described applies to the keyboard mode, too. When ever the 'bar' is referred to it means the bar at the bottom of the screen when using a touch screen but the space bar in the keyboard mode. Responses made to an item in the keyboard mode actually refer to response made to the number of the item shown on the screen.

In the keyboard mode, the bar at the bottom of the screen is still present and provides the same visual feedback as in the touch screen mode. The only difference between the two modes is where the testee in making a response, on the keyboard or the touch screen. Of course, because all visual feed back occurs on the monitor screen (and cannot be made to occur on the keyboard) testees using the touch screen will have a greater sense of immediacy because things are changing on the screen where they are making there response. In the keyboard mode, changes on the screen must be connected to responses made some distance away on the keyboard.

Press Bar Response

For most of the tests, the testee initiates a trial by pressing the bar and keeping his finger on the bar until required to make a decision. This allows the testee to control the pace of individual trials (or items) but even more importantly it
allows the measurement of Decision Time (DT) which is the amount of time it
takes the testee to make a decision. Because it is possible to tell when the testee
lifts his finger from the bar, DT can be separated from Movement Time (MT)
which is the amount of time it takes to make a response.

In tests which are not testee-initiated, DT and MT cannot be obtained as
separate measures. Instead, they are combined into a single measure referred to
as Reaction Time (RT).

The bar which appears on the screen is .97 inches wide (31/32 inches, 2.46 cm)
by .38 inches (3/8 inches, .95 cm) wide. The outside border is green and when
pressed it fills with blue.

**Position Response**

For some of the tests, the testee is presented with a probe item and asked to
indicate in which position the item was located by touching that position. A
variant of this method is used in the Self-Paced Probe Test (SP) and the
Progressive Matrices Test (PM). In these tests, testees are presented with a list
of alternatives and are asked to pick the one that belongs in a particular
position. (See the description of stimuli for physical measurements.) In most
cases, the sensitive area on the touch screen extends about 8 pixels beyond the
stimulus in each direction.

**Same-Different Response**

Perhaps the most difficult of the response requirements used by CAT is the
same-different response. In this response, a same response is made to two small
filled squares (?? pixels X ?? pixels) on the left side of the screen and a different
response is made to a filled and unfilled box (of the same dimensions) on the
right side of the screen. In the Sternberg Search Test (ST), the same boxes
mean the stimulus was present and the different boxes mean absent.

Each of the boxes for the same-different response positions are .5 inches (1.27
cm) wide by .63 inches (5/8 inches, 1.59 cm) high. There are two boxes in each
display .5 inches (1.27 cm) apart. Each box has a green outline and, if filled, is
filled with blue.

**Summary of Required Responses by Test**

The following table indicates how each trial or item is initiated. CAT means the
trial is initiated by the program and Bar means it is initiated by the testee
touching the bar. TW means that the screen can be touched anywhere.
Response indicates how the testee makes an answer. PI requires the testee
indicate which position (P) a probed item (I) is in. P is a response to a position
that lights up. IP requires the testee to select the item (I) which was in the
probed position (P). SD is same-different and PA is present-absent.

<table>
<thead>
<tr>
<th>Test</th>
<th>Initiated</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN</td>
<td>TW</td>
<td>PI</td>
</tr>
<tr>
<td>LR</td>
<td>CAT</td>
<td></td>
</tr>
</tbody>
</table>
Feedback

Auditory feedback is presented using four different sounds. These sounds are referred to as Beep 1 to 3 and Buzz.

Correct Response (Beep 1)
A correct response is signalled by a beep consisting of a 1,000 Hertz tone for 100 milliseconds followed by a 1,500 Hertz tone for 200 milliseconds. This tone is given for each correct response made.

Incorrect Response (Buzz)
An incorrect response is indicated by a buzz consisting of a 100 Hertz tone for 200 milliseconds followed by a 50 Hertz tone for 300 milliseconds. This buzz is presented whenever an incorrect response is made or when the testee inappropriately removes his finger from the bar.

Release Bar (Beep 2)
A beep of 2000 Hertz is presented for 50 milliseconds when a testee removes his finger from the bar.

Press Bar (Beep 3)
Whenever the testee presses the bar a beep of 3,000 Hertz is presented for 50 milliseconds. This beep is also used at the beginning of a trial to get a testee's attention.

Visual Feedback
In addition to auditory feedback, every effort has been made to provide visual feedback to indicate what has happened. Touching the bar causes it to fill with blue. Releasing the bar causes the bar to appear unfilled. When a position is
touched as a response, one of several things can happen: 1) The entire display may go blank. 2) The square may 'light up'. 3) The correct position may 'light up' or show the correct item.

In most tests, the state of the screen unambiguously indicates what is expected of the testee. There are only a few cases in which this is not true. In most of these cases, only two alternative actions are available to the testee and whichever action is selected, the task will work. The major exception is when same-different responses are required. In these tests, the testee may become confused about whether to touch the bar to begin a new trial or make a response to the same or different windows. For example, a testee may repeatedly press the bar expecting a new trial to begin when CAT is waiting for an answer to an already presented item. If it looks like any test is not working, try performing all of the steps in a complete trial to be sure the testee has not lost track of what is expected.

Data Output File

Each test stores a data output file. This file contains the trial-by-trial raw data for the test. These files are made read-only to protect them from changes or deletion. When the battery is completed, each of the data files are analyzed and the summary results placed in what is called a DT (DaTa) file.

Output File Names

All output files are named in the same way. The testee identification string is appended to a two-letter file identification. For each of the tests, the two letter test codes are used. The letters DT are used for the summary data file and the letters IN for the participant information and progress file.

Output File Content

Each data file has as the first line, the name of the file. This must agree with the DOS name for further processing. This is protection against accidental name changes. The second line of the file contains the number of data lines contained in the file.

The contents of each file are explained by a set of data documentation lines listed at the end of each file. These data documentation lines come from the input data files.

Format of Data Lines

Data files may have up to 9 numbers per line. Each number is written in a field 11 columns wide with three decimal digits.
Removing Data Files - MAR

Standard DOS procedures such as delete or edlin do not work on read only files (although you may copy them). To erase read only files the whole disk may be reformatted or you may use MAR (Make ARchival) to change the file to an ordinary DOS archival file. MAR is included in the TOOLS directory. To make a file archival, execute MAR at the prompt line followed by the file name. To make LRTWAA00.003 archival do the following:

```
> MAR LRTWAA00.003
```

Hit enter and the file will be archival. No method is provided to make an archival file read-only.

Testee Progress File (IN???????.???)

The testee progress file is constructed or updated anytime a test is given by CAT. It, therefor, contains information about what was administered and when it was administered. It also contains all of the entries on participant information screen.

The following is an example of a testee progress file, INTWAA00.003:

```
Thorndike, Edward L.
Department of Pedagogy
Case Western Reserve University
Cleveland
OH
44106
07/08/68
(216) 368-2686
123-45-6789
dkd
```
Testee Progress File (Continued)

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>T1</td>
<td>2</td>
<td>1</td>
<td>1988</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>LR</td>
<td>2</td>
<td>0</td>
<td>1988</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>2</td>
<td>0</td>
<td>1988</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>RL</td>
<td>2</td>
<td>0</td>
<td>1988</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>2</td>
<td>0</td>
<td>1988</td>
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<td>8</td>
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<td>0</td>
<td>1988</td>
<td>6</td>
<td>8</td>
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<td>SP</td>
<td>2</td>
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</tr>
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<td>RC</td>
<td>2</td>
<td>0</td>
<td>1988</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>TT</td>
<td>1</td>
<td>1</td>
<td>1988</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>TD</td>
<td>1</td>
<td>0</td>
<td>1988</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>PM</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The first 10 lines are the information lines taken from the testee information screen. The eleventh line is the number of tests recorded in the file, in this case 12. There are 12 lines following, one for each test.

Each of the 12 lines has the following format: 1) a two-letter test code; 2) a number - either 0, 1, or 2; 0 indicates the test has not been attempted, 1 indicates it has been attempted but not completed, and 2 indicates the test has been completed; 3) a number indicating if there have been previous attempts of the test before the attempt documented by time and date. If the test has not been previously attempted, the line ends here. A previous attempt is an uncompleted attempt at an earlier time. In the above example T1 was unsuccessfully attempted previous to successful completion.

If the test has been previously attempted or completed additional information follows: 4) the year in which the test was begun; 5) the month in which the test was begun; 6) the day on which the test was begun; 7) the hour the test was begun; 8) the minute the test was begun; 9) the second the test was begun; 10) the hour the test ended; 11) the minute the test ended; 12) the second the test ended. If item 2 is 1 and 10 through 12 are zero (as for TD in the example) the test ended abnormally either by turning the power switch off or pulling the plug. If item 2 is 1 and items 10 through 12 are times (as for TT above), the test was terminated by the tester using the F1-F5-Home keys.

All times are in 24 hour format and are taken from the time-of-day clock. It is important that it be set correctly if this information is to be correct.

Programming Information

Programming Languages

CAT consists of approximately 11,000 lines of Turbo Pascal code. Portions of the program are written in assembler for speed. CAT was originally written in UCSD Pascal for use on Terak computers.
Timing

Millisecond timing is accomplished by reading the system clock in Mode 3. CAT expects that 1 millisecond is 1,193,181.7 ticks of the system clock. In other words, each tick of the system clock is 1/1,193,181.7 micro seconds.

The speed at which a particular computer operates (8 megahertz, 12 megahertz, etc.) is determined by dividing this standard clock rate appropriately. Therefore, all computers should time correctly so long as their system clock has the same tick rate.
# Chapter 6 Description of Tests

<table>
<thead>
<tr>
<th>Test Instructions (TI)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Description</td>
<td>55</td>
</tr>
<tr>
<td>Instruction Format</td>
<td>55</td>
</tr>
<tr>
<td>Output Data File</td>
<td>55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning (LR)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Description</td>
<td>55</td>
</tr>
<tr>
<td>Practice Trials</td>
<td>56</td>
</tr>
<tr>
<td>Number of Trials</td>
<td>56</td>
</tr>
<tr>
<td>Blocks</td>
<td>56</td>
</tr>
<tr>
<td>Timing</td>
<td>56</td>
</tr>
<tr>
<td>Criteria</td>
<td>57</td>
</tr>
<tr>
<td>Stimuli</td>
<td>57</td>
</tr>
<tr>
<td>Screen Layout</td>
<td>57</td>
</tr>
<tr>
<td>Programming Details</td>
<td>57</td>
</tr>
<tr>
<td>Input Data File</td>
<td>57</td>
</tr>
<tr>
<td>Output Data File</td>
<td>58</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reaction Time (RT)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Description</td>
<td>59</td>
</tr>
<tr>
<td>Practice Trials</td>
<td>59</td>
</tr>
<tr>
<td>Number of Trials</td>
<td>59</td>
</tr>
<tr>
<td>Blocks</td>
<td>59</td>
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<tr>
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<td>Criteria</td>
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<td>Stimuli</td>
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<td>60</td>
</tr>
<tr>
<td>Programming Details</td>
<td>60</td>
</tr>
<tr>
<td>Input File</td>
<td>60</td>
</tr>
<tr>
<td>Output Data File</td>
<td>61</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relearning (RL)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sternberg Memory Search Test (ST)</td>
<td>62</td>
</tr>
<tr>
<td>General Description</td>
<td>62</td>
</tr>
<tr>
<td>Test Type</td>
<td>Pages</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Input Data File</td>
<td>71</td>
</tr>
<tr>
<td>Output Data File</td>
<td>72</td>
</tr>
<tr>
<td>Recognition Memory (RC)</td>
<td>72</td>
</tr>
<tr>
<td>General Description</td>
<td>72</td>
</tr>
<tr>
<td>Practice Trials</td>
<td>72</td>
</tr>
<tr>
<td>Number of Trials</td>
<td>73</td>
</tr>
<tr>
<td>Timing</td>
<td>73</td>
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<tr>
<td>Stimuli</td>
<td>73</td>
</tr>
<tr>
<td>Screen Layout</td>
<td>73</td>
</tr>
<tr>
<td>Input Data File</td>
<td>73</td>
</tr>
<tr>
<td>Output Data File</td>
<td>73</td>
</tr>
<tr>
<td>Tachistoscopic Threshold (TT)</td>
<td>74</td>
</tr>
<tr>
<td>General Description</td>
<td>74</td>
</tr>
<tr>
<td>Practice Trials</td>
<td>74</td>
</tr>
<tr>
<td>Blocks</td>
<td>74</td>
</tr>
<tr>
<td>Number of Trials</td>
<td>75</td>
</tr>
<tr>
<td>Timing</td>
<td>75</td>
</tr>
<tr>
<td>Criteria</td>
<td>75</td>
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<tr>
<td>Stimuli</td>
<td>75</td>
</tr>
<tr>
<td>Screen Layout</td>
<td>75</td>
</tr>
<tr>
<td>Programming Details</td>
<td>76</td>
</tr>
<tr>
<td>Input Data File</td>
<td>76</td>
</tr>
<tr>
<td>Output Data File</td>
<td>76</td>
</tr>
<tr>
<td>Tachistoscopic Delay (TD)</td>
<td>77</td>
</tr>
<tr>
<td>General Description</td>
<td>77</td>
</tr>
<tr>
<td>Practice Trials</td>
<td>77</td>
</tr>
<tr>
<td>Blocks</td>
<td>77</td>
</tr>
<tr>
<td>Number of Trials</td>
<td>77</td>
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<tr>
<td>Timing</td>
<td>78</td>
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<td>Criteria</td>
<td>78</td>
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<td>Stimuli</td>
<td>78</td>
</tr>
<tr>
<td>Screen Layout</td>
<td>78</td>
</tr>
<tr>
<td>Programming Details</td>
<td>78</td>
</tr>
<tr>
<td>Input Data File</td>
<td>78</td>
</tr>
<tr>
<td>Output Data File</td>
<td>78</td>
</tr>
<tr>
<td>Progressive Matrices (PM)</td>
<td>80</td>
</tr>
<tr>
<td>General Description</td>
<td>80</td>
</tr>
<tr>
<td>Practice Trials</td>
<td>80</td>
</tr>
<tr>
<td>Number of trials</td>
<td>80</td>
</tr>
<tr>
<td>Blocks</td>
<td>80</td>
</tr>
</tbody>
</table>
Test Instructions (TI)

General Description
Test Instructions (TI) provide an opportunity to give the testee an introductory set of instructions about the whole battery to be presented. TI presents a screen of text to the testee. When the testee finishes reading the presented screen he responds as directed and another screen is given. This continues until all directions have been presented. If the battery is being administered using the keyboard as the response device, practice in using the keyboard is given. If the touch screen is being used, a brief initiation to the touch screen is presented. The instructions presented can be easily modified to fit the needs of the tester.

Instruction Format
The instructions presented are in a file called ININST.TXT for the keyboard instructions and ININSTTW.TXT for the touch screen version. Both of these files must be on the same directory as CAT.

The format of both files is identical. The text for a single screen is followed by the word END. END must be in capital letters and in the first column of the line after the last line of the screen text. To present new instructions, rewrite the two files listed above using the format described. Use the current instruction files as an example.

Output Data File
No data are recorded but the length of time to complete the instructions is kept in the testee progress file (IN???????.???) as it is for all tests in the battery.

Learning (LR)

General Description
Learning is a test which presents increasingly larger sets of stimuli to be learned using a probed recall, multitrial method. Test trials have 3, 5, 7 or 9 positions in a set. Practice trials have two stimulus positions in the set. During practice, the testee sees two blank windows in the lower portion of the screen with a probe window centered in the upper portion of the screen. A stimulus appears in each blank window at a fixed presentation rate. Following presentation of the stimuli, one of the previously presented stimulus items is shown in the probe window. The testee must indicate which bottom window contained the probed stimulus by
touching the appropriate position within a fixed period of time. After the testee responds, another position is probed and the testee must again respond. Items are probed in random order until all positions in the set are tested.

All trials in a set are identical and use the same stimuli in the same positions. The testee must learn which item is in which position. A maximum of ten trials are presented for each set size. Criterion is reached when the testee is able to identify the position of all probes. When a subject meets criterion, the next larger set size is presented. If the testee does not reach criterion, the next trial within the same set size is presented. If the testee, finishes ten trials of a particular set size without meeting criterion, the next larger set is presented if the testee got 67% of the items correct on the last trial of the previous set. If the testee fails to meet criterion, the test is ended at the current block.

**Practice Trials**

Unlike the regular test, there is no criterion for practice trials. A fixed number of trials are given regardless of performance. The testee receives 5 trials with 2 positions. Performance on these trials is not recorded.

**Number of Trials**

The maximum number of trials that can be given is 40 (4 blocks by 10 trials per block) and the minimum is 4. However, since each position is tested on each trial the actual number of responses recorded is equal to trials multiplied by positions tested. The maximum number of trials X positions that can be presented in LR is \((3 \times 10 + 5 \times 10 + 7 \times 10 + 9 \times 10 = )\) 240. The minimum number of trials X positions in which LR can be completed is 24 (one trial for each set size = 3 + 5 + 7 + 9 positions).

**Blocks**

As indicated above, the trials are divided into 4 blocks which are distinguished by the number of items in the set. The four blocks present 3, 5, 7, or 9 items.

**Timing**

After the blank windows appear on the screen there is a 2.0 second delay before the trial begins. A beep is heard followed by a 1.0 second delay after which the first stimulus is presented. During testing, stimuli are presented for 1.0 second each. During practice, each stimulus is presented for 1.5 seconds. During both test and practice trials, a response must be made within 10.0 seconds or an error is recorded which appears in the data as a 10. Trial time includes all presentation times.
Criteria
A block of trials is ended when 10 trials are completed or when all items on any trial are all correct. The next block is administered if the testee got more than 67% of the previous trial block correct.

Stimuli
-32314, -31496, -27093, -25382, -24814, -20502, -19244, -17539, -15501, -15130, -12874, 1059, 1632, 7345, 8983, 9382, 10520, 12837, 14046, 17301, 17572, 22287, 23130, 23507, 25325, 31400

Screen Layout
The following are the screen coordinates used in LR:

<table>
<thead>
<tr>
<th>Position</th>
<th>X Coord</th>
<th>Y Coord</th>
</tr>
</thead>
<tbody>
<tr>
<td>0(Bar)</td>
<td>288</td>
<td>36</td>
</tr>
<tr>
<td>1</td>
<td>24</td>
<td>140</td>
</tr>
<tr>
<td>2</td>
<td>112</td>
<td>140</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>140</td>
</tr>
<tr>
<td>4</td>
<td>288</td>
<td>140</td>
</tr>
<tr>
<td>5</td>
<td>376</td>
<td>140</td>
</tr>
<tr>
<td>6</td>
<td>464</td>
<td>140</td>
</tr>
<tr>
<td>7</td>
<td>552</td>
<td>140</td>
</tr>
<tr>
<td>8</td>
<td>216</td>
<td>228</td>
</tr>
<tr>
<td>9</td>
<td>360</td>
<td>228</td>
</tr>
</tbody>
</table>

Position 8 and 9 are used for two-item practice. The 3-item block is presented in positions 3, 4, and 5. The 5 item block uses positions 2 through 6. The 7 item block used positions 1 to 7. The 9 item block uses all 9 positions.

Programming Details
Note that a response must be released before the next probe item will be presented. This prevents inadvertent repeating of responses from continuous responding to one position or from holding down one key.

Input Data File
The file follows the standard described previously (Chapter 5) through screen coordinate information. The first five data lines contain stimuli used in each set of trial blocks. The stimuli appear in the position in which they are presented in each block. The next ten blocks describe the practice trials. Each line records the order in which stimulus positions are to be tested. The remaining 40 lines of data specify the stimulus test order for each of the possible ten trials within the block.
Output Data File

The following is an example of a data file from LR:

<table>
<thead>
<tr>
<th>LRTWAA00.003</th>
</tr>
</thead>
<tbody>
<tr>
<td>137</td>
</tr>
<tr>
<td>3.000</td>
</tr>
<tr>
<td>5.000</td>
</tr>
<tr>
<td>4.000</td>
</tr>
<tr>
<td>0.001</td>
</tr>
<tr>
<td>8.969</td>
</tr>
<tr>
<td>3.000</td>
</tr>
<tr>
<td>3.000</td>
</tr>
<tr>
<td>3.000</td>
</tr>
<tr>
<td>0.001</td>
</tr>
<tr>
<td>1.458</td>
</tr>
<tr>
<td>3.000</td>
</tr>
<tr>
<td>4.000</td>
</tr>
<tr>
<td>4.000</td>
</tr>
<tr>
<td>0.001</td>
</tr>
<tr>
<td>1.055</td>
</tr>
<tr>
<td>3.000</td>
</tr>
<tr>
<td>3.000</td>
</tr>
<tr>
<td>3.000</td>
</tr>
<tr>
<td>0.001</td>
</tr>
<tr>
<td>6.973</td>
</tr>
<tr>
<td>3.000</td>
</tr>
<tr>
<td>4.000</td>
</tr>
<tr>
<td>4.000</td>
</tr>
<tr>
<td>0.001</td>
</tr>
<tr>
<td>1.268</td>
</tr>
<tr>
<td>3.000</td>
</tr>
<tr>
<td>5.000</td>
</tr>
<tr>
<td>4.000</td>
</tr>
<tr>
<td>0.001</td>
</tr>
<tr>
<td>1.235</td>
</tr>
<tr>
<td>.</td>
</tr>
<tr>
<td>.</td>
</tr>
<tr>
<td>.</td>
</tr>
<tr>
<td>9.000</td>
</tr>
<tr>
<td>5.000</td>
</tr>
<tr>
<td>5.000</td>
</tr>
<tr>
<td>0.001</td>
</tr>
<tr>
<td>1.421</td>
</tr>
<tr>
<td>9.000</td>
</tr>
<tr>
<td>6.000</td>
</tr>
<tr>
<td>6.000</td>
</tr>
<tr>
<td>0.001</td>
</tr>
<tr>
<td>1.132</td>
</tr>
<tr>
<td>9.000</td>
</tr>
<tr>
<td>8.000</td>
</tr>
<tr>
<td>8.000</td>
</tr>
<tr>
<td>0.001</td>
</tr>
<tr>
<td>1.394</td>
</tr>
</tbody>
</table>

COLUMN 1 = NUMBER OF ITEMS (3..9).
COLUMN 2 = CORRECT POSITION.
COLUMN 3 = SUBJECTS RESPONSE.
COLUMN 4 = LATENCY OF RESPONSE.
COLUMN 5 = TRIAL TIME.

The first line is the file name. The second line is the number of data lines in the file. Each position tested occupies a separate data line. Each trial requires as many data lines as positions in the list. Therefore, the number of data lines equals the number of trials times the number of positions tested per trial or the total number of positions tested.

The first column of a data line indicates the number of items in the list being tested. The second column indicates the position being probed. The third column is the subject's response. The fourth column is the reaction time measured from the presentation of the probe until the testee's response. The fifth column is the trial time. However, only the first position of each trial includes the presentation time and intertrial time. This time is (3.0 intertrial time + 1.0 * Number of items + computer setup time). All later positions (lines) only record the time between probes. To obtain, the length of each trial the reported trial time for each position in a block should be added up. This measure would include trial time with presentation time.
Reaction Time (RT)

General Description
Reaction time is a test which includes simple and choice reaction time. A semicircular array of from 1, 2, 4, 6, or 8 empty windows appears on the screen. On each trial, the testee initiates the trial by touching a bar at the bottom of the screen. After a variable length of time, one of the windows lights up (i.e., is filled with blue) and the testee's task is to pick his finger from the bar and touch the lit window as quickly as possible. The testee must make the correct response before the next trial can begin.

Practice Trials
There are 9 practice trials all using an 8 alternative display.

Number of Trials
There are 120 total trials with 24 trials given for each of the five blocks.

Blocks
There are five blocks of trials having 1, 2, 4, 6, and 8 alternatives. These block sizes were selected because they represent powers of 2 useful in calculating information content of the number of alternatives. Blocks are presented in ascending order which means that number of alternatives is perfectly confounded with degree of practice. This was done because it is the way this task has been typically presented and because earlier research indicated that randomizing number of alternatives eliminated most of the differences due to number of alternatives usually obtained with this paradigm.

Timing
When the testee touches the bar at the bottom of the screen a trial begins. One of the squares lights up following a variable interval after the bar is touched. This interval is varied so testees cannot anticipate stimulus onset. The interval is either 200, 300 or 400 milliseconds. Interval was randomly assigned to trials with the restriction that each interval occur equally often.

If a testee lifts his finger from the bar before this interval is over, the trial is restarted. The testee also hears a buzz and a message is written below the bar instructing the testee to keep his finger on the bar.

Criteria
The testee must make a correct response to end the trial. An error is counted if the testee touches any position other than the correct position before making the correct response.
Stimuli

Only two stimuli are used in RT. They are 0 for the empty window and -1 (all squares filled) for the lit window.

Screen Layout

The window placement was constructed so that the distance from the bar to the center of each window is approximately the same. Average distance from the bar to the center of each stimulus window is about 4.5 inches (11.5 cm). The screen coordinates are as follows:

<table>
<thead>
<tr>
<th>Position</th>
<th>X Coord</th>
<th>Y Coord</th>
</tr>
</thead>
<tbody>
<tr>
<td>0(Bar)</td>
<td>288</td>
<td>270</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>240</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>141</td>
</tr>
<tr>
<td>3</td>
<td>120</td>
<td>56</td>
</tr>
<tr>
<td>4</td>
<td>232</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>344</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>456</td>
<td>56</td>
</tr>
<tr>
<td>7</td>
<td>536</td>
<td>141</td>
</tr>
<tr>
<td>8</td>
<td>576</td>
<td>240</td>
</tr>
</tbody>
</table>

The 1 position block (simple reaction time) uses position 4 exclusively. The two position block uses positions 4 and 5. The 4 position block uses positions 3 to 6 and the six position block uses positions 2 to 7 and the eight position block uses all 8 positions. The distance from the bar to the center of each touch window is ??? cm (??? in).

Programming Details

The most complex portion of this test is ensuring that the testee keeps his finger on the bar until stimulus onset. It is not possible for the program to determine if the testee is using two hands to do this task.

Input File

The input file uses the standard format for input files through screen coordinates as previously described(Chapter 5). Following the screen coordinates there is one line for each trial. Each line has three columns. The first column uses a code to specify the empty windows that appear on the screen. The code is as follows:

<table>
<thead>
<tr>
<th>Position</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>6</td>
<td>32</td>
</tr>
</tbody>
</table>
Any set of positions can be selected by adding the code numbers together from the selected positions and using that new code number in column 1 of the data files. For example, 97 would select positions 1, 6, and 7. Positions 1, 2, 3, and 4 would be selected with the code number 15.

The second column is the position (1 to 8) to be tested (i.e., that lights up). The position tested should be one of those included in the code though CAT does not check for this.

The third column is the delay interval in milliseconds between the subjects initiation of a trial and stimulus onset.

**Output Data File**

The following is an example of a condensed RT output data file:

```
RTTWAA00.003
120
  0.043  1.879  4.000  0.000  400.000  8.818
  0.034  1.417  4.000  0.000  400.000  7.045
  0.181  1.256  4.000  0.000  400.000 13.582

*************
COLUMN 1= DT.
COLUMN 2= MT.
COLUMN 3= POSITION TESTED.
COLUMN 4= SUBJECTS RESPONSE.
COLUMN 5= DELAY.
COLUMN 6= TRIAL TIME.
*************
```

The first line is the file name. The second line is the number of trials completed. Lines 3 to 122 are data from the 120 trials. The first column is the decision time defined as the time from the onset of the stimulus (the window lights up) to the time the testee raises his finger from the bar. The second column records movement time which is the time from the testee lifting his finger until a correct response is made. The third column is the position tested. The fourth column is the testee's response. The response will be zero unless an error was made in which case it will be the incorrect position that was touched. Even if an error was made the testee must make a correct response to terminate the trial.
Relearning (RL)

Relearning is identical in every respect to Learning (LR). It is presented to obtain measures of savings in relearning.

Sternberg Memory Search Test (ST)

General Description

The Sternberg Search Task (ST) is a widely used experimental task. The original idea of the task was to determine the amount of time it takes to search well-known or easy stimulus sets of various sizes. By noting the difference in speed for the various set sizes, the search rate per item could be estimated.

In this version of the Sternberg Search task, four set sizes are used. Each set contains either 1, 2, 3, or 4 items. For any one set size, the stimuli are the same on every trial and are presented in the same position. Following presentation of the search set consisting of 1, 2, 3 or 4 items, the testee is presented with a probe. Half of the time this probe is one of the items from the presented set. The other (randomly determined) half of the time the probe is from a set of distractors equal in size to the memory or search set. The subjects task is to decide if the probe is from the presented set or if it is a distractor. If the probe was part of the memory set the testee indicates the item was present in the set by pressing the 'same boxes' on the left but if it was not in the set then he touches the 'different boxes' on the right.

ST begins with extensive practice so the testee can learn the stimuli used for each set size. Following practice, each block representing a different set size is presented from smallest to largest set size. Within each set, each trial is identical with the exception of the probe which may be from the set or a distractor.

Practice Trials

There are 8 practice trials for each of the 4 blocks which vary set size (1, 2, 3, or 4 items) for a total of 32 practice trials. The same stimuli are used in practice as are used in the test trials to give the testee as much familiarity as possible with the stimuli.

Number of Trials

There are 36 test trials for each of the 4 blocks for a total of 144 trials. However, incorrect trials are reinserted in the trial cue and readministered until all trials are gotten correct. Therefore, the number of trials depends on the number of errors made by the testee and will equal 144 + number of errors.
Blocks

The trials are divided into 4 blocks (as are practice trials). A different set size (1, 2, 3, or 4 items) is presented within each set size. The blocks are presented in with smallest set sizes first.

Timing

After the bar is touched to begin a trial there is a 0.5 second delay before the first stimulus is presented. Each stimulus item is presented for 1.00 seconds.

Criteria

The test continues until the testee gets all items right on one trial or until 280 trials are presented.

Stimuli

Set size 1: -4081; set size 2: 22610, 17456; set size 3: 26214, 28662, -28638; set size 4: 1632, -27575, 10760, 13740. Distractors (set size)[Number of times used including practice]: 24853 (1)[22], -27031 (2)[11], 9282(2)[11], -26368 (3)[7], 10596 (3)[8], 30030 (3)[7], -1334 (4)[6], 3999 (4)[5], 14698(4)[6], 18590 (4)[5]

Screen Layout

The following positions are used in ST. Numbers in parentheses indicate the set size those positions are used for.

<table>
<thead>
<tr>
<th>Position</th>
<th>X Coord</th>
<th>Y Coord</th>
</tr>
</thead>
<tbody>
<tr>
<td>0(Bar)</td>
<td>288</td>
<td>300</td>
</tr>
<tr>
<td>1(1)</td>
<td>288</td>
<td>128</td>
</tr>
<tr>
<td>2(2)</td>
<td>240</td>
<td>128</td>
</tr>
<tr>
<td>3(2)</td>
<td>336</td>
<td>128</td>
</tr>
<tr>
<td>4(3)</td>
<td>200</td>
<td>128</td>
</tr>
<tr>
<td>5(3)</td>
<td>288</td>
<td>128</td>
</tr>
<tr>
<td>6(3)</td>
<td>376</td>
<td>128</td>
</tr>
<tr>
<td>7(4)</td>
<td>144</td>
<td>128</td>
</tr>
<tr>
<td>8(4)</td>
<td>240</td>
<td>128</td>
</tr>
<tr>
<td>9(4)</td>
<td>336</td>
<td>128</td>
</tr>
<tr>
<td>10(4)</td>
<td>432</td>
<td>128</td>
</tr>
<tr>
<td>11(Probe)</td>
<td>288</td>
<td>24</td>
</tr>
<tr>
<td>12(Same)</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td>13(Same)</td>
<td>168</td>
<td>240</td>
</tr>
<tr>
<td>14(Diff)</td>
<td>440</td>
<td>240</td>
</tr>
<tr>
<td>15(Diff)</td>
<td>488</td>
<td>240</td>
</tr>
</tbody>
</table>
Input File
This input file follows the general rules for the input files given above (Chapter 5) through screen coordinates. The first 10 numbers following the screen coordinates (lines -36 to -32) are the stimulus items. Practice trials go from -31 to 0 and test trials go from 1 to 144. Each data line includes two numbers. The first is the set size and the second is the stimulus number for the probe stimulus.

Output Data File
The following is an example of the condensed output data file:

<table>
<thead>
<tr>
<th>STTWAA00.003</th>
</tr>
</thead>
<tbody>
<tr>
<td>163</td>
</tr>
<tr>
<td>1.000 0.000 0.000 0.000 0.865 2.299 296.961</td>
</tr>
<tr>
<td>1.000 1.000 0.000 1.000 1.737 1.807 5.603</td>
</tr>
<tr>
<td>1.000 0.000 1.000 0.000 2.779 1.759 7.284</td>
</tr>
<tr>
<td>.  .  .  .  .</td>
</tr>
<tr>
<td>4.000 1.000 1.000 9.000 1.794 2.372 10.407</td>
</tr>
<tr>
<td>4.000 1.000 1.000 7.000 1.226 2.487 16.939</td>
</tr>
</tbody>
</table>

*****************************************************************************
COLUMN 1 = SET SIZE
COLUMN 2 = TRIAL TYPE (YES OR NO)
COLUMN 3 = RESPONSE
COLUMN 4 = POSITIONqueried
COLUMN 5 = DECISION TIME
COLUMN 6 = MOVEMENT TIME
COLUMN 7 = TRIAL TIME
*****************************************************************************
Set size refers to the number of items in the search set (1, 2, 3 or 4). Trial type is 0 = distractor presented (correct response = no); 1 = stimulus from set presented (correct response = yes). Response (Column 3): 0 = absent, 1 = present, should match trial type to be correct. Position Queried (Column 4): 0 = distractor presented, 1 to 10 - number of position (and stimulus) presented.

Probe Recall (PR)

General Description
This test presents the testee with an array of six empty windows. Centered above the six windows is a seventh, or probe, window. The testee touches the bar, the bar disappears and the trial begins. A stimulus item appears in each of the six windows consecutively from left to right. Each stimulus disappears when the
next appears. After all six stimuli have been presented, a probe appears in the probe window. The probe is identical to one of the six stimulus items in the row. The testee’s task is to remember the position of the probe stimulus and to indicate the answer by touching that position.

**Practice Trials**

There is one practice trial.

**Number of Trials**

There are 72 trials. Each of the six serial positions is tested 12 times. Each of the 24 stimuli are tested 3 times. The stimuli presented on each trial were randomly determined with the restriction that each item and each position be probed equally often.

**Timing**

The testee touches the bar to begin a trial. After a 1.0 second delay, the first item is presented. Each stimulus item is presented for 1.0 second. The correct position displays the stimulus -1 (all cells filled) for 1.0 second after the testee responds.

**Stimuli**

The stimuli used in PR are: -31579, -30577, -28663, -27607, -27136, -26215, -26088, -24583, -13261, -12424, -11596, -1633, 1632, 2596, 4080, 4369, 10243, 12424, 12684, 21029, 22554, 24582, 27030, 27328. Each stimulus item is used as probe 3 times.

**Screen Layout**

In the following screen layout for PR, positions 1 to 6 are where the items appear:

<table>
<thead>
<tr>
<th>Position</th>
<th>X Coord</th>
<th>Y Coord</th>
</tr>
</thead>
<tbody>
<tr>
<td>0(Bar)</td>
<td>288</td>
<td>296</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>112</td>
</tr>
<tr>
<td>2</td>
<td>120</td>
<td>112</td>
</tr>
<tr>
<td>3</td>
<td>232</td>
<td>112</td>
</tr>
<tr>
<td>4</td>
<td>344</td>
<td>112</td>
</tr>
<tr>
<td>5</td>
<td>456</td>
<td>112</td>
</tr>
<tr>
<td>6</td>
<td>568</td>
<td>112</td>
</tr>
<tr>
<td>7(Probe)</td>
<td>288</td>
<td>25</td>
</tr>
</tbody>
</table>
Input File
The data input file follows the standard input file format as described above through screen coordinate information. The remainder of the file consists of 73 lines (1 practice and 72 test trials) of seven stimulus items. The first six items are the stimulus set and the seventh item is the probe.

Output Data File
The following is a condensed output data file:

<table>
<thead>
<tr>
<th>PRTWAA00.003</th>
<th>72</th>
</tr>
</thead>
<tbody>
<tr>
<td>-27607.000</td>
<td>0.914 2.000 2.000 7.479</td>
</tr>
<tr>
<td>24582.000</td>
<td>1.364 3.000 2.000 10.426</td>
</tr>
<tr>
<td>10243.000</td>
<td>1.684 4.000 3.000 10.336</td>
</tr>
<tr>
<td>.</td>
<td></td>
</tr>
<tr>
<td>.</td>
<td></td>
</tr>
<tr>
<td>.</td>
<td></td>
</tr>
<tr>
<td>21029.000</td>
<td>1.135 5.000 6.000 10.158</td>
</tr>
<tr>
<td>-1633.000</td>
<td>0.922 2.000 2.000 9.244</td>
</tr>
</tbody>
</table>

******************************************************************************
COLUMN 1 = STIMULUS INTEGER FOR PROBE.
COLUMN 2 = LATENCY OF RESPONSE (RT).
COLUMN 3 = SUBJECTS RESPONSE POSITION.
COLUMN 4 = CORRECT RESPONSE.
COLUMN 5 = TRIAL TIME.
******************************************************************************

Break (BK)

General Description
This 'test' provides a programmed break in the battery by including it like any other test. When CAT executes Break, a five-minute break is given. The testee may continue with testing at any time by touching the screen to end the break. If the testee, takes longer than the scheduled break time, the time late is displayed but no other action is taken.

Screen Layout
The screen during the break is black with yellow letters and appears as follows:
Time Break Ends is 13:52:00

Take a break for 5.00 minutes

Time Left
0:05:00

Touch screen to continue

When the five minute break ends, 'Time Left' changes to 'Time Late'.

Input Data File
The actual break time taken is not recorded but can be obtained from the Information file.

Self-Paced Probe Recall Test (SP)

General Description
The Self-Paced Probe test (SP) is designed to optimize the development of rehearsal strategies. Seven empty windows appear on the screen. When the testee touches the bar, a stimulus item is presented in the first window. This stimulus stays on until the testee touches the bar again when the stimulus in the first window goes off and a stimulus is presented in the second window. The testee continues to self-present all seven items by pressing the bar for each new item and studying each item for as long as he wishes.

When the testee presses the bar after the seventh item is presented, the bar disappears and the seven stimuli just presented appear in random order in a row below the original row where the stimuli were presented. The screen now displays two rows of seven windows. The top row is empty and the bottom row displays a stimulus in each row. The fifth window in the top row becomes completely filled. This signals the testee to find the stimulus in the bottom row that was presented in the position lighted in the top row. When the testee decides which of the seven stimulus items in the bottom row is the one that appeared in the fifth position, he touches that item in the bottom row and is given feedback indicating if the answer was correct.

After indicating which item was presented in the fifth position, the fifth position appears as an empty window and the sixth position lights up. The testee must now indicate which of the seven test items in the bottom row was presented in the sixth position. All positions are tested in the same way. The order of testing is Positions 5, 6, 7, 1, 2, 3, and 4. Theoretically, this order of recall provides an
optimal retrieval strategy if the testee develops the expected rehearsal strategy. The expected rehearsal strategy is that increasing amounts of study time will be given to early items of the list until position 4. Then the last three items will be quickly completed which, given the way items are tested (5, 6, and 7 first), is all the consideration they require. The seven test items in the bottom row are always presented in the same order on each trial.

If the testee develops an appropriate rehearsal strategy to this task, it should be evident as a larger amount of study time to position 4 than to earlier items. To facilitate the development of a strategy, SP uses very easy items that can be verbally labelled. These stimulus items are the same on each trial, only the order changes.

**Practice Trials**

There are 14 practice trials. Unlike other tests, performance on the practice trials is recorded and saved in the data file.

**Number of Trials**

There are 14 test trials.

**Timing**

Stimulus presentation is testee paced an is recorded as study time in the data output file. There is a restriction that each item be studied for at least 0.250 seconds.

**Stimuli**

The stimuli used in this task are: -31135(1), -28959(2), -9637(5), -8185(3), -6863(7), -5737(6), 26214(4). The number in parentheses indicates the number of the test alternative when this item is presented during the test phase.

**Screen Layout**

In the following table, P indicates a presentation position where the stimulus items to be studied are presented and T indicates a test position where the test stimulus items are presented:

<table>
<thead>
<tr>
<th>Position</th>
<th>X Coord</th>
<th>Y Coord</th>
</tr>
</thead>
<tbody>
<tr>
<td>0(Bar)</td>
<td>288</td>
<td>272</td>
</tr>
<tr>
<td>1(1P)</td>
<td>24</td>
<td>100</td>
</tr>
<tr>
<td>2(2P)</td>
<td>112</td>
<td>100</td>
</tr>
<tr>
<td>3(3P)</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>4(4P)</td>
<td>288</td>
<td>100</td>
</tr>
<tr>
<td>5(5P)</td>
<td>376</td>
<td>100</td>
</tr>
<tr>
<td>6(6P)</td>
<td>464</td>
<td>100</td>
</tr>
<tr>
<td>7(7T)</td>
<td>552</td>
<td>100</td>
</tr>
<tr>
<td>-------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>8(1T)</td>
<td>24</td>
<td>200</td>
</tr>
<tr>
<td>9(2T)</td>
<td>112</td>
<td>200</td>
</tr>
<tr>
<td>10(3T)</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>11(4T)</td>
<td>288</td>
<td>200</td>
</tr>
<tr>
<td>12(5T)</td>
<td>376</td>
<td>200</td>
</tr>
<tr>
<td>13(6T)</td>
<td>464</td>
<td>200</td>
</tr>
<tr>
<td>14(7T)</td>
<td>552</td>
<td>200</td>
</tr>
</tbody>
</table>

**Programming Details**

In order to prevent multiple responses from being recorded each response requires that the testee pick his finger from the position (or key) touched. If a testee is using two hands or responding extremely quickly it is possible that CAT will miss the finger lift and it may appear that the program is stuck. Repeat whatever response was made last.

**Input Data File**

The input data file is standard (as described in Chapter 5) through the screen coordinate information. The first data line (-14) consists of the stimulus numbers for the seven stimuli used in the task. The order of these items determines the order of the test alternative. Following the stimulus line, there is a line for each of the 14 practice (-13 to 0) and 14 test (1 to 14) trials. Each line contains a random order of the numbers 1 to 7. These numbers indicate which of the seven stimuli in the stimulus line will be presented in that position during the study phase of the test. For the sequence (2 6 1 4 7 5 3), stimulus 2 would appear in the first position. Stimulus 2 is the second stimulus in the stimulus line.

**Output Data File**

The format used in the data output file is somewhat different from other tests. Each trial has seven test items and five measures are collected for each test item. To accommodate all data, five lines of seven numbers each are saved for each trial. In addition, the 14 practice trials are saved as well as the 14 test trials. So there are 140 data lines in the file. The following is a compressed example of the data output file:
Stimulus Discrimination (SD)

General Description
Stimulus Discrimination (SD) is a modified match-to-sample test. The testee is presented with six empty windows in a row slightly below the center of the screen. Centered above this row of windows is a probe window. When the testee presses the bar, the six windows each display a different stimulus. The probe window displays a probe identical to one of the stimulus items in the row below. The testee is required to find the match to the probe in the bottom row, lift his finger, and touch the position where the item is presented.

When the testee lifts his finger, all windows become empty. But to view them again, he may press the bar. The testee can view the stimulus display as long as desired but the bar must be pressed or the display shows only empty windows. Decision Time is totalled from the first bar press to the last bar press before a response.

Practice Trials
There are four practice trials for SD. If an error is made the trial is not represented.

Number of Trials
There are 72 test trials. If an error is made (defined as selecting a stimulus that does not match the probe), the trial is presented again. The test ends when all
72 trials are correctly responded to or if the number of trials reaches 280. The final number of trials will equal 72 + the number of errors made by the testee.

**Timing**
The pacing of this task is entirely determined by the testee.

**Stimulus Items**
Practice trials use the stimulus items -1, 1, 12, 51, 204, and 105. Test trials use the stimulus items -31579, -30577, -28663, -27607, -27136, -26215, -26209, -26088, -24583, -13261, -11596, -1633, 1632, 2596, 4080, 4369, 10243, 12424, 12684, 21029, 22554, 24582, 27030, 27328.

**Screen Layout**

<table>
<thead>
<tr>
<th>Position</th>
<th>X Coord</th>
<th>Y Coord</th>
</tr>
</thead>
<tbody>
<tr>
<td>0(Bar)</td>
<td>288</td>
<td>280</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>144</td>
</tr>
<tr>
<td>2</td>
<td>120</td>
<td>144</td>
</tr>
<tr>
<td>3</td>
<td>232</td>
<td>144</td>
</tr>
<tr>
<td>4</td>
<td>344</td>
<td>144</td>
</tr>
<tr>
<td>5</td>
<td>456</td>
<td>144</td>
</tr>
<tr>
<td>6</td>
<td>568</td>
<td>144</td>
</tr>
<tr>
<td>7(Probe)</td>
<td>288</td>
<td>40</td>
</tr>
</tbody>
</table>

**Programming Details**
To make the display change as quickly as possible, paging is used in this task. Each display (empty windows and filled windows) are written on separate video memory pages. Pages are flipped to achieve fast display changes. All page changes are synchronized with the delay between screen retrace intervals. This task requires an EGA card with 256K of memory.

**Input Data File**
The input data file follows the standard input file order (as described in Chapter 5) through screen coordinates. The next 4 lines(-4 to 0) have seven stimulus numbers per line. The first six numbers are the stimuli which appear in the bottom row. The seventh number is the probe stimulus which is the same as one of the first six. The next 72 lines have the same format.
Output Data File

Note that repeated trials are those that the testee gets wrong and are given again until they are gotten correct. The first column contains the original trial number for repeated trials in the order they were given. In the following compressed example, trial 3 is given twice:

<table>
<thead>
<tr>
<th>SDTWAA00.003</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
</tr>
<tr>
<td>1.000</td>
</tr>
<tr>
<td>4.000</td>
</tr>
<tr>
<td>4.000</td>
</tr>
<tr>
<td>2.020</td>
</tr>
<tr>
<td>0.785</td>
</tr>
<tr>
<td>-28663.000</td>
</tr>
<tr>
<td>3.212</td>
</tr>
<tr>
<td>2.000</td>
</tr>
<tr>
<td>2.000</td>
</tr>
<tr>
<td>2.000</td>
</tr>
<tr>
<td>3.829</td>
</tr>
<tr>
<td>1.483</td>
</tr>
<tr>
<td>10243.000</td>
</tr>
<tr>
<td>5.329</td>
</tr>
<tr>
<td>3.000</td>
</tr>
<tr>
<td>1.000</td>
</tr>
<tr>
<td>2.000</td>
</tr>
<tr>
<td>1.678</td>
</tr>
<tr>
<td>2.051</td>
</tr>
<tr>
<td>-24583.000</td>
</tr>
<tr>
<td>3.746</td>
</tr>
</tbody>
</table>

******************************************************************************
COLUMN 1 = INPUT DATA FILE LINE
COLUMN 2 = CORRECT POSITION
COLUMN 3 = SUBJECTS RESPONSE
COLUMN 4 = DECISION TIME
COLUMN 5 = MOVEMENT TIME
COLUMN 6 = STIMULUS INTEGER FOR PROBE
COLUMN 7 = TRIAL TIME
******************************************************************************

Recognition Memory (RC)

General Description

Two blank windows appear on the screen. When the testee touches the bar, the windows display two stimuli. One of the stimulus items has been seen by the testee on a previous test, the other is novel and has not been shown before. The testee must decide which of the stimuli has been shown before and touch the position where that stimulus is presented. When the testee lifts his finger from the bar, the two windows become blank.

Practice Trials

Two practice trials are given.
Number of Trials
There are 24 test trials.

Timing
The timing of the task is entirely determined by the testee.

Stimuli
The pairs tested are given in the order which follows. The number in parentheses indicates whether the first (1) or the second (2) stimulus item is the correct member of the pair that has appeared in a previous task: -661, 2596(2); 16072, -28663(2); -13261, -3856(2); -31711, -30577(1); -2449, 21029(2); 9636, 4080(2); 27030, 1568(2); -27136, -28166(1); -27607, 14316(1); 22554, 1641(1); -27551, -24583(1); -16, 12684(2); -26088, 22441(2); 2400, -26215(1); -11596, 2448(2); 594, 4369(1); 1632, 26208(2); -4081, 27328(1); -26209, 28662(2); -31579, -32767(1); -1633, -32759(1); 8580, 12424(1); -5011, 24582(2); 10243, 5345(2).

Screen Layout

<table>
<thead>
<tr>
<th>Position</th>
<th>X Coord</th>
<th>Y Coord</th>
</tr>
</thead>
<tbody>
<tr>
<td>0(Bar)</td>
<td>288</td>
<td>288</td>
</tr>
<tr>
<td>1</td>
<td>240</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>336</td>
<td>100</td>
</tr>
</tbody>
</table>

Input Data File
The file has the standard structure (see Chapter 5) through screen coordinate information. There are 2 practice trial (-1 to 0) and 24 test trial (1 to 24) lines. Each line begins with the number of the correct item followed by the number of the stimulus items appearing in the first and second stimulus window, respectively.

Output Data File
This is an example of a condensed output data file from RC:
Tachistoscopic Threshold (TT)

General Description
This test is designed to determine the minimum amount of time required for a testee to decide if two stimulus items are the same or different. The initial screen has a bar at the bottom. Same (left) and different (right) response alternatives are above and to the sides of the bar. When the testee touches the bar, a fixation point appears on the screen. After a brief delay, two stimuli appear for a very short period. These stimuli are then covered by a solid mask. The testee must decide if the two stimuli were the same or different and indicate his choice by touching one of the response areas.

If the testee makes an error, stimuli on the next trial are presented for a longer duration. A block of trials continues until the testee reaches a certain criterion of performance.

Practice Trials
Three practice trials are given. The stimuli on all three trials are presented for 0.050 (3/60) seconds.

Blocks
The test trials are divided into 20 blocks. Each block begins by presenting stimuli for 0.0167 (1/60) seconds. When a testee makes an error, the stimulus exposure duration is increased by 0.0167 (1/60) seconds. This ascending method of limits continues until the testee makes five correct responses in a row. The
stimulus duration on the last trial is considered to be the testee’s threshold for that block of trials.

Number of Trials
The test continues until all 20 blocks have been completed or 287 individual trials have been given. Since five trials are required to reach criterion on each block, a minimum of 100 trials must be given.

Timing
Stimulus exposure durations are determined by the screen refresh rate. A standard video monitor refreshes 60 times per second. By synchronizing presentation of the stimulus with the screen refresh rate, it is possible to expose the stimuli for any number of 0.0167 (1/60) seconds intervals. The mask follows immediately after the stimulus presentation and is presented for 0.250 seconds.

Criteria
The testee must reach a criterion of 5 correct responses in a row to end each block.

Stimuli
Stimuli used are: -32314, -31496, -27093, -25382, -24814, -20502, -19244, -17539, -15501, -15130, -12874, 1059, 7345, 8983, 9382, 10520, 14046, 17301, 17572, 22287, 23507, 25325, 31400

Screen Layout
In the following screen layout, positions 1 through 4 are used for the same-different response boxes, positions 5, 6, and 7 are used for stimulus (5 and 6) and mask presentation (5 is upper left corner of mask), and position 8 is the center of the fixation point presentation. The fixation point is 8 pixels by 8 pixels. The mask is blue and is 144 pixels wide by 64 pixels high. This exactly covers the two stimuli and the space between them (64 pixels per stimulus + 16 pixels between them).

<table>
<thead>
<tr>
<th>Position</th>
<th>X Coord</th>
<th>Y Coord</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (Bar)</td>
<td>288</td>
<td>324</td>
</tr>
<tr>
<td>1</td>
<td>120</td>
<td>272</td>
</tr>
<tr>
<td>2</td>
<td>168</td>
<td>272</td>
</tr>
<tr>
<td>3</td>
<td>440</td>
<td>272</td>
</tr>
<tr>
<td>4</td>
<td>488</td>
<td>272</td>
</tr>
<tr>
<td>5</td>
<td>240</td>
<td>116</td>
</tr>
<tr>
<td>6</td>
<td>320</td>
<td>116</td>
</tr>
<tr>
<td>7</td>
<td>248</td>
<td>116</td>
</tr>
<tr>
<td>8</td>
<td>320</td>
<td>144</td>
</tr>
</tbody>
</table>
Programming Details

To achieve fast and precise stimulus exposure durations, the stimulus items are written to a screen page not shown. The page is flipped between screen refresh intervals. Stimulus duration is adjusted by changing the number of screen refresh intervals the stimulus is allowed to stay on the screen (1/60 second per interval). When the stimulus has been exposed for the desired interval, the page is flipped off and the mask is presented.

Input Data File

The data input file follows standard structure (Chapter 5) through screen coordinate information. The screen coordinate information is followed by 150 pairs of stimulus numbers. This array of stimulus pairs includes about 50% same and 50% different pairs. These are haphazard pairings of the stimuli listed above. The pairs are used, in order, on each trial. If there are more than 150 trials, the sequence begins again.

Output Data File

The following is a compressed example of a output data file. Data for all trial, not just criterion trials, is recorded.

\begin{verbatim}
TTTWAA00.003
  170
  1.000  2.000  2.000  0.017  0.259  2.381  4.362
  1.000  2.000  2.000  0.017  0.037  2.914  5.067
  1.000  1.000  1.000  0.017  0.444  2.293  4.427
  .
  .
  .
  20.000  2.000  2.000  0.100  0.050  1.853  3.773
  20.000  2.000  2.000  0.100  0.316  2.541  5.141
******************************************************************************
COLUMN 1 = TRIAL GROUP.
COLUMN 2 = CORRECT RESPONSE.
COLUMN 3 = SUBJECTS RESPONSE.
COLUMN 4 = TIME STIM. IS PRESENTED.
COLUMN 5 = DECISION TIME.
COLUMN 6 = MOVEMENT TIME.
COLUMN 7 = TRIAL TIME.
******************************************************************************
\end{verbatim}
Tachistoscopic Delay (TD)

General Description
The tachistoscopic delay presents a screen identical to the TT display screen. There is a bar at the bottom of the screen with the same-different response alternatives on the left and right. This test, however, requires that the testee determine if two stimuli were separated by a brief interval or a longer interval.

The testee presses the bar to begin a trial. A fixation point appears in the center of the screen. After a brief interval, a stimulus appears on the left of the screen. (On all trials the first and second stimulus items are the same.) Then that stimulus goes off and after a brief interval, a stimulus item appears on the right side of the screen. Finally, a mask covers the entire stimulus display area. The interval between the offset of the first stimulus and the onset of the second can be for either the standard duration or a longer duration. The testee's task is to decide if the interval was of the standard duration or longer. If it was of the standard duration, then the testee is to decide that offgo and onset were the same and to indicate this choice by touching the 'same' squares. If, on the other hand, the interval was longer, the testee should decide that offgo and onset were at different times and should so indicate by touching the different squares.

If the testee makes an error, the long duration gets longer. This ascending method of limits is continued until the standard and longer interval can be reliably discriminated.

Practice Trials
The testee receives six practice trials with duration of the long interval set a 0.100 seconds. Practice trials begin with the first items in the input array. No response criterion is set; incorrect trials are not repeated.

Blocks
Each testee receives 10 blocks of trials. A block of trials ends when the testee reaches criterion. The long delay at the time the testee reaches criterion is the threshold.

Number of Trials
The number of trials on TT is not fixed. Ten blocks of trials on which the testee reaches criterion are given. If an upper limit of 287 trials is reached, the task ends even if all blocks have not been given. The minimum number of trials required to complete this test is 40 (10 blocks X 4 criterion trials per block). Approximately half of the trials present a standard interval between stimuli and half present a longer interval.
Timing

After the testee touches the bar there is a 0.500 second delay before the fixation point is presented. The fixation point remains on the screen for 0.200 seconds. The fixation point disappears and the left hand stimulus appears for 0.200 seconds (this duration is extended somewhat by several computer operations that occur immediately after this delay). The left hand stimulus disappears and a standard or long interval is presented. The standard interval averages 0.008 (.5/60) seconds. This interval is the shortest possible delay that can be taken and still synchronize the presentation of the second stimulus with the screen refresh rate. It assumes that the screen refresh is in the middle of a refresh cycle. It is possible for this interval to vary from nearly 0 to 0.017 (1/60) seconds. The longer interval begins at 0.017 (1/60) seconds and is increased by 0.033 (2/60) seconds each time the testee makes an error.

Following either the long or the standard interval the second stimulus is presented for 0.100 seconds. A mask then appears covering both stimulus items and remains on for 0.250 seconds.

Criteria

The testee must be correct on 4 successive trials to meet the criterion for one block of trials.

Stimuli

Stimuli used are: -32314, -31496, -27093, -25382, -24814, -20502, -19244, -17539, -15501, -15130, -12874, 1059, 7345, 8983, 9382, 10520, 14046, 17301, 17572, 22287, 23507, 25325, 31400. Only one stimulus is used in both stimulus positions on any trial. Stimulus order and stimulus used across trials was randomly determined for the 150 trial input list. If a trial presented a standard or long presentation interval was randomly determined with the restriction that half of the trials in the 150 trial input list be of each type.

Screen Layout

In the following screen lay out, positions 1 through 4 are used for the same-different response boxes, positions 5, 6, and 7 are used for stimulus (5 and 6) and mask presentation (5 is upper left corner of mask), and position 8 is the center of the fixation point presentation. The fixation point is 8 pixels by 8 pixels. The mask is blue and is 144 pixels wide by 64 pixels high. This exactly covers the two stimuli and the space between them (64 pixels per stimulus + 16 pixels between them).

<table>
<thead>
<tr>
<th>Position</th>
<th>X Coord</th>
<th>Y Coord</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (Bar)</td>
<td>288</td>
<td>300</td>
</tr>
<tr>
<td>1</td>
<td>120</td>
<td>266</td>
</tr>
<tr>
<td>2</td>
<td>168</td>
<td>266</td>
</tr>
<tr>
<td>3</td>
<td>440</td>
<td>266</td>
</tr>
<tr>
<td>4</td>
<td>488</td>
<td>266</td>
</tr>
</tbody>
</table>
Programming Details

TD uses the same programming techniques as are used in TT.

Input Data File

The data input file follows the standard input file format (see Chapter 5) through screen coordinates. Following the screen coordinates are 150 lines containing a stimulus number and a 1 or a 2. A 1 stands for a standard delay trial and a 2 stands for a long delay trial. These 150 lines determine what occurs on each trial. If more than 150 trials are given the program begins at line 1 of the input lines again.

Output Data File

In the following compressed output data file, 'Time stimulus is presented' is actually the long interval. Trial type can be determine from the 'correct response' column: 2 = long interval; 1 = standard interval:

```
TDTWAA00.00
   64
   1.000  1.000  1.000  0.017  0.619  1.445  4.662
   1.000  2.000  2.000  0.017  1.924  2.077  6.878
   1.000  1.000  1.000  0.017  0.580  2.238  5.934
   .
   .
   .
  10.000  1.000  1.000  0.050  0.078  2.766  6.283
  10.000  1.000  1.000  0.050  0.305  1.885  5.510

******************************************************************************
COLUMN 1 = TRIAL GROUP.
COLUMN 2 = CORRECT RESPONSE.
COLUMN 3 = SUBJECTS RESPONSE.
COLUMN 4 = TIME STIM. IS PRESENTED.
COLUMN 5 = DECISION TIME.
COLUMN 6 = MOVEMENT TIME.
COLUMN 7 = TRIAL TIME.
******************************************************************************
```
Progressive Matrices (PM)

General Description
This test is more complex than the others. It is modelled after progressive matrices-type intelligence tests. The screen displays a matrix of stimulus items. The stimulus item in the lower right hand corner of the matrix is absent. Below the matrix is a row of six alternatives. The testee must decide which of the alternatives best completes the matrix. When he decides, he touches the alternative. The correct alternative immediately appears in the appropriate position in the matrix. The testee may study the matrix by continuing to press the chosen alternative. When the testee lifts his finger, a new item is presented.

Practice Trials
Four practice trials are given. There are two 2 X 3 matrix problems and two 2 X 2 matrix problems.

Number of trials
Fifty two trials are presented. There are three 2 X 3 matrix problems, seven 2 X 2 matrix problems and 42 3 X 3 matrix problems.

Blocks
Trials are blocked by matrix size.

Timing
Trials on PM are entirely testee paced except that the correct alternative appears for 1 second after an answer is chosen. It may be made to appear longer by continuing to press the selected alternative instead of lifting the finger.

Criteria
The correct response that best completes the matrix is selected by the test maker. Items used have been validated by correlating item passed (1) or failed (0) with total score on the Raven's Progressive Matrices.

Stimuli Used
The stimuli used in this test were designed by the test maker to complete matrices. Therefore, nearly every stimulus could be used. For a complete listing, see the input data file, PMDATA_A.TXT.
Screen Layout

Positions 1 through 6 are the positions for the alternatives. Positions 7 through 22 form a 4 X 4 matrix. The following are the upper left hand corner positions for each matrix size: 2 X 3 (Position 7); 2 X 2 (Position 8); 3 X 3 (Position 7) and 4 X 4 (Position 7). All of the positions used in this test are:

<table>
<thead>
<tr>
<th>Position</th>
<th>X Coord</th>
<th>Y Coord</th>
</tr>
</thead>
<tbody>
<tr>
<td>0(Bar)</td>
<td>295</td>
<td>300</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>270</td>
</tr>
<tr>
<td>2</td>
<td>120</td>
<td>270</td>
</tr>
<tr>
<td>3</td>
<td>232</td>
<td>270</td>
</tr>
<tr>
<td>4</td>
<td>344</td>
<td>270</td>
</tr>
<tr>
<td>5</td>
<td>456</td>
<td>270</td>
</tr>
<tr>
<td>6</td>
<td>568</td>
<td>270</td>
</tr>
<tr>
<td>7</td>
<td>190</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>260</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>330</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>400</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>190</td>
<td>67</td>
</tr>
<tr>
<td>12</td>
<td>260</td>
<td>67</td>
</tr>
<tr>
<td>13</td>
<td>330</td>
<td>67</td>
</tr>
<tr>
<td>14</td>
<td>400</td>
<td>67</td>
</tr>
<tr>
<td>15</td>
<td>190</td>
<td>129</td>
</tr>
<tr>
<td>16</td>
<td>260</td>
<td>129</td>
</tr>
<tr>
<td>17</td>
<td>330</td>
<td>129</td>
</tr>
<tr>
<td>18</td>
<td>400</td>
<td>129</td>
</tr>
<tr>
<td>19</td>
<td>190</td>
<td>191</td>
</tr>
<tr>
<td>20</td>
<td>260</td>
<td>191</td>
</tr>
<tr>
<td>21</td>
<td>330</td>
<td>191</td>
</tr>
<tr>
<td>22</td>
<td>400</td>
<td>191</td>
</tr>
</tbody>
</table>

Input Data File

The input data file follows the standard input file structure (Chapter 5) through screen coordinate information. There are three data lines of nine numbers each for each trial. The first number in line 1 indicates the matrix size: 1 = 2 X 3, 2 = 2 X 2, 3 = 3 X 3, and 4 = 4 X 4. The second number indicates the position of the correct response. These two numbers are followed immediately by the stimulus numbers for the entire matrix. These stimulus numbers should go from the upper left hand corner of the matrix through the lower right hand corner. The first and second rows should be completed with zeros so that there are nine numbers per line.

The third line contains the alternatives. The first six positions are stimulus numbers for the six alternatives (with the correct response occurring in the relative position indicated by the second number of the first line. For example, if the second number is 2 the correct response must be the second stimulus item listed. The third line is completed with two zeros and the trial number.
Output Data File
The following is an example of a data output file obtained from PM:

<table>
<thead>
<tr>
<th>PMTWAA00.003</th>
<th>52</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.000</td>
<td>4.000</td>
<td>4.000</td>
<td>1.216</td>
</tr>
<tr>
<td></td>
<td>1.000</td>
<td>6.000</td>
<td>6.000</td>
<td>1.483</td>
</tr>
<tr>
<td></td>
<td>1.000</td>
<td>2.000</td>
<td>2.000</td>
<td>1.131</td>
</tr>
</tbody>
</table>

**********
COLUMN 1 = MATRIX SIZE.
COLUMN 2 = CORRECT RESPONSE.
COLUMN 3 = SUBJECTS RESPONSE.
COLUMN 4 = RT OR TT (BOTH THE SAME).
**********
Chapter 7  Statistical Analyses

General Description of Statistical Analyses .......................................................... 84
   Making DT Files ......................................................................................... 84
   What is analyzed? ...................................................................................... 84
   Outliers ...................................................................................................... 84
   Measures of Central Tendency, Variation,
   Slope and Intercept ................................................................................... 84
   Measures of Reliability .............................................................................. 84

DT Parameters for Each Test .............................................................................. 85
   Abbreviations ............................................................................................ 85
   Variable Name Conventions ................................................................       85
   Variable Labels .......................................................................................... 87
   Learning (LR) ............................................................................................ 88
   Relearning (RL) ........................................................................................ 89
   Reaction Time (RT) .................................................................................... 90
   Probe Recall (PR) ....................................................................................... 92
   Stimulus Discrimination (SD) ..................................................................... 94
   Sternberg Memory Search Test (ST) ......................................................... 95
   Recognition Memory (RC) ......................................................................... 97
   Self-Paced Probe Memory (SP) ................................................................. 98
   Tachistoscopic Threshold (TT) .................................................................... 100
   Tachistoscopic Delay (TD) ......................................................................... 102
   Progressive Matrices (PM) ........................................................................... 103
General Description of Statistical Analyses

The following descriptions apply to the statistical analyses conducted by CAT to create the DT file. The DT file is not created automatically. The tester must explicitly tell CAT to analyze the data.

Making DT Files
There are several ways to make CAT analyze the test data. When the testee has finished the tests (or any time the last subject screen appears) type S and analyses will be conducted. At the menu or command line, enter SA. Typing SA will cause the final screen to appear. When the final screen appears type S and analyses will be carried out..

What is analyzed?
The statistical analysis program will analyze whatever test files are in the current testee directory. If the whole battery has not been completed, then those tests that have not been done will be passed over. Therefore, the DT file will contain output for only the tests that have been completed. Abnormally terminated files: Statistical Analyses; (Aborted files are not completed even though there are data files.) It is important to remember that DT files can include data from any number of tests. It should also be clear that DT files can be created at any time so the existence of a DT file does not mean the battery has been completed.

Outliers
All time data is screened for outliers. To do this, each testee's data for the measure being considered is converted to z scores. If any data point has a z score over 3.5, then the raw score is given the value of the mean in all further analyses. The data value is not changed in the file. It is only changed for the purposes of creating the DT file.

Measures of Central Tendency, Variation, Slope and Intercept.
Standard statistical procedures have been used to calculate the mean, median, standard deviation, slope and intercept.

Measures of Reliability
For every measure obtained an effort has been made to provide a split half measure so that an estimate of reliability can be determined within a particular sample
DT Parameters for Each Test

The following is a list of DT parameters for all tasks. An explanation of the measure is provided only when the variable name and variable label are not self-explanatory. The name in bold letters is the variable name. The brief description in italics is the variable label. Both the variable name and label are included in each DT file. Percent, when used in the variable label, generally refers to a proportion, not a percent.

Abbreviations

The following abbreviations are used frequently:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>DT</td>
<td>Decision Time</td>
</tr>
<tr>
<td>MT</td>
<td>Movement Time</td>
</tr>
<tr>
<td>RT</td>
<td>Response Time</td>
</tr>
<tr>
<td>TT</td>
<td>Trial Time</td>
</tr>
</tbody>
</table>

Variable Name Conventions

All variables are named according to a convention. A variable name is no more than 8 characters long. The first two letters of each variable name consist of the task code from the following list:

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR</td>
<td>Learning</td>
</tr>
<tr>
<td>RL</td>
<td>Relearning</td>
</tr>
<tr>
<td>RT</td>
<td>Reaction time</td>
</tr>
<tr>
<td>SD</td>
<td>Stimulus discrimination</td>
</tr>
<tr>
<td>SP</td>
<td>Self-paced probe</td>
</tr>
<tr>
<td>PR</td>
<td>Probe memory</td>
</tr>
<tr>
<td>RC</td>
<td>Recognition memory</td>
</tr>
<tr>
<td>ST</td>
<td>Sternberg search</td>
</tr>
<tr>
<td>TT</td>
<td>Tachistoscopic threshold</td>
</tr>
<tr>
<td>TD</td>
<td>Tachistoscopic delay</td>
</tr>
<tr>
<td>PM</td>
<td>Progressive matrices</td>
</tr>
<tr>
<td>DT</td>
<td>Data file</td>
</tr>
<tr>
<td>IN</td>
<td>Information</td>
</tr>
<tr>
<td>IQ</td>
<td>Intelligence quotient</td>
</tr>
<tr>
<td>DM</td>
<td>Demographic information</td>
</tr>
</tbody>
</table>

The third position is a code indicating the statistic being computed:

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Mean</td>
</tr>
<tr>
<td>M</td>
<td>Median</td>
</tr>
<tr>
<td>S</td>
<td>St. dev.</td>
</tr>
</tbody>
</table>
V  Variance  
L  Slope  
I  Intercept  
P  Percent  
N  Number  
O  Outliers  
C  Correction  
Q  IQ table  
R  Raw score  
T  Standard. score  
Z  Z-score  

The fourth position in the variable name indicates the dependent variable:

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>DT</td>
</tr>
<tr>
<td>M</td>
<td>MT</td>
</tr>
<tr>
<td>R</td>
<td>RT</td>
</tr>
<tr>
<td>E</td>
<td>Errors</td>
</tr>
<tr>
<td>T</td>
<td>TT</td>
</tr>
<tr>
<td>H</td>
<td>Threshold</td>
</tr>
<tr>
<td>C</td>
<td>Correct</td>
</tr>
<tr>
<td>W</td>
<td>Wrong</td>
</tr>
<tr>
<td>A</td>
<td>Attempted trials</td>
</tr>
<tr>
<td>S</td>
<td>Study time</td>
</tr>
<tr>
<td>B</td>
<td>Blocks</td>
</tr>
<tr>
<td>P</td>
<td>Positions</td>
</tr>
<tr>
<td>N</td>
<td>Num. of responses</td>
</tr>
</tbody>
</table>

The fifth position of the variable name is a code indicating the portion of the data used to compute the variable:

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Correct trials</td>
</tr>
<tr>
<td>W</td>
<td>Wrong trials</td>
</tr>
<tr>
<td>S</td>
<td>Same trials</td>
</tr>
<tr>
<td>D</td>
<td>Different trials</td>
</tr>
<tr>
<td>P</td>
<td>Present trials</td>
</tr>
<tr>
<td>N</td>
<td>Not present trials</td>
</tr>
<tr>
<td>T</td>
<td>All trials</td>
</tr>
<tr>
<td>O</td>
<td>Corr. for outliers</td>
</tr>
<tr>
<td>U</td>
<td>Uncompleted trials</td>
</tr>
<tr>
<td>F</td>
<td>Finished trials</td>
</tr>
<tr>
<td>J</td>
<td>Pres.corr.</td>
</tr>
<tr>
<td>K</td>
<td>Absent corr.</td>
</tr>
<tr>
<td>L</td>
<td>Pres. wrong</td>
</tr>
<tr>
<td>M</td>
<td>Absent wrong</td>
</tr>
</tbody>
</table>

The sixth and seventh positions of the variable name, if used, indicate blocks or positions being considered:
<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Block 1</td>
</tr>
<tr>
<td>B2</td>
<td>Block 2</td>
</tr>
<tr>
<td>B3</td>
<td>Block 3</td>
</tr>
<tr>
<td>B4</td>
<td>Block 4</td>
</tr>
<tr>
<td>B5</td>
<td>Block 5</td>
</tr>
<tr>
<td>B6</td>
<td>Block 6</td>
</tr>
<tr>
<td>B7</td>
<td>Block 7</td>
</tr>
<tr>
<td>B8</td>
<td>Block 8</td>
</tr>
<tr>
<td>B9</td>
<td>Block 9</td>
</tr>
<tr>
<td>P1</td>
<td>Pos. 1</td>
</tr>
<tr>
<td>P2</td>
<td>Pos. 2</td>
</tr>
<tr>
<td>P3</td>
<td>Pos. 3</td>
</tr>
<tr>
<td>P4</td>
<td>Pos. 4</td>
</tr>
<tr>
<td>P5</td>
<td>Pos. 5</td>
</tr>
<tr>
<td>P6</td>
<td>Pos. 6</td>
</tr>
<tr>
<td>P7</td>
<td>Pos. 7</td>
</tr>
<tr>
<td>P8</td>
<td>Pos. 8</td>
</tr>
<tr>
<td>P9</td>
<td>Pos. 9</td>
</tr>
<tr>
<td>I1</td>
<td>Item 1</td>
</tr>
<tr>
<td>I2</td>
<td>Item 2</td>
</tr>
<tr>
<td>I3</td>
<td>Item 3</td>
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<td>I4</td>
<td>Item 4</td>
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<td>I5</td>
<td>Item 5</td>
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<tr>
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<td>I7</td>
<td>Item 7</td>
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<td>I8</td>
<td>Item 8</td>
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<td>I9</td>
<td>Item 9</td>
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<tr>
<td>IA</td>
<td>Item 10</td>
</tr>
<tr>
<td>IB</td>
<td>Item 11</td>
</tr>
<tr>
<td>IC</td>
<td>Item 12</td>
</tr>
</tbody>
</table>

(blank or __) All data

The eight position, if used, indicates the half of the data being used:

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Half 1</td>
</tr>
<tr>
<td>2</td>
<td>Half 2</td>
</tr>
</tbody>
</table>

(blank) Both halves

**Variable Labels**

Variable labels are made following the same convention as variable names. In fact, the variable label consists of a string of 'meaning' phrases from the above lists. One phrase is included for each code letter or code letter pair in the variable name. Task code letters are not defined in the variable label but all other code letters are.

Each phrase begins with a capital letter so it is possible to associate the letters in the variable names with the phrases in the variable label. Each capital letter in
the variable label marks the beginning of a phrase for the next code letter or code letter pair. Each variable label is no more than 40 characters in length.

**Learning (LR)**

'Block' refers to the trials of a particular list length being learned. A position is the test of a particular position within a specific list length. A trial is a test of all positions for a given list length. Trial times are different for the first position tested and all other positions. The first position tested includes the list presentation time. All other trials only include the testee's RT.

**LRORT.** Outliers RT All trials.

**LROTT.** Outliers TT All trials.

**LRNPT.** Number Positions All trials. This refers to the product of the number of positions for a particular list length times the number of trials completed for that list length.

**LRNATB3** Number Attempted trials All trials Block 3. This equals the number of positions attempted divided by 3. Each of the following is computed in the same way: the number of positions attempted are counted and divided by list length.

**LRNATB5** Number Attempted trials All trials Block 5.

**LRNATB7** Number Attempted trials All trials Block 7.

**LRNATB9** Number Attempted trials All trials Block 9.

**LRNAT.** Number Attempted trials All trials. This refers to the number of trials attempted. It does not count the number of positions per trial. A trial on a 9-item list is equivalent to a trial on a 3-item list.

**LRXRT.** Mean RT All trials.

**LRSRT.** St. dev. RT All trials.

**LRXTT.** Mean TT All trials.

**LRSTT.** St. dev. TT All trials. This will be large because of the way TT is recorded. (see above)

**LRPCT.** Percent Correct All trials. This is the number of correct position divided by the number of positions attempted.

**LRMTT.** Median TT All trials.

**LRMRT.** Median RT All trials.

**LRNBT.** Number Blocks completed All trials. This is the last block attempted. It can range from 1 to 4. 1 = 3-position; 2 = 5-position; 3 = 7-position; 4 = 9-position.

**LRCBU.** Jacks correction of uncompleted blocks (early finish). This measure was devised by Jack Mayer and is the truncated sum of 10 minus the number of blocks completed for each trial: TRUNC((10.0 - TB3) + (10.0 - TB5) + (10.0 - TB7) + (10.0 - TB9)) where TB? is the number of trials completed for that list length.
LRCTU. *Jacks num. of trials corr. for early finish.* This is the number of trials not completed by the testee and is computed using the following formula: 
\[ \text{SMAT} := \text{TRUNC}(10.0 - \text{TB3}) \ast 3.0 + (10.0 - \text{TB5}) \ast 5.0 + (10.0 - \text{TB7}) \ast 7.0 + (10.0 - \text{TB9}) \ast 9.0) \]

LRCBN. *Jacks corr. for unattempted blocks.* This is the number of trials not administered due to failure to reach criterion on the previous block and is computed as: 
\[ \text{DUMB} := ((4 - \text{BLKS}) \ast 10) \]

LR CPC. *Jacks corrected prop. correct.* This uses the above two corrections to compute a corrected percentage correct: 
\[ \text{PCOR} := ((\text{NCOR} + \text{SMAT} + \text{DUMB})/240) \]

LRPCTB3. *Percent Correct All trials Block 3.* For this and the three following measures, percent correct is the number of items correct within each list length divided by the number of items attempted.

LRPCTB5. *Percent Correct All trials Block 5.*

LRPCTB7. *Percent Correct All trials Block 5.*

LRPCTB9. *Percent Correct All trials Block 9.*

**Relearning (RL)**

Relearning is analyzed identically to Learning.

RLORT. *Outliers RT All trials.*

RLOTT. *Outliers TT All trials.*

RLNPT. *Number Positions All trials.*

RLNATB3. *Number Attempted trials All trials Block 3.*

RLNATB5. *Number Attempted trials All trials Block 5.*

RLNATB7. *Number Attempted trials All trials Block 7.*

RLNATB9. *Number Attempted trials All trials Block 9.*

RLNAT. *Number Attempted trials All trials.*

RLXRT. *Mean RT All trials.*

RLSRT. *St. dev. RT All trials.*

RLXTT. *Mean TT All trials.*

RLSTT. *St. dev. TT All trials.*

RLPCT. *Percent Correct All trials.*

RLMTT. *Median TT All trials.*

RLMRT. *Median RT All trials.*

R LNB T. *Number Blocks completed All trials.*

RLCBU. *Jacks correction of uncompleted blocks (early finish).*

RLCTU. *Jacks num. of trials corr. for early finish.*
RLCBN. Jacks corr. for unattempted blocks.
RLCPC. Jacks corrected prop. correct.
RLPCTB3. Percent Correct All trials Block 3.
RLPCTB5. Percent Correct All trials Block 5.
RLPC7P. Proportion correct for 7-position task.
RLPCTB9. Percent Correct All trials Block 9.

Reaction Time (RT)
Data from reaction time are organized into 24 trials for each of the set sizes (1, 2, 4, 6, and 8). When halves are used each block is split into first and last half. The first half consists of the first half of each block size and the second half the second half of each block size.

RTODT. Outliers DT All trials.
RTOMT. Outliers MT All trials.
RTOTT. Outliers TT All trials.

RTNAT. Number Attempted trials All trials. This should always be 120.

RTNET. Number Errors All trials. An error is counted if an area outside the correct response area is touched before the correct response is made. A correct response must be made to end a trial. If the touch screen is not calibrated correctly, errors can be produced even if the correct response area is touched. A more likely cause of an error is a very rapid response that lands slightly outside the touch area.

RTXTT. Mean TT All trials including practice. Time for practice trials is added to first trial time.

RTSTO. St. dev. TT Corr. for outliers.
RTXDO. Mean DT Corr. for outliers.
RTSDO. St. dev. DT Corr. for outliers.
RTXMO. Mean MT Corr. for outliers.
RTXDOB1. Mean DT Corr. for outliers Block 1.

RTLDO. Slope DT Corr. for outliers. All slopes and intercepts for reaction time are computed by using the mean value for each set size and correlating this with the log (base 2) of the set size (1 = 0; 2 = 1.00; 4 = 2.00; 6 = 2.58; 8 = 3.00).

RTIDO. Intercept DT Corr. for outliers.
RTLMO. Slope MT Corr. for outliers.
RTIMO. Intercept MT Corr. for outliers.
RTNET__1. Number Errors All trials Half 1 by block.
RTNET__2. Number Errors All trials Half 2 by block.
RTXDOB1. Mean DT Corr. for outliers Block 1 Half 1.
RTXMOB1. Mean MT Corr. for outliers Block 1 Half 1.
RTXDOB1. Mean DT Corr. for outliers Block 1 Half 1.
RTXDOB42. Mean DT Corr for outliers Block 4 Half 2.
RTXDOB62. Mean DT Corr for outliers Block 6 Half 2.
RTXDOB82. Mean DT Corr for outliers Block 8 Half 2.
RTXMOB42. Mean MT Corr. for outliers Block 4 Half 2.
RTXMOB82. Mean MT Corr. for outliers Block 8 Half 2.

Probe Recall (PR)
PRORT. Outliers RT All trials.
PROTT. Outliers TT All trials.
PRNAT. Number Attempted trials All trials. This should always be 72.
PRXTT. Mean TT All trials.
PRSTT. St. dev. TT All trials.
PRXRT. Mean RT All trials.
PRSRT. St. dev. RT All trials.
PRPCT. Percent Correct All trials.
PRXRC. Mean RT Correct trials.
PRSRC. St. dev. RT Correct trials.
PRXRW. Mean RT Wrong trials.
PRSRW. St. dev. RT Wrong trials.
PRPCTP1. Percent Correct All trials Pos. 1.
PRPCTP2. Percent Correct All trials Pos. 2.
PRPCTP3. Percent Correct All trials Pos. 3.
PRPCTP4. Percent Correct All trials Pos. 4.
PRPCTP5. Percent Correct All trials Pos. 5.
PRPCTP6. Percent Correct All trials Pos. 6.
PRXROP3. Mean RT Corr. for outliers Pos. 3.
PRXROP5. Mean RT Corr. for outliers Pos. 5.
PRXRT_1. Mean RT All trials Half 1.
PRXRT_2. Mean RT All trials Half 2.
PRPCT_1. Percent Correct All trials Half 1.
PRPCT_2. Percent Correct All trials Half 2.
PRXRC_1. Mean RT Correct trials Half 1.
PRXRC_2. Mean RT Correct trials Half 2.
PRSRC_1. St. dev. RT Correct trials Half 1.
PRSRC_2. St. dev. RT Correct trials Half 2.
PRXRW_1. Mean RT Wrong trials Half 1.
PRXRW_2. Mean RT Wrong trials Half 2.
PRS RW_1. St. dev. RT Wrong trials Half 1.
PRS RW_2. St. dev. RT Wrong trials Half 2.
PRPCTP11. Percent Corr All trials Pos. 1 Half 1.
PRPCTP12. Percent Corr All trials Pos. 1 Half 2.
PRPCTP22. Percent Corr All trials Pos. 2 Half 2.
PRPCTP31. Percent Corr All trials Pos. 3 Half 1.
PRPCTP32. Percent Corr All trials Pos. 3 Half 2.
PRPCTP41. Percent Corr All trials Pos. 4 Half 1.
PRPCTP42. Percent Corr All trials Pos. 4 Half 2.
PRPCTP51. Percent Corr All trials Pos. 5 Half 1.
PRPCTP52. Percent Corr All trials Pos. 5 Half 2.
PRPCTP61. Percent Corr All trials Pos. 6 Half 1.
PRPCTP62. Percent Corr All trials Pos. 6 Half 2.
PRXROP11. Mean RT Corr for outliers Pos. 1 H 1.
PRXROP12. Mean RT Corr for outliers Pos. 1 H 2.
PRXROP22. Mean RT Corr for outliers Pos. 2 H 2.
PRXROP31. Mean RT Corr for outliers Pos. 3 H 1.
PRXROP32. Mean RT Corr for outliers Pos. 3 H 2.
PRXROP41. Mean RT Corr for outliers Pos. 4 H 1.
PRXROP42. Mean RT Corr for outliers Pos. 4 H 2.
PRXROP51. Mean RT Corr for outliers Pos. 5 H 1.
PRXROP52. Mean RT Corr for outliers Pos. 5 H 2.
PRXROP61. Mean RT Corr for outliers Pos. 6 H 1.
PRXROP62. Mean RT Corr for outliers Pos. 6 H 2.

Stimulus Discrimination (SD).

SDODT. Outliers DT All trials.
SDOMT. Outliers MT All trials.
SDOTT. Outliers TT All trials.

SDNAT. Number Attempted trials All trials. Incorrect trials are repeated. This number is 72 (number of trials) + errors (repeated trials).

SDXDO. Mean DT Corr. for outliers.
SDSDO. St. dev. DT Corr. for outliers.
SDXMO. Mean MT Corr. for outliers.
SDSMO. St. dev. MT Corr. for outliers.
SDXTO. Mean trial time for all trials.
SDSTO. St. dev. TT Corr. for outliers.

SDNET. Number Errors All trials. The number of errors subtracted from total trials attempted should equal 72.

SDXDC. Mean DT Correct trials.
SDSDC. St. dev. DT Correct trials.
SDXMC. Mean MT Correct trials.
SDSMC. St. dev. MT Correct trials.

SDNET__1. Number Errors All trials Half 1.
SDNET__2. Number Errors All trials Half 2.
SDXDC__1. Mean DT Correct trials Half 1.
SDXDC__2. Mean DT Correct trials Half 2.
SDSDC__1. St. dev. DT Correct trials Half 1.
SDSDC__2. St. dev. DT Correct trials Half 2.
SDXMC__1. Mean MT Correct trials Half 1.
SDXMC__2. Mean MT Correct trials Half 2.
SDSMC__1. St. dev. MT Correct trials Half 1.
SDSMC__2. St. dev. MT Correct trials Half 2.

**Sternberg Memory Search Test (ST)**

**STNUTR.** Number of errors. This is the number of trials minus 144 (the number of expected trials if there were no errors). Incorrect trials are represented.

**STNODT.** Number of outliers for decision time.

**STNOMT.** Number of outliers for movement time.

**STOTT.** Outliers TT All trials.

**STXDO.** Mean DT Corr. for outliers.

**STSDO.** St. dev. DT Corr. for outliers.

**STXMO.** Mean MT Corr. for outliers.

**STSMO.** St. dev. MT Corr. for outliers.

**STXTO.** Mean TT Corr. for outliers.

**STSTO.** St. dev. TT Corr. for outliers.

**STNETB1.** Number Errors All trials Block 1. Each block consists of 36 trials for a given set size (1, 2, 3, or 4). If errors are made, the incorrect trials are represented. Therefore, the number of errors is the number of trials for a set size minus 36.
STNETB2. **Number Errors All trials Block 2.**

STNETB3. **Number Errors All trials Block 3.**

STNETB4. **Number Errors All trials Block 4.**

STXDJB1. **Mean DT Pres.corr. Block 1.** This is the mean DT for all correct trials on which the probe was contained in the presented set.

STXDJB2. **Mean DT Pres.corr. Block 2.**

STXDJB3. **Mean DT Pres.corr. Block 3.**

STXDJB4. **Mean DT Pres.corr. Block 4.**

STLDJ. **Slope DT Pres.corr.** All slopes and intercepts are computed by correlating the value being considered with set size (1, 2, 3, or 4). In this case, mean DT for correct trials on which the probe was present is computed for each set size and then the mean DT for each set size is correlated with the set size for each testee.

STLDJ. **Intercept DT Pres.corr.**

STXDKB1. **Mean DT Absent corr. Block 1.** This is the mean DT for correct trials on which the probe was not contained in the presented set.

STXDKB2. **Mean DT Absent corr. Block 2.**

STXDKB3. **Mean DT Absent corr. Block 3.**

STXDKB4. **Mean DT Absent corr. Block 4.**

STLDK. **Slope DT Absent corr.**

STLDK. **Intercept DT Absent corr.**

STXMJB1. **Mean MT Pres.corr. Block 1.**

STXMJB2. **Mean MT Pres.corr. Block 2.**

STXMJB3. **Mean MT Pres.corr. Block 3.**

STXMJB4. **Mean MT Pres.corr. Block 4.**

STLMJ. **Slope MT Pres.corr.**

STICPM. **Intercept MT Pres.corr.**

STXMKB1. **Mean MT Absent corr. Block 1.**

STXMKB2. **Mean MT Absent corr. Block 2.**

STXMKB3. **Mean MT Absent corr. Block 3.**

STXMKB4. **Mean MT Absent corr. Block 4.**

STLMK. **Slope MT Absent corr.**

STLMK. **Intercept MT Absent corr.**

STXDO_1. **Mean DT Corr. for outliers Half 1.**

STXDO_2. **Mean DT Corr. for outliers Half 2.**

STSDO_1. **St. dev. DT Corr. for outliers Half 1.**
STXDJB42. Mean DT Pres.corr. Block 4 Half 2.

Recognition Memory (RC)
RCODT. Outliers DT All trials.
RCOMT. Outliers MT All trials.
RCOTT. Outliers TT All trials.
RCPCT. Percent Correct All trials. This is the number of correct trials divided by 24.
RCNAT. Number Attempted trials All trials. This should always be 24.
RCXTO. Mean TT Corr. for outliers.
RCMTO. Median TT Corr. for outliers.
RCSTO. St. dev. TT Corr. for outliers.
RCXDO. Mean DT Corr. for outliers.
RCSDO. St. dev. DT Corr. for outliers.
RCXMO. Mean MT Corr. for outliers.
RCSMO. St. dev. MT Corr. for outliers.
RCMRO. Median RT Corr. for outliers.
RCXRO. Mean RT Corr. for outliers.


RCPCT_1. Percent Correct All trials Half 1.
RCPCT_2. Percent Correct All trials Half 2.

Self-Paced Probe Memory (SP)
There are 28 trials. The first 14 trials may be considered practice but unless otherwise stated the parameters include all 28 trials. Those measures of half 2 (last digit 2) are based on the last 14 trials.

SPORT. Outliers RT All trials.
SPXST. Mean Study time All trials. This is the mean amount of time each item is studied.
SPSST. St. dev. Study time All trials.
SPXRO. Mean RT Corr. for outliers.
SPSRO. St. dev. RT Corr. for outliers.
SPPCT. Percent Correct All trials.
SPXSC. Mean Study time Correct trials. This is the amount of study time spent on items that are gotten correct.
SPXRC. Mean RT Correct trials.
SPXSTP1. Mean Study time All trials Pos. 1.
SPXSTP2. Mean Study time All trials Pos. 2.
SPXSTP3. Mean Study time All trials Pos. 3.
SPXSTP4. Mean Study time All trials Pos. 4.
SPXSTP5. Mean Study time All trials Pos. 5.
SPXSTP6. Mean Study time All trials Pos. 6.
SPXSTP7. Mean Study time All trials Pos. 7.
SPXROP3. Mean RT Corr. for outliers Pos. 3.
SPXROP5. Mean RT Corr. for outliers Pos. 5.
SPPNTP1. Perc Num. of resp All trials Pos 1. This is the number of responses the testee made to this position, both correct and incorrect. This measure can be used to correct for position response bias.
SPPNTP2. Perc Num. of resp All trials Pos 2.
SPPNTP3. Perc Num. of resp All trials Pos 3.
SPPNTP4. Perc Num. of resp All trials Pos 4.
SPPNTP5. Perc Num. of resp All trials Pos 5.
SPPNTP6. Perc Num. of resp All trials Pos 6.
SPPNTP7. Perc Num. of resp All trials Pos 7.
SPOTT. Outliers TT All trials.
SPXTO. Mean TT Corr. for outliers.
SPSTO. St. dev. TT Corr. for outliers.
SPSTO_2. St. dev. Study time All trials Half 2.
SPXST_1. Mean Study time All trials Half 1.
SPXST_2. Mean Study time All trials Half 2.
SPSST_1. St. dev. Study time All trials Half 1.
SPSST_2. St. dev. Study time All trials Half 2.
SPPCT_1. Percent Correct All trials Half 1.
SPPCT_2. Percent Correct All trials Half 2.
SPXSC_1. Mean Study time Correct trials Half 1.
SPXSC_2. Mean Study time Correct trials Half 2.
SPXRC_1. Mean RT Correct trials Half 1.
SPXRC_2. Mean RT Correct trials Half 2.
SPXSTP11. Mean Study time All trials Pos 1 Half 1.
SPXSTP12. Mean Study time All trials Pos 1 Half 2.
SPXSTP21. Mean Study time All trials Pos 2 Half 1.
SPXSTP22. Mean Study time All trials Pos 2 Half 2.
SPXSTP31. Mean Study time All trials Pos 3 Half 1.
SPXSTP32. Mean Study time All trials Pos 3 Half 2.
SPXSTP41. Mean Study time All trials Pos 4 Half 1.
SPXSTP42. Mean Study time All trials Pos 4 Half 2.
SPXSTP51. Mean Study time All trials Pos 5 Half 1.
SPXSTP52. Mean Study time All trials Pos 5 Half 2.
SPXSTP61. Mean Study time All trials Pos 6 Half 1.
SPXSTP62. Mean Study time All trials Pos 6 Half 2.
SPXSTP71. Mean Study time All trials Pos 7 Half 1.
SPXSTP72. Mean Study time All trials Pos 7 Half 2.

**Tachistoscopic Threshold (TT)**

**TTODT.** Outliers DT All trials.

**TTOMT.** Outliers MT All trials.

**TTOTT.** Outliers TT All trials.

**TTNAT.** Number Attempted trials All trials. This is the number of trials completed for all blocks including criterion trials.

**TTNBT.** Number Blocks All trials. This is the number of blocks begun. The last block may not reach criterion because the test may be terminated if 287 trials are completed. There are a maximum of 20 blocks.

**TTMHT.** Median Threshold All trials. The amount of exposure time required for the last stimulus in each of the blocks administered is taken as the threshold on that block. The median of these measures is obtained.

**TTMHT_1.** Median Threshold All trials Half 1. Half 1 refers to the first half of the blocks. That is, halves are divided on the basis of blocks, not trials. If there
are an odd number of blocks, the last half gets the extra block. Only threshold is halved by block. All other measures are halved on the basis of trial.

**TTMHT**__2. Median Threshold All trials Half 2.

**TTXDO.** Mean DT Corr. for outliers.

**TTMDO.** Median DT Corr. for outliers.

**TTSDO.** St. dev. DT Corr. for outliers.

**TTXMO.** Mean MT Corr. for outliers.

**TTMDO.** Median MT Corr. for outliers.

**TTSMO.** St. dev. MT Corr. for outliers.

**TTXTO.** Mean TT Corr. for outliers.

**TTMTO.** Median TT Corr. for outliers.

**TTSTO.** St. dev. TT Corr. for outliers.

**TTNCS.** Number Correct Same trials. Same trials are those on which the two stimuli presented are the same.

**TTNCD.** Number Correct Different trials. Different trials are those on which the two stimuli presented are different.

**TTNWS.** Number Wrong Same trials.

**TTNWD.** Number Wrong Different trials.

**TTXDJ.** Mean DT Same corr.

**TTXDK.** Mean DT Diff. corr.

**TTXDL.** Mean DT Same wrong.

**TTXDM.** Mean DT Diff. wrong.

**TTXDO**__1. Mean DT Corr. for outliers Half 1. Half 1 is the first half of the trials, not blocks. All measures but threshold are halved on the basis of trials.

**TTXDO**__2. Mean DT Corr. for outliers Half 2. Half 2 is the last half of trials, not blocks. If there are an odd number of trials, Half 2 gets the extra trial.


TTSTO₂. St. dev. TT Corr. for outliers Half 2.

Tachistoscopic Delay (TD)
TDODT. Outliers DT All trials.
TDOMT. Outliers MT All trials.
TDOTT. Outliers TT All trials.
TDNAT. Number Attempted trials All trials. This is the number of total trials attempted without regard to blocks.
TDNB1. Number Blocks All trials. The maximum number of blocks is 10. This is the number of the last block started. The last block may not be finished if 287 trials, the trial cutoff, are completed before criterion is reached.
TDNHT. Median Threshold All trials.
TDNHT₁. Median Threshold All trials Half 1. Half 1 is based on the first half of the blocks without regard to number of trials. If there are an odd number of blocks, half 2 contains the extra block. Only threshold is halved by block.
TDNHT₂. Median Threshold All trials Half 2.
TDXDO. Mean DT Corr. for outliers.
TDMDO. Median DT Corr. for outliers.
TDSDO. St. dev. DT Corr. for outliers.
TDXMO. Mean MT Corr. for outliers.
TDMMO. Median MT Corr. for outliers.
TDSMO. St. dev. MT Corr. for outliers.
TDXTO. Mean TT Corr. for outliers.
TDMTO. Median TT Corr. for outliers.
TSTO. St. dev. TT Corr. for outliers.
TDNCS. Number Correct Same trials.
TDCS. Number Correct Different trials.
TDNWS. Number Wrong Same trials.
TDNWD. Number Wrong Different trials.
TDXDJ. Mean DT Same corr.
TDXDK. Mean DT Diff. corr.
TDXDL. Mean DT Same wrong.

TDXDM. Mean DT Diff. wrong.

TDXDO 1. Mean DT Corr. for outliers Half 1. Half 1 refers to the first half of the trials, not blocks as for threshold. This is true for all measures except for threshold.

TDXDO 2. Mean DT Corr. for outliers Half 2. Half 2 is the last half of trials (not blocks). If there is an odd number of trials, Half 2 receives the extra trial.


**Progressive Matrices (PM)**

PMORT. Outliers RT All trials.

PMNAT. Number Attempted trials All trials.

PMXRO. Mean RT Corr. for outliers.


PMNCT. Number Correct All trials.

PMNATB1. Number Attempted trials Block 1. Block 1 is composed of 2 X 2 matrices.

PMNCTB1. Number Correct All Trials Block 1.

PMXROB1. Mean RT Corr. for outliers Block 1.

PMNATB2. Number Attempted trials Block 2. Block 2 is made of 2 X 3 matrices.
PMNCTB2. Number Correct All Trials Block 2.
PMNATB3. Number Attempted trials Block 3. Block 3 is made up of 3 X 3 matrices.
PMNCTB3. Number Correct All Trials Block 3.
PMPCT_1. Percent Correct All trials Half 1. Half 1 refers to odd trials while Half 2 is composed of even trials. This is different than for any of the other tests.
PMPCT_2. Percent Correct All trials Half 2.
Chapter 8 DTTOSPS - Using DT files in SPSS Analyses

DTTOSPS .................................................................................................................. 106
DATA.DAT .................................................................................................................. 106
DTMODEL.TMP ......................................................................................................... 107
Copying DT Files to a Directory ............................................................................... 108
Running DTTOSPS .................................................................................................. 108
Using DTTOSPS Output in SPSS/PC ...................................................................... 111
DTTOSPS

The program, DTTOSPS.EXE, converts DT files to a single SPSS data file which may be used forthwith in SPSS. Several files are required to run DTTOSPS. These files are briefly explained on the first screen presented by the program. To see this screen, execute DTTOSPS at the DOS prompt line.

DATA.DAT

This file should be in the same directory as the DTTOSPS program. It contains the path and name for 3 files and a list of testee numbers.

The first line contains the path and name of the DT model template file. This file tells the program which variables are to be included in the SPSS data file. If the line is blank, DTTOSPS assumes that the file name is DTMODEL.TMP and that it is in the same directory as DTTOSPS.

The second line contains the path and name of the output file for the SPSS data file. If the line is blank, DTTOSPS assumes that the name of the SPSS data file will be NEWDATA.SPS and places this file in the same directory as DTTOSPS.

The third line specifies the full path and base for the DT file. Generally, the base will be something like DTTWAA00.0. The base is that portion of the DT file name that is the same for all testees.

The following lines are a list of postfixes which are attached to the base to specify individual testee DT files. These are the testee data which will be included in the SPSS file. This postfix also becomes the variable, SUBJECT, in the SPSS file. It is best if this postfix contains only numbers and not letters.

An example of a DATA.DAT file might be:

```
C:\DATA\PRELIM.SPS
C:\DATA\RAW\DTTWAA00.0
100
101
102
103
104
105
108
109
110
```
In the above example, the first line is blank so the template file is assumed to be DTMODEL.TMP and located in the same directory as DTOSPS. The SPSS file will be PRELIM.SPS and will be written to the C:\DATA directory. The raw dt files are to be found in a directory called C:\DATA\RAW. The prefix for each DT file is DTTWAA00.. (Note the period on the prefix. It must be included since it is part of the file name.) The list of numbers specifies analysis of testees from 100 to 110.

**DTMODEL.TMP**

Constructing the DTMODEL.TMP file is simple. Copy the DT file of any testee who has completed the entire set of tests to be analyzed into a file called DTMODEL.TMP. Using a word processor or editor, delete all of the testee's data from the file (i.e., the first number in each line). Only the variable names and variable labels will remain. Place an asterisk in front of each variable to be included in the SPSS file. Make sure to put 1 blank space after the asterisk and before the variable name. Also be sure that the asterisk is in the first column.

Variable names not to be included should be preceded by two blank spaces. (SPSS/PC will not take more than 200 variables so you should start no more than 200 variables for any file.) Here is an example of a few lines from a DTMODEL.TMP file:

```
* LQRT   Outliers RT All trials.
* LQTT   Outliers TT All trials.
* LRP    Number Positions All trials.
* LRTB   Number Attempted trials All trials Block 3.
* LRTB5  Number Attempted trials All trials Block 5.
* LRTB7  Number Attempted trials All trials Block 7.
* LRTB9  Number Attempted trials All trials Block 9.
* LRT    Number Attempted trials All trials.
* LRT    Mean RT All trials.
* LRTT   St. dev. RT All trials.
* LRTT   Mean TT All trials.
* LRTT   St. dev. TT All trials.
* LRPC   Percent Correct All trials.
* LRTTT  Median TT All trials.
* LRTT   Median RT All trials.
* LRNB   Number Blocks completed All trials.
* LRSC   Jacks correction of uncompleted blocks (early finish).
* LRCT   Jacks num. of trials corr. for early finish.
* LRCT   Jacks corr. for unattempted blocks.
* LRCP   Jacks corrected prop. correct.
* LRPM   Percent Correct All trials Block 3.
* LRPM   Percent Correct All trials Block 5.
```
Copying DT Files to a Directory

In the DATA.DAT file, DT files were specified in a directory, C:\DATA\RAW\. That information is given to the program by the third line of the file. The DT files must be copied from the floppy diskettes onto the designated directory. This can be done using the batch file, COPYDATA.BAT found in the \CAT\TOOLS directory of the CAT diskette. This batch file copies DT files from the disk drive to the specified directory. After all files are copied from one diskette it calls for a new diskette and copies any DT files on that diskette to the specified directory. The batch file continues to copy files until halted by CTRL-C at the prompt. All DT files on the diskette must be in the root directory to be copied.

The following is an example of using COPYDATA.BAT to copy files from a diskette in Drive A: to the C:\DATA\RAW\ directory:

```
>COPYDATA A:\ C:\DATA\RAW\  
Batch file for copying DT files  
Form is COPYDATA A: C:  
Type Ctrl-C to end  
Insert diskette to copy  
Strike a key when ready ...  
A:\DTTWAM00.001  
A:\DTTWAM00.002  
A:\DTTWAM00.003  
   3 File(s) copied  
Type Ctrl-C to end  
Insert diskette to copy  
Strike a key when ready ... ^C  

Terminate batch job (Y/N)? Y
```

Bold characters are keyboard input.

Running DTTOPS

Once the DATA.DAT and DTMODEL.TMP files have been constructed and the DT files have been copied to the directory specified in the DATA.DAT file, DTTOPS.EXE can be run. Be sure that DTTOPS is in the appropriate directory if path names have not been completely specified. To run the program, at the DOS prompt type:

```
>DTTOPS
```

Follow the prompts provided by the program. If all works well, you will see the DTMODEL.TMP file on the screen. Following that, each of the numbers in the data file will be read and put into the SPSS file. There will be a report to the screen as each file is read. When the program ends, the file designated in the
second line of the DATA.DAT file will be an SPSS file ready to be read by SPSS/PC+.

The following are example lines from the file, PRELIM.SPS, made as described:

```
DATA LIST /
SUBJECT  1-10/
  LRORT  1-10  LROTT  11-20  LRNPT  21-30  LRNATB3  31-40  LRNATB5  41-50  /
  LRNATB7 1-10  LRNATB9 11-20  LRNAT  21-30  LRXRT  31-40  LRSRT  41-50  /
  LRXTT  1-10  LRSRT  11-20  LRPCT  21-30  LRMRT  31-40  LRMRT  41-50  /
  LRNBT  1-10  LRCBU  11-20  LRCU  21-30  LRCBN  31-40  LRCPC  41-50  /
  LRPCTB3 1-10  LRPCTB5 11-20  LRPCTB7 21-30  LRPCTB9 31-40  /
  RTNET  1-10  RTXTT  11-20  RTSTO  21-30  RTXDO  31-40  RTSDO  41-50  /
```

TTWUS 1-10  TTWOD 11-20  TTXDJ 21-30  TTXDK 31-40  TTXDL 41-50 /  
TTXDM 1-10 .

VARIABLE LABELS /
  LRCTT 'Outliers RT All trials.'/
  LROTT 'Outliers TT All trials.'/
  LRNP'T 'Number Positions All trials.'/
  LRNATB3 'Number Attempted trials All trials Block' /
  LRNATB5 'Number Attempted trials All trials Block' /
  LRNATB7 'Number Attempted trials All trials Block' /
  LRNATB9 'Number Attempted trials All trials Block' /
  LRNAT 'Number Attempted trials All trials.'/
  LRXRT 'Mean RT All trials.'/
  LRSRT 'St. dev. RT All trials.'/
  LRXTT 'Mean TT All trials.'/
  LRSTT 'St. dev. TT All trials.'/
  LRPC 'Percent Correct All trials.'/
  LRMTT 'Median TT All trials.'/
  LRMMT 'Median RT All trials.'/
  LRNB T 'Number Blocks completed All trials.'/
  LRCBU 'Jacks correction of uncompleted blocks ()' /
  LRCTU 'Jacks num. of trials corr. for early fin' /
  LRCBN 'Jacks corr. for unattempted blocks.'/
  LRPCP 'Jacks corrected prop. correct.'/
  LRPCTB3 'Percent Correct All trials Block 3.'/
  LRPCTB5 'Percent Correct All trials Block 5.'/
  LRPCTB7 'Percent Correct All trials Block 7.'/
  LRPCTB9 'Percent Correct All trials Block 9.'/
  RTNET 'Number Errors All trials' /
  RTXTT 'Mean TT All trials including practice.' /
  RTSTO 'St. dev. TT Corr. for outliers' /
  RTXDO 'Mean DT Corr. for outliers' /
Chapter 8 Using DT files in SPSS 111

```
TTNWS 'Number Wrong Same trials'/
TTNW 'Number Wrong Different trials'/
TTXDJ 'Mean DT Same corr.'/
TTXDK 'Mean DT Diff. corr.'/
TTXDL 'Mean DT Same wrong'/
TTXDM 'Mean DT Diff. wrong'.
BEGIN DATA.
  002  215.000  0.000  215.000  4.000  10.000  SUBJECT 002
  9.000  10.000  33.000  0.001  0.000  LRNATB 7 002
  2.897  3.342  0.688  1.575  0.001  LRT 002
  4.000  7.000  25.000  0.000  0.721  LRNBT 002
  0.750  0.740  0.714  0.633  LRPC 002
  2.000  6.408  1.123  0.126  0.096  RTNET 002

  003  15.000  19.000  0.185  0.163  0.123  TTNWS 002
  0.150  TTXDM 002
  003  SUBJECT 003

END DATA.
MISSING VALUE ALL(999).
```

This file begins with variable names. All variables selected by asterisks are included in the list. The variable names are followed by variable labels. Data for each testee specified in the file follows the variable labels.

The data for each testee in the file follows the exact order of the variable names. In fact, the variable names exactly mirror each data line for a testee.

The right-most line indicators are only for reference and are not read by SPSS. Data for each testee start on a new line and the variable 'SUBJECT' has the same number as that appended to the DT file. The data for each test also begin on a new line. Missing data are designated by 999. Note that DTTOSPS includes a missing value statement which tells SPSS that any variable having a value of 999 is a missing value.

Using DTTOSPS Output in SPSS/PC

To use this file with SPSS/PC, get into SPSS/PS and obtain the SPSS/PC prompt (you should be at the prompt line, not in Review). At the prompt, type 'include' and the name of the output file created by DTTOSPS (the file name from the second line of the DATA.DAT file). The following would be typed for the example given above:
SPSS: INCLUDE C:\DATA\PRELIM.SPS

SPSS will report reading in the data and the data are now ready to be analyzed using the SPSS commands.
References

Theory

Presentations

Publications

Experimental Work Using CAT

Presentations

Publications

114

114

114

115

115

115
Theory

The following is a list of presentations and publications which are directly relevant to the theory underlying CAT.

Presentations


Publications


Experimental Work Using CAT

The following publications and presentations include work that used CAT or earlier forms of the tests.

Presentations


Publications


Index

??TSK.DAT File 14
??XTRA.DAT File 15
??DATA A.TXT 37
??INST.TXT 37
??INSTTW.TXT 37

Abnormal End, Effect on Data 29
ALL 25

Backing Up Data 17
Bar Press Response 43
Batch file
   CAT commands 26
      Compared to ??TSK.DAT 27
Binary Representation of Stimuli 41
BK, see Break
   (BK) 66
Black screen 37
Black screens 21
Blue screens 20, 29
Break 66
   General Description 66
   Input Data File 67
   Screen Layout 66

Calibration
   Touch Screen 27
CAT 2
   Command Line 26
   Cover 20
   Deleting 7
   Directories 20
   Menu 23
      ALL 25
      CHN 25
      Graph 25
      SIX 25
      Statistical Analysis 25
      TST 25
   Running 20
   Stopping 28
   Testee Progress 22
Chain To Line 40
Children, testing 33
CHN 25
Cognitive Abilities Tests 2
COM1 4
COM2 4

Command Line 26
Computer 3
Computer speed 3
Configuring CAT 13
COPYDATA.BAT 108
Correct Response (Beep 1) 45
Cover 20
Ctrl-C 29

Data Diskette
   generation 12
      series 11
      version 11
Data Diskette Structure 10
Data Documentation 39
Data Input File
   Chain To Line 40
   Data Documentation 39
   Data Lines 39
   Parameter Line 38
   Screen Coordinates 39
   Task Code 38
Data Lines 39
Data Output File 46
   Contents 46
   Data Lines 46
   MAR 47
   Output File Names 46
   Removing 47
DATA.DAT 106
Debriefing 33
Decimal Representation of Stimuli 42
Deleting CAT 7
DIAGNOSE 5
Directories 20
Diskettes 5
DT Files 106
   copying to a directory (COPYDATA.BAT) 108
   Making 84
DT Parameters 85
DTMODEL.TMP 107
DTTOSPS 106
   DATA.DAT 106
   DTMODEL.TMP 107
      Example 107
   Running 108
   Use of Output in SPSS 111

Edmark 4
EGA 3
Ellinor Peripherals Limited 4
Enhanced Graphics Adapter 3
Equipment
  Computer 3
  Monitor 4
  Serial Adapter 4
  Touch Screen 4
    Edmark 4
    Ellinor Peripherals Limited 4
  Video Adapter 3
Equipment Problems 5
Equipment Requirements 3
Error Messages 20

F1-F5-Home 28
Feedback 45
Floppy Disk Setup 7

Generation
  input data file 37
GR, see Graph
Graph 25, 34

Hard Disk 5
Hard Disk Setup 6
Hexadecimal Representation of Stimuli 41

IBM AT 3
IN??????????? 47
Incorrect Response (Buzz) 45
Input data file 37
  Example 37
  generation 12
INSTALL 6
  Customizing 6
Instruction Files 37
Instructions 32
  Oral 32
  Written 32

Keyboard Input 27

Learning 2, 55
  Blocks 56
Criteria 57
DT Parameters 88
General Description 55
Input Data File 57
Number of Trials 56
Output Data File 58
Output File Size 10
Practice Trials 56
Programming Details 57
Responses 44
Screen Layout 57
Stimuli 57
Timing 56
LR, see Learning

MAKEDISK 37
  Descriptions 10
  Running 11
MAR 47
Menu 23
  ALL 25
  CHN 25
  Graph 25
  SIX 25
  Statistical Analysis 25
  TST 25
  Millisecond timing 49
Mode 3 49
Mode command 4
Monitor 4
Monitor Screen
  Dimensions 40

Normal Ending 28

Outliers 84
Output File Names 46
Output File Sizes 10

Parameter Line 38
PM, see Progressive Matrices
Position Response 44
PR, see Probe Recall
Practice 32
  Extra 32
    Help by the Tester 32
Press Bar (Beep 3) 45
Probe Recall 2, 64
  DT Parameters 92
  General Description 64
  Input File 66
  Number of Trials 65
  Output Data File 66
  Output File Size 10
  Practice Trials 65
  Responses 44
  Screen Layout 65
  Stimuli 65
  Timing 65
Programming Information 48
Programming Languages 48
Progressive Matrices 3, 80
  Blocks 80
  Criteria 80
  DT Parameters 103
  General Description 80
  Input Data File 81
  Number of trials 80
  Output Data File 82
  Output File Size 10
  Practice Trials 80
  Responses 44
  Screen Layout 81
  Stimuli Used 80
  Timing 80

RC, see Recognition Memory
Reaction Time 2, 59
  Blocks 59
  Criteria 59
  DT Parameters 90
  General Description 59
  Input File 60
  Number of Trials 59
  Output Data File 61
  Output File Size 10
  Practice Trials 59
  Programming Details 60
  Responses 44
  Screen Layout 60
  Stimuli 60
  Timing 59
Recognition Memory 3, 72
  DT Parameters 97
  General Description 72
  Input Data File 73
  Number of Trials 73

Output Data File 73
Output File Size 10
Practice Trials 72
Responses 44
Screen Layout 73
Stimuli 73
Timing 73
References 113
  Experimental Work Using CAT 115
  Theory 114
Relearning 2, 62
  DT Parameters 89
  Output File Size 10
  Responses 44
  Release Bar (Beep 2) 45
Reliability 84
Response 43
  Differences between Keyboard and Touch Screen 43
  Feedback
    Correct (Beep 1) 45
    Incorrect (Buzz) 45
    Press Bar (Beep 3) 45
    Release Bar (Beep 2) 45
  Position 44
  Press Bar 43
  Same-Different 44
  Summary by test 44
  Using index finger 33
  Visual Feedback 45
RL, see Relearning
RT, see Reaction Time
Running CAT 20

SA, see Statistical Analysis
Same-Different Response 44
Screen Coordinates 39
SD, see Stimulus Discrimination
Self-Paced Probe Memory
  DT Parameters 98
Self-Paced Probe Recall 2, 67
  General Description 67
  Input Data File 69
  Number of Trials 68
  Output Data File 69
  Output File Size 10
  Practice Trials 68
  Programming Details 69
  Responses 44
  Screen Layout 68
Stimuli 68
Timing 68
Serial adapter 4
Session Length 33
Progressive Matrices 33
Six Tests 33
Ten Tests 33
Setup
Dual Drive System 7
Floppy Disk 7
Hard Disk 6
Single Drive System 7
SIX 25
Size
Output Files 10
SP, see Self-Paced Probe Recall
SPSS
  Input File
    Example 109
    Making 106
Maximum Number of Variables 107
Using DTTOSPS Output Files 111
ST, see Sternberg Memory Search
Statistical Analysis 25, 84
Sternberg Memory Search 3, 62
  Blocks 63
  Criteria 63
  DT Parameters 95
  General Description 62
  Input File 64
  Number of Trials 62
  Output Data File 64
  Output File Size 10
  Practice Trials 62
  Responses 44
  Screen Layout 63
  Stimuli 63
  Timing 63
Stimuli
  Average viewing distance 41
  Color 41
  Dimensions 40
  Representation 41
    Binary 41
    Decimal 42
    Hexadecimal 41
  Stimulus color 41
  Stimulus dimensions 40
  Stimulus Discrimination 2, 70
  DT Parameters 94
  General Description 70
  Input Data File 71
  Number of Trials 70
  Output Data File 72
  Output File Size 10
  Practice Trials 70
  Programming Details 71
  Responses 44
  Screen Layout 71
  Stimulus Items 71
  Timing 71
  Stimulus Items 40
  Stopping CAT 28
  System clock 49
Tachistoscopic Delay 3, 77
  Blocks 77
  Criteria 78
  DT Parameters 102
  General Description 77
  Input Data File 79
  Number of Trials 77
  Output Data File 79
  Output File Size 10
  Practice Trials 77
  Programming Details 79
  Responses 44
  Screen Layout 78
  Stimuli 78
  Timing 78
Tachistoscopic Threshold 3, 74
  Blocks 74
  Criteria 75
  DT Parameters 100
  General Description 74
  Input Data File 76
  Number of Trials 75
  Output Data File 76
  Output File Size 10
  Practice Trials 74
  Programming Details 76
  Responses 44
  Screen Layout 75
  Stimuli 75
  Timing 75
Task Code 38
TD, see Tachistoscopic Delay
Terak computers 48
Test Instructions 55
  General Description 55
  Instruction Format 55
Output Data File 55
Test Sequence 28
Testee Information 21
Testee Progress 22
Testee Progress File 47
Example 47
Testing Environment 16
  Lighting 16
  Sound Levels 16
  Testee Space 16
TI, see Test Instructions
  (TI) 55
Timing 49
Touch Screen 4
  Calibration 27
Tsk.dat File 14
TST 25
TT, see Tachistoscopic Threshold
Turbo Pascal 48
Two's Complement 42

UCSD Pascal 48

Variable Labels 87
Variable Name Conventions 85
Variable Names
  blocks or positions used code 86
  data used code 86
  dependent variable code 86
  half used code 87
  statistic code 85
  task code 85
Video Adapter 3
Video Mode 16 3

XTRA.DAT file 15

Yellow letters 37
Appendix C

DEBRIEFING - GUARDIAN
Differences In Cognitive Abilities Between Various Phenotypes of Genetic Syndromes

Your child has just completed an experiment which explores the differences in cognitive abilities between individuals with different forms of genetic syndromes. The data we gathered today will help us to understand the differences between different genetic syndromes.

Your child’s information will be kept confidential, and under normal circumstances we will be the only people with access to this data.

At this time, please let me know if you have any questions or concerns. If any questions or concerns arise in the future you may call or email: Katherine Koenig at (216) 368-6670 or kag15@cwru.edu. You may also contact Dr. Detterman at (216) 368-2680 or dkd2@cwru.edu. If any of the data we have collected would be useful for educational or programming purposes, we would be glad to provide a report. However, these tests are not given by a licensed clinician and should be used for informational purposes only. We would require a signed (by the guardian) letter requesting the information and specifying exactly to whom it is to be sent. This letter can be sent to: Dr. Douglas K. Detterman; Department of Psychology; Mather Memorial Building #109; Case Western Reserve University; 10900 Euclid Avenue; Cleveland, Ohio 44106-7123

If you would like to talk to someone other than us about; (1) concerns regarding this study, (2) research participant rights, (3) research-related injuries, or (4) other human subjects issues, please contact Case Western Reserve University’s Office of Research Compliance at (216) 368-6925 or write: Case Western Reserve University; Office of Research Compliance; Sears Building 657; Cleveland, OH 44106-7015.

You will be given a copy of this information for your records.

Thank you very much for your time and assistance in this study. If there is anything we can do for you with regard to this study, please feel free to contact one of the individuals listed above.

Katherine A. Koenig