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Implicit and explicit memory in individuals with Down syndrome

Newman, Mary Catherine, M.A.

The University of Arizona, 1992

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

IMPLICIT AND EXPLICIT MEMORY
IN INDIVIDUALS WITH DOWN SYNDROME

by

Mary Catherine Newman

A Thesis Submitted to the Faculty of the

DEPARTMENT OF PSYCHOLOGY

In Partial Fulfillment of the Requirements
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STATEMENT BY AUTHOR

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APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

L. Nadel — 7/7/92

Lynn Nadel
Professor
Department of Psychology

Date

This work is dedicated to my family and friends whose love and encouragement made it possible.

My thanks ...

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ABSTRACT

A growing body of literature focuses on comparisons between developmental disabilities of diverse etiologies including Down syndrome (DS). Earlier research emphasized the limitations of this population, and frequently subjects with DS did not compare favorably with control groups. The current investigation examined the implicit and explicit memory skills of individuals with Down syndrome, other developmental disabilities, and MA-matched nonhandicapped children while controlling for confounding variables. In contrast to many previous studies, it was determined that under controlled conditions, free recall and recognition memory of children with DS are equivalent to that of NDS and NH groups. And performance on a pursuit rotor task was also comparable between groups. However, priming of subjects with DS was inferior to controls, a deficit similar to that previously identified in patients with Alzheimer's disease. In addition, the DS group was mildly impaired in both word fluency and attention.

Introduction

Careful examination of memory deficits in individuals with developmental disabilities and efforts to isolate the source and nature of these deficits began with the investigations of Ellis (1963). Ellis attributed poor cognitive performance in the mentally handicapped (MH) to impaired short-term memory, a decay of information prior to the establishment of a permanent memory trace. Early researchers like Ellis treated the mentally handicapped as a homogeneous group, and subjects were generally drawn from institutions. Most modern investigators recognize the need to distinguish between heterogeneous subgroups who often differ in cognitive abilities, and to exclude or control for the institutionalized whose performances appear to be artificially depressed by impoverished environments at least under some conditions (Stedman & Eichorn, 1964; Sharav & Shlomo, 1986; Balla & Zigler, 1982).

A growing body of literature from the past twenty years focuses on comparisons between developmental disabilities of diverse etiologies, one of which is Down syndrome (DS). The emphasis of research in the past has been on the limitations of this population, and the prognosis for the cognitive development of these individuals was poor. Results and conclusions about the source and nature of cognitive deficits often conflicted. Careful examination of the literature reveals that inconsistencies across studies appear to be due to a variety of confounding variables and differences in modality and task demands. Early researchers failed to determine whether the disabilities of this population are uniform and global or whether various cognitive abilities differ qualitatively within and between groups. A shift in emphasis and in the questions being asked about Down syndrome was critical. Identification of intellectual strengths and the nature and source of deficits are prerequisite to the understanding of the disorder, and to the development of appropriate and flexible training programs for these individuals.

The following review of the literature focuses on some of the major issues concerning the memory skills of individuals with DS. It begins with a summary of the physical, genetic and neurological characteristics associated with Down syndrome. This is followed by a review of relevant cognitive research and a brief overview of some of the implicit/explicit memory literature. Previous work is analyzed and integrated, illuminating the patterns emerging from these investigations. The paper then concludes with a report of the current investigation.

Review of the Literature

Physical, Genetic & Neurological Characteristics of DS

Down syndrome, also known as mongolism and Trisomy 21, was initially reported by Edward Seguin in 1846 (cited in Zellweger, 1981), but was later named for John Langdon Down, an English physician who published a clinical account of what he called Mongolian idiocy (1866). Langdon Down's paper describes the physical attributes of individuals with Down syndrome. Characteristics include short, flat-bridged noses and flat faces, atypical epicanthal folds (folds of skin adjacent to the nose), abnormalities of the hands and ears, and hypotonia (reduced muscle tone). In addition medical conditions such as heart disease, duodenal obstruction, cataracts, cleft palate and webbing of digits occur more frequently than normal in this population.

Down syndrome occurs in approximately one out of every six hundred live births (Wishart, 1988) as a consequence of a chromosomal abnormality. Lejeune, Turpin and Goutier (1959) first detected the presence of an extra twenty-first chromosome in some of these individuals. This triplication results from a chromosomal nondisjunction during the first meiotic division. More recently scientists have established that while most of those with DS have three twenty-first chromosomes rather than the usual two, this genetic disorder may also occur as a result of a mosaicism, an abnormal cell division at the second or later stage resulting in a third twenty-first chromosome in some cells and not in others. A third form is associated with the translocation of a portion of the twenty-first to another chromosome.

A variety of neuropathologies are also associated with DS (see Scott, Becker, & Petit, 1983, for review). Prenatal development proceeds fairly normally (Brooksbank, Walker, Balazs, & Jorgensen, 1989; Takashima, Becker, Armstrong, & Chan, 1981; Wisniewski et al., 1987). The brain is characteristically round, short and low in weight (Wisniewski, Laure-Kamionowska, Connell, & Wen, 1986) with diminished brainstem and cerebellar weight (Crome, Cowie, & Slater, 1966). The hippocampal formation (HF) is reduced in size and convolutions (Sylvester, 1983). There are alterations in the number and structure of neural processes (Purpura, 1975; Marin-Padilla, 1976; Suetsugu & Mehraein, 1980; Takashima et al., 1981). Synaptic pathologies (Petit, LeBoutillier, Alfano, & Becker, 1984; Wisniewski et al., 1986), abnormal electric membrane properties of dorsal root ganglia cells (Scott et al., 1983), atypical event-related potentials (Lincoln, Courchesne, Kilman, & Galambos, 1985), and biochemical abnormalities (Yates, Simpson, Maloney, & Gordon, 1980; Yates, Ritchie, Simpson, Maloney, & Gordon, 1981) are also concomitant with the disorder. Particularly remarkable is the poverty of the late-maturing granule cells throughout the cortex (Wisniewski et al., 1986), most notably in Layers II and IV of the hippocampus and parahippocampus (Ross, Galaburda, & Kemper, 1984; Wisniewski, Laure-Kamionowska, & Wisniewski, 1984; Wisniewski et al., 1986), the cerebellum (Scott et al., 1983) and the visual cortex (Wisniewski et al., 1984). Wisniewski (1984) suggested that the paucity of cells occurs as a result of prenatal arrest of neurogenesis. Reduced neuronal density and the presence of senile plaques and neurofibrillary tangles provide a link between Down syndrome and Alzheimer's disease both of which are associated with memory deficits (Jervis, 1948; Wisniewski, Jervis, & Moretz, 1979). In addition, they share abnormalities related to serotonin (Guttfires, 1970; Boullin & O'Brien, 1971), diminished quantities of noradrenaline in the hypothalamus (Yates, Ritchie, Simpson, Maloney, & Gordon, 1981), and some involvement of the twenty-first chromosome.

Cognitive Development

Down syndrome is responsible for approximately one third of all severe mental disabilities (Wishart, 1988). Subnormal memory skills have been reported in these children as early as three months of age (Carr, 1970). This population is characterized by an unusually broad range of abilities (Melyn & White, 1973; Morgan, 1979). Comparisons between the three forms of Down syndrome (trisomy twenty-one, mosaicism, translocation) suggest higher intellectual functioning associated with the mosaic form (Zellweger & Abbo, 1963; Rosecrans, 1968; Sachs, 1971; Fishler, 1975).

Langdon Down's prognosis for the cognitive development of these individuals was relatively encouraging, but many who followed him believed them to have limited intellectual potential and expected little of them. Frequently, DS groups have not compared favorably with matched mentally handicapped and nonhandicapped controls (e.g., McDonald & MacKay, 1974; Zekulin, Gibson, Mosley, & Brown, 1974; Miezejeski, 1974). However, some studies provide evidence of performance that is equivalent or superior to controls on some tasks (e.g., Rohr & Burr, 1978; Prior & Chen, 1976; Sinson & Wetherick, 1972; Gupton, 1984; Stratford & Alban Metcalfe, 1982). Even premature regression of adaptive and cognitive skills due to the Alzheimer-like neuropathology occurs later than had been previously reported, often not until age fifty or older (Zigman, Schupf, Lubin, & Silverman, 1987; Thase, Tigner, Smeltzer, & Liss, 1984). These results reflect greater than expected intellectual ability both early in development (Sharav & Shlomo, 1986; Morss, 1984; Wishart, 1986) and later into the second, third and fourth decades (Fisher & Zeaman, 1970; Clunies-Ross, 1979; Berry, Groeneweg, Gibson, & Brown, 1984). Such optimistic reports have lead to greater expectations for and a new surge of interest in this population. (See Gibson, 1978, and Carr, 1985, for review of intelligence-related research.)

Single Information Processing System vs Modular Model of Cognition

Traditionally the cognitive deficits of the mentally handicapped have been regarded as fairly uniform and global, a concept consistent with the view of human cognition as a single, powerful information processing system (see Anderson, 1983). But current neurological evidence of brain development in those with Down syndrome would predict a modular arrangement with relative preservation of some cognitive functions and impairment of those dependent upon the integrity of modules with greatest pathology. Prenatal neural development proceeds fairly normally in this population (Brooksbank, Walker, Balazs, & Jorgensen, 1989; Takashima, et al., 1981; Wisniewski, Schmidt-Sidor, & Shepard, 1987). Marked neuropathologies only begin to appear just prior to or at the time of birth.

The question of whether cognitive development in children with Down syndrome is merely slow or if it differs qualitatively from that of nonhandicapped children and those with other developmental disabilities has only recently been addressed. Given the diffuse yet irregular distribution of neuropathology, one might expect both delays and qualitative differences (Nadel, 1986). Examination of the literature reveals that the relative performance of subjects with Down syndrome depends upon task and modality demands (Lincoln et al., 1985; Miranda & Fantz, 1973; Sinson & Wetherick, 1972, 1973, 1975; Stratford, 1979a, 1979b, 1980; Stratford & Alban Metcalfe, 1981; Stratford & Alban Metcalfe, 1982; Morss, 1983, 1984, 1985).

Morss (1983, 1984, 1985) studied the performance of NH infants and those with DS on object permanence tasks from the Uzgiris and Hunt (1975) assessment scales for sensorimotor intelligence. Both groups solved the problems in the same order, but the DS subjects solved them at a later age. Not only was initial success delayed, but inconsistencies were evident. These subjects demonstrated less systematic error patterns than normal. Initial success by nonhandicapped children on these sensorimotor tasks tended to be followed by consistent success thereafter; this was not true of the infants with DS. This instability appeared to occur only at the stage of acquisition as Morss demonstrated perfect test-retest results in older children with DS. In a later study (1984), subjects were trained on simpler tasks for a more complex deduction problem. It appeared that success could be reached before spontaneous achievement occurred, but again success was not stable. Morss (1985) proposed that the information processing of individuals with Down syndrome is not just slow, but is qualitatively different than normal. A case was not made for different processes. Rather the author suggested that inadequate organization and structure of cognitive processes might be responsible for these deficits, a hypothesis consistent with hippocampal lesions. Morss proposed that the individual with Down syndrome may fail to impose order on his learning environment, and might therefore benefit from structured approaches to teaching.

Wishart (1987) postulates that testing infants with DS on single occasions may result in underestimation of their abilities. Children with DS aged 3 to 5 years were compared to nonhandicapped children of similar age on three object concept tasks designed for use with considerably younger infants. Performance of the DS group increased across sessions, surpassing that of the NH group in later sessions. In contrast, scores in the NH group declined which the author suggests was due to 'teasing' or deliberate failure. Wishart & Duffy (1990) also reported inconsistent patterns after testing children with DS aged 6 months to 4 years on the Mental Scale of the Bayley Scales of Infant Development and on four progressively difficult object concept tasks. Success rates on the object concept tests were poor in both groups considering that much younger children routinely pass them. The DS group failed to reproduce the normed heirarchy of difficulty from test 1 to test 4. As in the Morss studies, success rates were inconsistent: these children sometimes solved problems during one session and failed to solve them in a subsequent session. These results provide evidence for the notion that the development of children with DS is qualitatively different than normal, and suggest that single-session testing is probably inadequate in evaluating their abilities. In addition, the work of Morss and Wishart draws attention to the need for longitudinal studies.

Analyzing the inconsistent patterns of neuropathology, Nadel (1986) predicted that there should be significant impairment on some tasks and relatively spared functioning on others. He proposed that cognitive function relying on the integrity of areas normally rich in granule cells would be compromised more than early developing areas. Of particular interest with regard to DS is the medial temporal lobe including the hippocampal formation and dentate gyrus. The results of a number of studies support this 'difference' argument, and suggest that the behavioral patterns of individuals with DS differ from NH and other MH individuals (e.g., Stratford, 1979a, 1980; Stratford & Alban Metcalfe, 1981, 1982; Marcell & Weeks, 1988; Fantz, 1971; Miranda & Fantz, 1973, 1974; Lincoln et al., 1985; Mangan, 1992).

Hippocampal Formation. The hippocampal formation suffers marked departures from normal in the brains of individuals with DS primarily due to a reduced population of granule cells. It has been suggested that this structure plays a critical role in both long- and short-term memory, acquisition and retrieval of new information (Scoville & Milner, 1957), inhibition (Kolb & Whishaw, 1980), integration, consolidation, and the formation of cognitive maps (O'Keefe & Nadel, 1978). O'Keefe and Nadel argued that the hippocampus integrates information acquired from the environment, and that it acts as an index to information stored in the neocortex. Squire, Cohen and Nadel (1982) suggested that the medial temporal lobe (HF) is involved in identifying and storing bits of information and their relationships. Drawing on evidence such as this, Nadel (1986) argues for the modular model of cognition (Fodor, 1983; Gardner, 1983) suggesting that the premature arrest of neural development in one module should affect only the behavior dependent upon the integrity of that one subsystem leaving relatively preserved function in early developing subsystems. In the case of Down syndrome, one might expect greater deficits in functions mediated by structures normally rich in granule cells. Conversely, relative sparing of behavior dependent upon areas which normally have few granule cells would be predicted. Consistent with this hypothesis, results from a number of studies (Anwar, 1981; Frith & Frith, 1974; Kerr & Blais, 1985; Berry, Groeneweg, Gibson, & Brown, 1984; Morss, 1983; Wishart, 1986; Lincoln, Courchesne, Kilman, and Galambos, 1985; Sinson & Wetherick, 1972; Stratford & Alban Metcalfe, 1981; Mangan, 1992) indicate that those with Down syndrome fail to exhibit uniform impairment, demonstrating instead strengths and weaknesses according to task and modality demands. And rather than a simple delay and ceiling in development, these subjects manifest patterns of cognitive growth which are different from those of nonhandicapped subjects and from those of other developmentally disabled groups. Some apparent conflicts in results across studies are probably due to confounding variables, but this explanation does not account for all between-group differences. Indeed, inconsistencies in cognitive performance would be expected if one adopts Nadel's hypothesis of selective cognitive impairment with islands of relatively preserved function. According to Nadel's (1991) hypothesis, one might predict difficulty acquiring new information, impaired retrieval due to errant organization, and reduced ability to integrate information (McDade & Adler, 1980; Morss, 1983, 1984, 1985; Berry, Gunn, & Andrews, 1984; Farb & Throne, 1978; MacKay & McDonald, 1976; Buckley, 1985). Deficits in spatial skills (Prior & Chen, 1976; Mangan, 1992) and possibly in verbal skills (Ross, 1982; Scheffelin, 1968; Rohr & Burr, 1978; Dodd, 1975; Bilovsky & Share, 1965) would also be expected.

Inferotemporal Lobe. Another area of the brain in which granule cells are present, albeit in smaller numbers than in the hippocampal formation, is the inferotemporal lobe. This region, connected with the hippocampus through the entorhinal cortex (Moss, 1974; Van Hoesen & Pandya, 1975; Van Hoesen, Pandya, & Butters, 1972; cited in Squire & Butters, 1984), plays a role in the analysis of sensory features and retention of visual information in monkeys (Fuster & Jervey, 1981; Gross, Bender, & Gerstein, 1979; Mikami & Kubota, 1980; cited in Squire & Butters, 1984), and in visual discrimination and object recognition (see Mishkin, 1982; Mishkin, Ungerleider, & Macko, 1983). Cell activity in this area depends upon the physical features of the stimulus (e.g., color), the relevance of the features to the task (e.g., background vs stimulus color), and the attention of the animal. Provided the human counterpart of this brain region functions in a similar manner, one might predict varying degrees of impairment in analyzing and attending to appropriate features of a stimulus depending upon the degree of stimulus and task complexity and the degree of pathology in the inferotemporal cortex. Deficits in vigilance and shifting of attention (perhaps resulting from diminished cell populations in the frontal lobes) which have already identified in subjects with Down syndrome would exacerbate dysfunctions associated with the inferotemporal lobe if they exist.

Based on evidence of reduced populations of granule cells in other cortical areas, a poverty of these neurons in the inferotemporal region of someone with DS and consequent impairment in associated processing skills might be expected. While neurological evidence is not yet available, several studies provide evidence to support this hypothesis. For instance, subjects with DS have experienced difficulty on tasks requiring manipulation of more than one variable, e.g., color and shape (Sinson & Wetherick, 1972, 1973, 1975; Stratford & Mills, 1984), or size and pattern (Stratford, 1980). Manipulating level of difficulty and number of variables in a color vs shape memory task, Sinson and Wetherick (1976) found that the performance of participants with DS was relatively impaired on a task with one relevant and one irrelevant cue. The authors concluded that these subjects attended to irrelevant information, a finding consistent with inferotemporal lobe pathology. Fisher (1970) compared DS and NDS children on seven visual attention tasks including the Early Childhood Embedded Figures Test (Karp & Konstadt, 1963). They reported equally impaired performance for the DS and NDS groups on all but the embedded figures task. As in the Sinson and Wetherick study, the relative deficit of the DS group on this task may have been due to an inability to attend to relevant features of stimuli.

Examining recognition memory for faces in infants with DS, Miranda and Fantz (1974) noted that acquisition of ability to differentiate between familiar and unfamiliar faces was delayed. They attributed the delay to impaired memory for the overall configuration or relation among elements of a stimulus. In the current investigation, performance of subjects with DS was equivalent on visual recall and recognition using simple black-and-white line drawings. But in the fragmented pictures task in which successful subjects analyzed and remembered discontinuous features of visual stimuli, priming scores of the experimental group were significantly lower than those of controls. Perhaps this too can be attributed to a failure to remember the overall configuration or relation of elements.

Although lesions in other areas may produce deficits similar to those in each of the above investigations, these impairments observed together may be indicative of abnormal inferotemporal lobe development.

<u>Source of Cognitive Deficits Associated With Down Syndrome</u>

Results and conclusions concerning the cognitive abilities of this population are diverse and often contradictory. A number of researchers attribute poor performance primarily to auditory processing deficits (Bilovsky & Share, 1965; Scheffelin, 1968; Rohr & Burr, 1978; Marcell & Armstrong, 1982; Marcell & Weeks, 1988; Marcell, Harvey, & Cothran, 1988; Ross, 1982; Lincoln, Courchesne, Kilman, & Galambos, 1985; Rynders, Behlen, & Horrobin, 1979). Others report deficits in attention (Miranda & Fantz, 1973; Zekulin, Gibson, Mosley, & Brown, 1974; Sinson & Wetherick, 1972, 1973, 1975; Stratford, 1979b, 1980; Stratford & Metcalfe, 1982; Lunzer & Stratford, 1984; Zylstra, 1984; Morss, 1985). Sequential processing (Bilovsky & Share, 1965;

Snart, O'Grady, & Das, 1982; Varnhagen, Das, & Varnhagen, 1987; Rohr & Burr, 1978), motor and articulatory deficiencies (Dodd, 1975; Frith & Frith, 1974), and impaired short-term memory for color (Sinson & Wetherick, 1972, 1973, 1975) are also implicated. But as suggested by some authors (Pueschel, 1988; Snart, O'Grady, & Das, 1982; Varnhagen, Das, & Varnhagen, 1987; McDade & Adler, 1980; Farb & Throne, 1978), cognitive performance patterns are certainly the product of a number of factors. The effect of any one or combination of factors appears to depend upon modality and task demands.

Auditory Processing Deficits. Converging evidence from a variety of behavioral studies suggests that individuals with DS are at a particular disadvantage on tasks requiring auditory processing, perhaps due to a middle ear disorder (Libb, Dahle, Smith, McCollister, & McLain, 1985). Performance on auditory tasks is consistently inferior to visual skills (although these are also subnormal), and impaired relative to the abilities of NDS controls.

Bilovsky & Share (1965) conducted one of the earliest investigations of noninstitutionalized individuals with Down syndrome. Nine skills were assessed using the Illinois Test of Psycholinguistic Abilities (McCarthy & Kirk, 1961). These subjects experienced difficulty remembering nonmeaningful symbols. They did poorly on sequential processing tasks and on a task requiring the prediction of future linguistic events from sentence structure. They exhibited deficits in auditory and verbal processing. Visual reception and motor expression, on the other hand, were well above language performance. More recent research appears to verify their findings (Scheffelin, 1968; Rohr & Burr, 1978; Marcell & Weeks, 1988; Marcell, Harvey & Cothran, 1988; Pueschel, 1988; Ross, 1982; Rynders, Behlen, & Horrobin, 1979).

Lincoln, Courchesne, Kilman, and Galambos (1985) provided electrophysiological evidence of abnormal auditory processing in children with DS. Reaction time and event-related brain potentials (ERPs) of these children were compared to those of nonhandicapped mental and chronological age-matched children. Compared to controls, subjects in the experimental group had slower reaction times and longer latencies in some ERP components. It appeared that individuals with DS oriented to and processed some auditory information more slowly than nonhandicapped children, suggesting a problem with shifting attention. Lincoln et al. suggested that underdevelopment of the hippocampus may be at least partially responsible for cognitive deficits such as those demonstrated in this experiment: the normal hippocampus generates one ERP component and is involved in memory function.

Sequential vs Simultaneous Processing Deficits. Sequential processing deficits have been addressed in a number of studies (Bilovsky & Share, 1965; Rohr & Burr, 1978; Snart et al., 1982; Varnhagen et al., 1987). Often subjects with DS did not compare favorably with controls. However, sequential performance in most studies was confounded with auditory (Rohr & Burr, 1978; Varnhagen et al., 1987; Snart et al., 1982) and motor performance (Varnhagen et al., 1987). In at least one case (Pueschel, 1988), sequential and simultaneous processing were equivalent. Further investigation is necessary to determine whether individuals with Down syndrome experience difficulty with sequential processing of information.

Attention Deficits. The above research provides clear evidence of impaired auditory processing associated with Down syndrome, but not all data lead to the conclusion that this is the primary deficit. One group of authors has made a fairly strong case for inadequate attention skills and lack of motivation in individuals with Down syndrome, factors which impact on mnemonic performance (Miezejeski, 1974; McDonald & MacKay, 1974; Zekulin et al., 1974; Sinson & Wetherick, 1972, 1973, 1975; Stratford, 1979b, 1980; Stratford & A. Metcalfe, 1982; Lunzer & Stratford, 1984; Zylstra, 1984; Lincoln et al., 1985). Evidence of impaired attention has even been suggested in infants with DS (Morss, 1985; Miranda, 1970; Fantz, Fagan & Miranda, 1975).

Use of the term 'attention' varies across studies, sometimes referring to selective attention to features of a stimulus or task, or a failure to shift attention from one feature to another; sometimes regarding a state of vigilance or general attention to a task. Subjects with DS seem to experience difficulty with both selective attention and vigilance. These individuals neglect or fail to integrate pertinent features of complex stimuli, fail to use all available information and experience difficulty maintaining levels of attention adequate for task completion.

Several investigators introduced auditory distractors during cognitive tasks. Miezejeski (1974) found that white noise had a detrimental effect on simple visual reaction time in subjects with Down syndrome whereas it had no effect on NH and MH control groups. McDonald and MacKay (1974) ran a series of studies to examine the effects of proximal and distal proactive interference on the performance of individuals with Down syndrome, epilepsy and nondifferentiated mental handicaps using an auditory digit span recall task. Subjects were matched for CA, MA and digit span. Participants first heard a tone, either 3, 6 or 9 seconds in duration. This was either followed immediately by presentation of the digit span to be learned, or was followed by a 1.5 or 3 second delay and then the digit span. Recall memory for these number strings in the DS group was inferior to NDS controls: irrelevant auditory stimuli interfered more with the performance of the DS group. The authors postulated an attention deficit: the speed at which reactive inhibition built up and dissipated varied between groups resulting in diverse patterns of performance.

In a study by Zekulin, Gibson, Mosley and Brown (1974), DS, NDS and NH groups attempted to place pegs in a pegboard either with no distractor, or during an auditory or visual distractor. Subjects in the DS group exhibited greater distractability than controls in the auditory conditions. Like McDonald and MacKay (1974), these authors proposed an inhibitory deficit: DS subjects failed to habituate to the noise as quickly as control groups, continuing to attend to the extraneous stimulus rather than the assigned task. This conclusion is supported by the findings of Lunzer and Stratford (1984). A related suggestion was made by Lincoln et al. (1985): electrical activity over the front and back of the heads of subjects with DS may indicate response to all stimuli as "relatively novel". Consistent with this notion is Grossberg's (1982) mathematical model of memory (cited in Mattis & Kovner, 1984) in which attention and orienting play a critical role in learning and memory. Grossberg (1982) postulates a central role for the hippocampus in a gating mechanism which determines cue saliency and selectivity. Abnormalities in gating would result in a failure to select information for encoding.

<u>Deficits Involving Color or Multiple Dimensions</u>. Three one-trial learning experiments reported by Sinson & Wetherick (1972) compared the recognition memory of severely mentally handicapped DS and NDS groups. Three conditions were compared in Experiment 1: memory for a geometric shape which could be discriminated by color and/or shape (Condition 1), color only (Condition 2), and shape only (Condition 3). The DS group scored significantly better than the NDS group when shape and color were perfectly correlated. There were no between-group differences when color or shape varied alone. In the next two

experiments, the performance of the DS group was equivalent to the NDS group in generalizing shape discrimination from a salient cue (candy) to a nonsalient cue (black shapes). But the NDS group excelled in generalization of color (from a colored candy to a colored geometric shape). This is consistent with results reported by Stratford (1980, below). Sinson and Wetherick found that children with Down syndrome demonstrated color naming and retention deficits in subsequent studies (1973 & 1975). Both groups succeeded on the simultaneous matching of both color and shape. The groups performed equally well on successive shape matching, but only the NDS group retained color long enough to recognize the target in the successive matching condition. Sinson and Wetherick (1976) found that scores in the experimental group tended to increase with age except on the only task in which there was one relevant cue (color) and one irrelevant cue (a superimposed shape). In this case, performance of all age groups was at chance level suggesting that subjects with Down syndrome were attending to the irrelevant information. This occurred even though they could solve the problem when color alone was varied and could handle additional relevant information in the more difficult problems, results which may suggest inferotemporal lobe dysfunction and/or selective attention deficits.

Stratford and Mills (1984) also reported that although children with DS appear to be capable of sorting shapes and matching colors, organization of the two is impaired. Added to the results of Sinson and Wetherick's work, it seems that the use of color in educational materials should be carefully evaluated. And as the authors pointed out, attempts to learn some information might be more successful later in the course of education. Furthermore, attending to pertinent elements of a visual problem and ignoring irrelevant information is difficult at all ages for this population. This, too, should be taken into consideration by those developing and presenting curriculum.

Summary

Interpretation of the collective results of the research reviewed here is made difficult by the range of individual differences within the Down syndrome population, the diversity of tasks, controls, modalities, response requirements, and motor and auditory confounds of earlier investigations, and by the need for longitudinal studies. No one factor or set of factors has yet been identified that can account for the cognitive deficits of this population. However, several patterns appear to be emerging from existing data.

First, evidence across studies suggests that multiple factors interact to produce aberrant cognitive processing patterns which vary with task demands and modality. Converging behavioral and neurophysiological evidence suggests that auditory processing is particularly at risk. In addition, deficits in directing and maintaining attention is characteristic. Subjects with Down syndrome experience difficulty with vigilance and selective attention to relevant stimuli, both auditory and visual.

Evidence of neuropathological patterns in granular brain regions such as the hippocampal formation, and the behavioral evidence reviewed here suggest the need for examination of the inferotemporal lobe. Consistent with the notion of lesions in this structure, visual memory skills in these individuals vary according to task and stimulus complexity, the number and type of variables included, and attentional demands of the task. While these factors would certainly impact on performance in control groups, the presence of color and the requirement to remember or manipulate more than one variable seem to differentially affect subjects with DS. Impaired verbal and motor skills compound the effects of the above factors on behavior. Although it appears that there are deficits and inconsistencies in visual memory performance, visual processing skills are consistently superior to auditory processing skills. This factor should be considered by educators and caregivers. Presenting material in the preferred modality (visual) and controlling for stimulus characteristics which may adversely affect learning (stimulus complexity, color, etc.) should be beneficial.

Finally, while DS, NDS and MA-matched NH subjects have demonstrated similar abilities in some cases, the argument for qualitative differences in cognitive processing between these groups is compelling. Behavioral evidence reviewed here and results of the priming task in the current investigation support Nadel's argument for a modular model of cognition in which premature arrest of neural development results in more severely impaired skills associated with brain regions such as the hippocampus. Differences in cognitive performance patterns which vary according to task and modality probably reflect qualitative differences in cortical and subcortical development.

Early Diagnosis of DS: Advantages vs Disadvantages

One disadvantage associated with Down syndrome and not with most other cognitive disabilities is that it is usually diagnosed at birth, increasing the likelihood that these individuals will immediately be treated differently than normal. In addition to physical evidence of the disorder, there is evidence of reduced levels of vocalizing (Buckhalt, Rutherford, & Goldberg, 1978), and diminished smiling, laughter (Cicchetti & Sroufe, 1978; Emde, Katz, & Thorpe, 1978), and intensity of distress cries (Freudenberg, Driscoll, & Stern, 1978). These aberrant behavior patterns may lead to decreased attention and stimulation from caretakers, creating unnecessarily impoverished early environments. It is reasonable to assume that some parents continue to stimulate their children regardless of feedback, which may partially account for the variance in cognitive abilities within this population.

This apparent disadvantage at birth could be translated into a significant advantage for these infants with the proper education of caregivers. Some investigators have demonstrated positive effects from home rearing, enrichment of environment, and increased stimulation (Sharav & Shlomo, 1986; Salzberg & Villani, 1983; Morss, 1984; Wishart, 1986). Caregivers should be trained to provide appropriate early stimulation and education even when it appears the child is not learning. Imposing structure on learning experiences, limiting extraneous or irrelevant variables, and presenting material to be learned in the preferred modality may significantly improve learning and development. Alerting parents to the specific needs, and potential strengths and weaknesses of their children would maximize learning potential from birth. Early intervention may ameliorate the effects of cell and synapse loss in the postnatal period during which there is a paring back of what is an abundance of use-dependent connections in the normal brain. Retention of a maximal number of connections should increase learning potential. This is particularly critical in areas affected by premature arrest of neurogenesis. Identification and understanding of factors which affect learning in addition to enriching early home environments should lead to increased cognitive potential of children with Down syndrome giving them an advantage over those whose handicaps remain undiagnosed during early development.

Implicit vs Explicit Memory

Subjects with developmental disabilities such as Down syndrome have consistently experienced difficulty consciously retrieving information, evidence of what Graf and Schacter (1985, 1987; Schacter & Graf, 1986a, 1986b) classify as 'explicit memory'. It is most often assessed using tests of free recall, cued recall or recognition. Recently the study of what Graf and Schacter refer to as 'implicit memory' has generated a considerable amount of research interest. Implicit memory is reflected in the influence of experience on performance even in the absence of conscious recall of that learning experience. These and other investigators (e.g., Milner, 1962, cited in Schacter, 1987; Warrington & Weiskrantz, 1968, 1974; Cohen & Squire, 1980; Graf, Squire & Mandler, 1984; Glisky, Schacter, & Tulving, 1986: Glisky & Schacter, 1987; Gardner, Boller, Moreines, & Butters, 1973; Hashtroudi, Parker, DeLisi, Wyatt, & Mutter, 1984) have demonstrated dissociations between these two types of memory in normal and memory-disordered populations.

Schacter (1987) traced the history of implicit memory phenomena from the seventeenth to the mid-twentieth century at which point he introduced the modern era of implicit memory research. This author divided modern investigations into five areas: savings during relearning, effects of subliminally encoded stimuli, learning and conditioning without awareness, repetition priming, and preserved learning in amnesic patients.

Savings refers to facilitation in relearning a task. Whereas it is not necessary to recall the initial learning experience, performance is enhanced in some way due to that prior episode. Nelson (1978, cited in Schacter, 1987) demonstrated savings in the absence of recall or recognition.

Subliminal perception involves the processing and encoding of a stimulus in memory without conscious awareness of its presence. In one such study (Kunst-Wilson & Zajonc, 1980), the experimenters briefly presented geometric shapes, and subjects were subsequently asked to choose the matching shape in a recognition task. Performance on this test of explicit memory was at chance level. But when asked which of two shapes they liked better (one previously exposed for one millisecond, one novel), subjects chose the familiar stimulus significantly more often, demonstrating memory for a stimulus without conscious awareness of prior exposure to it. Lewicki (1985) found similar effects using subliminal presentation of adjective-noun pairs.

Learning without awareness has been demonstrated in the use of rules or contingencies in problem-solving without conscious knowledge of the learning process. For example, Reber (1976) and Reber, Allen, & Regan (1985) presented strings of letters conforming to the rules of a synthetic language. Subjects learned to recognize gramatically correct strings while unaware of the rules.

Skill-learning and direct or repetition priming studies represent the bulk of modern investigations of implicit memory in amnesia. Implicit memory has been demonstrated by normal subjects, both adults and children, (Graf, Mandler & Haden, 1982; Tulving, Schacter & Stark, 1982; Greenbaum & Graf, 1988) and memory-impaired patients (Korsakoff, 1899; Claparede, 1911, 1951; Milner, 1962; Milner, Corkin & Teuber, 1968; Warrington & Weiskrantz, 1968; Moscovitch, Winocur, & McLachlan, 1986).

Dunn (1845) provided the earliest account of skill-learning in a case of amnesia caused by a near-drowning and prolonged unconsciousness. The woman subsequently acquired the skills of a seamstress but failed to recall having made any garments. Milner (1962), Milner, Corkin, & Teuber, (1968) and Corkin (1965) introduced the formal investigation of skill acquisition with H.M. who suffered dense amnesia due to a bilateral medial temporal lobe resection. H.M. demonstrated the ability to acquire motor and perceptual motor skills (e.g., mirror-tracing, pursuit rotor tracking, traversing a tactile maze), improving performance time across trials despite his failure to remember the learning experiences. Similar results have been found across amnesic populations and tasks (e.g., Butters, 1987; Brooks & Baddeley, 1976; Cermak, Lewis, Butters, & Goodglass, 1973; Cohen & Squire, 1980; Kinsbourne & Wood, 1975; Nissen & Bullemer, 1987).

Direct or repetition priming is the most frequently used index of implicit memory. Priming refers to the facilitated processing of a stimulus to which the subject has had prior exposure. Tests commonly used to measure priming include lexical decision, word identification, and word completion tasks. Lexical decision tasks involve determining whether or not a string of letters represents a real word or a nonsense word, and priming effects are measured by the difference in reaction time between the first and second presentation of identical letter strings. Word identification (or perceptual identification) tests require that the subject view a stimulus very briefly (e.g., for 30 ms) and attempt to identify it. Increases in accuracy between the first and second exposure or decreases in exposure time necessary for identification are accepted as evidence of priming. In the first phase of a word completion test, subjects are exposed to a group of target words within a study list. Subsequently, the experimenter provides word stems or fragments and participants fill in the blanks to form the first word that comes to mind. Production of study list words occurs more frequently than other equally likely words providing evidence of priming.

Repetition priming research began with a series of studies by Warrington and Weiskrantz (1968, 1970, 1974, 1978). In the first experiment, the authors tested amnesic patients with Korsakoff psychoses and right temporal lobectomy, and non-amnesic patients with peripheral nerve lesions on three consecutive days. A graded series of fragmented pictures developed by Gollin (1960) and fragmented words developed by the authors were organized into ten sets: five versions of each picture per set and four versions of each word per set. The most incomplete version of the stimulus was presented first, and increasingly complete stages followed until the picture or word was identified or recognized. Whereas those with amnesia were severely impaired on traditional recall and recognition tests, both groups demonstrated savings on the fragmented words and pictures. Results indicated that learning was specific to the test stimuli and did not generalize to new fragmented pictures. Subsequent studies of amnesia patients by these investigators also indicated priming on word-stem and fragment cues in the presence of severely impaired explicit memory.

Lorsbach and Worman (1989) compared learning disabled and nondisabled third and sixth graders on tests of explicit (free and cued recall) and implicit (fragmented pictures) visual memory. The fragmented pictures task required that subjects view a graded series of four fragmented line drawings (Snodgrass & Vanderwart, 1980) from very incomplete to nearly complete. Results of this study revealed the expected dissociation between explicit and implicit memory: significant effects of age and group were observed on free and cued recall tests whereas there were no significant differences between groups on the fragmented pictures task.

Priming effects have been demonstrated in a number of studies examining normal subjects, both adults and children (Graf, Mandler, & Haden, 1982; Greenbaum & Graf, 1988). Graf et al. (1982) assigned normal college students to two groups: one group rated preference for a list of twenty words (elaborative processing); the other group searched for vowels in these same words (nonelaborative processing). After studying the lists, the word stem completion (priming) task was administered. Subjects were presented with a three-letter stem for each list word and were asked to complete it with any English word. This test was followed by a test of free recall for the target words. Although amnesia patients were unable to remember a list of words explicitly, their performance on the stem completion task was equivalent to normal. Graf et al. demonstrated that priming and free recall results could also be dissociated in normal subjects. Whereas no significant difference was found between groups on the priming task, free recall scores between groups were markedly different. Preventing elaborative processing from occurring in normal subjects resulted in free recall performance similar to that of patients with amnesia, but stem completion scores were equivalent.

In a study by Greenbaum and Graf (1988) three-, four- and five-year-old children were asked to identify sets of categorized line drawings with explicit instructions to remember them. Explicit memory was subsequently tested with recognition and recall tasks. Implicit memory (priming) was assessed using a word production task: a brief story was told about a particular place, e.g., the zoo, after which subjects were asked what might be found in this place. The investigators measured implicit memory by calculating the proportion of target words produced. Evidence of priming was similar across groups for child-normed category items but priming effects for adult-normed items increased with age. Age-related improvement was also demonstrated on traditional explicit memory tasks. The authors propose that the interaction of child- versus adult-normed words associated with word production but not with recall performance suggests that implicit and explicit memory tap different aspects of memory. Explicit memory appeared to improve with age: whereas recognition performance was poor in the youngest group after a two week delay, it was good in other groups. However, performance on the implicit task was equivalent across groups and conditions. No correlation was found between savings and recognition scores in any of the groups. Like Warrington and Weiskrantz (1968), these authors found that savings was item-specific, that no generalization to new stimuli occurred. They concluded, as did Warrington and Weiskrantz, that implicit memory develops before explicit memory, and suggested that the two may be mediated by different systems.

Several theoretical models have been proposed in an attempt to explain portions of the implicit memory data. These include activation, processing, and multiple memory system models which are discussed in Schacter (1987). Activation theories are based on automatic activation of stored information which provide the effortless responses generated on implicit memory tests. Unlike activation theorists, proponents of processing models attribute both implicit and explicit memory performance to newly encoded information, and focus on encoding and retrieval processes. Multiple memory system views propose that implicit and explicit memory are supported by different neural substrates. Each of the theories developed thus far accounts for some implicit memory performance but, as Schacter points out, no one theory has yet been developed which is consistent with all or even a major portion of the data.

Implicit Memory and Down Syndrome

Frith & Frith (1974) and Kerr & Blais (1985) compared the motor skill-learning abilities of DS, NDS and NH groups using two different pursuit rotor tracking tasks. Performance of the Down syndrome group in each study proved to be inferior to that of the control groups. However, that may be due to the particular task demands. Frith and Frith (1974) matched children with Down syndrome and those with autism to NH children on initial pursuit rotor tracking performance and noted improvement rates across trials. In this task, the subject attempted to maintain contact between his finger (enclosed in a leather sheath tipped with a photoelectric cell) and a spot of light moving around a circular 'track'. These investigators found poor and erratic performance across groups, but the DS group was the only one which failed to improve significantly between the first and second trials. Frith and Frith hypothesized that members of this population either fail to develop motor programs or develop them more slowly than normal. However, motor deficits were probably compounded by the demands of this particular computer program and the length of trials and intervals. Perhaps use of a smaller track, which would not require as gross a hand or arm movement, and shorter, more frequent trials would have been more manageable for subjects with DS, resulting in better initial performance and a significant improvement across trials. Restricting participation to those who were less severely mentally handicapped might also have made a difference in the relative performance of these groups. Possible confounding factors from these two studies were considered in designing the present study. It was predicted that learning curves would be observed in the children with DS, though they would be flatter than those of the control groups due to known motor deficits. This task also served as a testing ground for use of the computer as a learning tool and possible source of employment for developmentally disabled students. Although motor deficits are concomitant with DS, it was expected that these subjects would be successful in using the Macintosh SE system and computer 'mouse' which are easy to operate and appealing to children, thus limiting attention problems. In addition, the rate of rotation can be controlled according to skill level while still allowing demonstration of a learning curve.

Kerr and Blais tested DS, NDS and NH subjects matched for chronological and functional age on an apparatus resembling a portion of a steering wheel which controlled a pointer. Five targets (lights) were arranged in a curved line. Upon illumination of a target, subjects turned the wheel attempting to align the pointer with the light. Illumination sequences were random, and probabilities for direction of movement from any one position were calculated. Subjects with Down syndrome were slower than those in control groups, but made fewer errors. There was a practice effect, but unlike controls, the participants in the DS group did not appear to make use of probability information to improve performance. The authors suggested two possible explanations: either individuals with DS fail to perceive probability information or they are unable to organize their responses to make use of this information. Other factors which the authors did not discuss may have differentially affected the DS group. Testing sessions of forty minutes with seven one-minute breaks probably demanded too much both in terms of attention and motor control. Shorter sessions and longer intertrial intervals probably would have had a positive effect on this group, facilitating motor performance and avoiding lapses in attention and motivation. Appropriate controls for these factors were used in the current investigation.

Repetition priming studies similar to those designed to examine the memory performance of amnesics have not yet been conducted with Down syndrome subjects. However, considering evidence of skill-learning in individuals with Down syndrome (Kerr & Blais, 1985), as well as the demonstration of implicit memory in other memory-disordered populations including those with hippocampal damage (e.g., see Corkin, 1965, below), subjects with DS were predicted to exhibit motor skill-learning and repetition priming. Because of known motor dysfunction associated with DS, skill-learning of these subjects was expected to be inferior to that of controls.

Purpose of the Present Study

Prior research has focused primarily on tasks that illuminate the cognitive limitations of individuals with Down syndrome. The primary emphasis of the present study was the identification of cognitive strengths while controlling for deficits in attention, auditory and linguistic processing and integration of complex visual stimuli. The specific purposes of the study were 1) to reexamine free recall and recognition (explicit memory) skills of DS and NDS groups while controlling for confounding variables; 2) to compare the implicit memory abilities of DS, NDS, and NH mental age-matched subjects 3) to compare the implicit versus explicit memory performance of these groups to that of other memory-impaired populations (e.g., amnesia patients); 4) to examine acquisition of a motor skill by subjects with DS while attempting to minimize motor and attentional limitations; 5) and to study the relative attentional skills and 6) verbal fluency of these three groups.

The following predictions were made: 1) that recognition memory would be superior to recall in all groups; 2) that by providing more optimal learning conditions for the DS group than were available in previous studies by controlling for visual complexity and attention factors, explicit memory would be enhanced, making visual memory performance equivalent or superior to that of the NDS group; 3) that all groups would exhibit equivalent priming effects whereas attempts to recognize or recall such information explicitly would be impaired in both MH groups; 4) that all groups would demonstrate motor skill-learning but that the learning curve of the DS group would be flatter than that of the other two groups due to known motor deficits; 5) that attentional deficits would be observed in subjects with Down syndrome; and 6) that fluency would be depressed in the experimental group.

Statement of the Problem

Problem I: Recognition Memory. Participants were tested for recognition memory using the Snodgrass, Smith, Feenan, & Corwin (1987) stimuli. (Items for the Recall and Priming tasks were also chosen from this set of simple line drawings.) At the beginning of the session, fifteen line drawings were presented for identification as a Pretest to ensure that subjects' vocabularies were developed enough to permit participation. Subjects were not informed that they would be tested for recognition of these drawings later in the session.

At the end of the same session, these fifteen stimuli (targets) plus fifteen unfamiliar stimuli (distractors) were presented in random order and subjects were asked whether or not each drawing had been presented earlier. It was predicted that recognition scores would exceed recall scores in all groups, and that the recognition skills of NH subjects would be superior to both MH groups. Because visual complexity of the stimuli and attentional demands of the tasks were controlled as carefully as possible, recognition skills of the DS and NDS groups were expected to be similar. Both Target scores (number of targets correctly identified as having been seen previously, a 'yes' response) and Distractor scores (number of distractors correctly identified as unfamiliar, a 'no' response) were compared.

Problem II: Free Recall. Fifteen additional line drawings served as the targets in a free recall task. Subjects viewed the drawings after receiving explicit instructions to remember them. Following intervening tasks, the children were asked to recall as many of the pictures as possible. It was expected that recall scores of all groups would be lower than recognition, and that the NH group would produce more of the stimuli than either of the MH groups. Considering the simplicity of these stimuli and the absence of color, the DS group was not expected to be at a disadvantage on this visual memory task, and it was predicted that these subjects would demonstrate recall skills equivalent to the NDS group.

Problem III: Priming. Fifteen fragmented pictures served as the targets in a Priming (implicit learning) task. Eight versions of each picture were arranged in order from most incomplete to complete and were presented during the Training phase. Subjects viewed the most incomplete version first. If the stimulus was not correctly identified, increasingly complete stages were presented until the drawing was identified or the complete picture was revealed. Scores obtained from this phase of the task will be referred to as 'Train' scores. Following an intervening task, the fifteen training targets (now identified as 'Old') and fifteen unfamiliar ('New') fragmented pictures were presented in random sequence following the same procedure as above. Priming was measured by comparing Train, Old and New scores. Significant differences between Old and New scores was accepted as evidence of priming. Differences between Train and New scores would have provided evidence of skill-learning. Based on the successful priming of young children (Greenbaum & Graf, 1988) and of memory-impaired populations, it was predicted that priming would be equivalent across groups.

Problem IV: Motor Skill-Learning. Subjects were tested across sessions on a pursuit rotor tracking (PR) task presented on a Macintosh SE microcomputer. Contact time (measured in seconds) between a figure of a mouse and a disk revolving around a circular 'track' was recorded. Motor skill acquisition was measured by comparing mean scores across sessions. All groups were predicted to improve across trials, but in view of the motor deficits associated with Down syndrome, this group was expected to be more impaired than the NDS group which was expected to be inferior to the NH group. In addition, it was expected that motor deficits in subjects with Down syndrome would result in more of the subjects in the experimental group operating at 7 rather than 14 RPMs than subjects in the control groups.

Problem V: Attention. A standard digit cancellation test was administered as a distractor task in Experiments 1 and 2. It was used as a measure of attention (both vigilance and attention to all parts of a visual stimulus) in Experiment 3. Children were instructed to draw a circle around every '6' on the page. Based on previous research indicating attention deficits, both in vigilance and in selective attention, it was predicted that the DS children would abandon the task before completion thereby detecting fewer targets than controls, and that they might 'neglect' some portions of the page, concentrating their efforts on other areas.

Problem VI: Word Fluency. A word fluency task was included in Experiment 3 both as a distractor and to determine whether deficits on other tasks might be due to impairments in word production. Both semantic (animals) and phonemic (c, f, l, h) fluency were examined.

Experiment 1: Preschool Pilot Study

Method

Subjects. Ten nonhandicapped (NH) children four to five years of age were included in the pilot study. This preliminary research was conducted to ensure that the tasks were manageable and directions were clear for children with a mental age of four or five years. Subjects were contacted through and tested at the Davis-Monthan Child Development Center, Davis-Monthan Air Force Base, Tucson, Arizona, serving a primarily military population.

Materials. The Pursuit Rotor Tracking task developed in the Psychology Department of Drexel University was presented on a Macintosh SE microcomputer. Stimuli for the Pretest, Recognition, Priming and Recall tasks were mounted on 3x5-inch index cards stored on a Rolodex-File Jr. and were presented manually by the investigator. Line drawings of seventy-five common objects and animals were chosen from the Snodgrass and Vanderwart (1987) pictures in the Recognition, Recall and Priming tasks. These particular items were selected because of their frequent occurrence in literature appropriate for children of preschool age (Carroll, Davies, & Richman, 1971). It was expected that these items would be familiar to the subject populations of all three experiments. Stimuli for the Pretest, Recognition and Recall tasks were complete line drawings. Stimuli for the Priming task consisted of thirty sets of fragmented line drawings ('fragpix' [Snodgrass et al, 1987]) degraded into eight stages of completion. Fifteen sets were primed and fifteen sets served as distractors. Five different forms of each of the visual tasks were developed using a Latin Square and five sets of fifteen pictures each. Sets were similar in complexity, and each set occurred equally often across subjects and conditions (Pretest/Recognition Target, Recognition Distractor, Priming Target, Priming Distractor, and Recall Target). The digit cancellation test consisted of six rows of fifty-two digits each (0-9), including forty-nine 6's, presented on a 4x11 sheet of paper.

Procedure. Testing was originally projected to take two sessions per subject. Due to fatigue and diminished attention in preliminary trials, testing was divided into three sessions of approximately thirty to forty-five minutes in duration conducted either on separate days, or in some cases during one session in the morning and one in the afternoon. Under the latter circumstances, the recall test was never given on the same day as the Priming and Recognition tests to avoid interference. Tasks were alternated to maintain the attention and cooperation of participants, to avoid fatigue on the motor task, and to provide a delay between phases of the Priming, Recognition and Recall tasks. Subjects were greeted in their classroom before each session, invited individually to play games with the investigator, and were accompanied to an area of the daycare center as free from distractions as possible. They were promised stickers and a certificate for participating. When a child lost interest, he or she was encouraged to finish the task to get a sticker. If necessary, a sticker was given immediately as an incentive to continue and another was given at the end of testing. It was not necessary to suspend testing or exclude any subject in this experiment due to lack of cooperation. Each child received several stickers during each session and a certificate upon completion of testing. Instructions for all tasks were read from the data sheets to ensure uniformity.

<u>Session I</u>. The first session consisted of six blocks of five Pursuit Rotor Tracking (PR) trials separated by distractor tasks. The session began with an introduction to the computer, monitor and computer mouse. The subject sat before the computer monitor, the center of which was approximately at eye level. A grey circular track appeared on the screen before each trial began along with an arrow which was controlled by the mouse. Once the game was activated, a white disk ('ball') appeared. After a delay of five seconds, the ball began traveling around the track in a counterclockwise direction at a speed of seven revolutions per minute. At the same time, the arrow controlled by the computer mouse became an image of a mouse. Subjects received the following instructions:

> Now we are going to play a game on the computer. This (show mouse) is a computer mouse. When you move the mouse up, this arrow (show arrow on monitor) moves up. When you move the mouse down, the arrow moves down. When you move the mouse to the side, the arrow moves to the side. Now you try it. (Allow child to hold mouse while you guide his/her hand.) (When child has learned to move the arrow) That's it! Good job. When the game begins, you will see a small white ball going around this circle (demonstrate with your finger) like this. And the arrow will turn into a picture of a mouse! Your job is to keep the little mouse on top of the ball by moving the computer mouse. Let's try it. (When ready signal appears) The game is about to begin! (Signal child throughout testing.)

Performance was measured by the amount of contact time (in seconds) between the image of the mouse and the revolving ball. Training consisted of three twenty-second testing periods with ten-second intertrial intervals. More training trials were given in a few cases to increase contact time to at least one second ensuring that subjects understood the task and were able to control the computer mouse before testing began. No subject had to be eliminated because of inability to maintain one second of contact time. For subjects who maintained more than three seconds of contact time on the initial trial, target speed was increased to fourteen revolutions per minute to permit demonstration of a learning curve while avoiding a ceiling effect. These subjects were given additional practice time to adapt to the increased speed. Following practice trials, the first block of PR test trials was run. Contact time was automatically recorded by the computer. PR blocks were alternated with non-motor tasks to allow subjects to rest. Testing blocks consisted of five twenty-second testing periods with ten-second intertrial intervals.

Session II. The Pretest, Recognition and Priming tasks were administered during this session beginning with the Pretest which consisted simply of the identification of fifteen Snodgrass et al. (1987) line drawings. Requiring the child to correctly identify the items controlled for vocabulary and linguistic skills, provided an opportunity for encoding while controlling for attention, and ensured that the stimuli were not too complex for the DS subjects (Stratford & Metcalfe, 1982). It was determined in advance that any student who failed to identify at least twelve of the fifteen Pretest stimuli would be eliminated from the study. Exclusion of subjects on these grounds was not necessary. Pretest pictures also served as targets for the Recognition memory test later in the session, but subjects were not given instructions to remember them.

Presentation of the fifteen novel sets of Priming fragpix (Train) began with the most incomplete stage of each picture. If the first version was not correctly identified, increasingly complete versions followed until the picture was identified or the complete picture was shown. Subjects received the following instructions:

> We are going to play a picture puzzle game! I will show you part of the puzzle and you tell me what it is. If you don't know, I will show you more and more of the puzzle until you know what it is, okay? Let's play! (Show COMPLETE stimulus after correct response. Be sure child sees stimulus.)

The first three fragmented pictures were used to introduce subjects to the task; these scores were not included in the analysis. The investigator identified for the child those few stimuli which were not recognized even in the complete stage. (This occurred very rarely during the study.) After a distractor task, the second half of the Priming test was administered. The target (Train) fragpix (now identified as Old) were presented with fifteen unfamiliar (New) fragpix sets presented in random order. Again the experimenter began with the most incomplete version, revealing increasingly complete stages until the stimulus was identified after which the complete picture was exposed.

The Recognition task was composed of the fifteen complete pictures identified in the Pretest (targets) presented in random order along with fifteen unfamiliar pictures (distractors). The investigator asked:

> Remember I showed you some pictures before and you told me what they were? (Investigator points to the now-covered pictures at the front of the Rolodex.) I am going to show you some pictures now. You tell me if you saw them before, okay? (Present first stimulus) Did you see this picture before? (Record all responses, even those which are incorrect. DO NOT provide child with feedback).

<u>Session III</u>. Subjects began this session by viewing the fifteen Recall stimuli. The children were given the following instructions:

> I am going to show you some pictures and you tell me what they are. Remember all of the pictures because I am going to ask you what they were later on, okay? (Present first stimulus) What is this? (Following correct response) Very good! (Proceed to next stimulus.)

Subjects were reminded during and following the task to remember the pictures. After an interval of approximately twenty minutes, subjects were asked:

> Remember I showed you some pictures before? Tell me what they were. (Write down ALL responses, even those which are incorrect. If child fails to generate items or generates only a few, encourage him/her to remember more pictures and tell you what they were.)

Instructions for the Digit Cancellation Task were as follows:

> Show me a '6'. (After correct response) Good! Now I want you to draw a circle around every '6' on the page. Then tell me when you are finished. (NO COACHING or asking 'Are you finished?'.)

Certificates were given to the children following testing, and subjects and their parents/guardians were thanked for their participation.

Results

Recognition Memory. The mean Target score (out of 15 possible targets) was 12.600 (s.d. = 4.006); the mean Distractor score (15 possible) was 14.800 (s.d. = 0.422). No significant difference was found between these means using a t-test, $p < .1243$. One subject responded 'no' to all but 2 stimuli earning a score of 15/15 distractors correctly identified, but only 2/15 targets correctly identified. When the data for this subject were excluded, the mean Target score was 13.778 (s.d. = 1.563); the mean Distractor score was 14.778 (s.d. = 0.441). A t-test still failed to reveal a significant difference,

$p < .1080$.

Free Recall. Mean recall scores were calculated for targets (15 possible) correctly recalled (mean = 3.4), for incorrect answers (mean = 0.3), and for intrusions of stimuli from other tasks (mean = 0.9).

Priming. Priming was measured by the difference between Old and New mean identification thresholds. Skill-learning was measured by the difference between mean scores for the Train and New phases. The mean identification scores were as follows: Train: 6.334 (s.d. = 0.403); Old score: 4.739 (s.d. = 0.800); New: 6.187 (s.d. = 0.574). A single factor repeated measures analysis of variance (ANOVA) indicated a main effect for phase, $F(2,18) = 81.724$, $p < .00001$. A Tukey HSD test revealed significant differences ($p < .01$) between Old vs New, and Old vs Train. There was no difference between Train and New.

Motor Skill-Learning. A t-test was used to compare the mean score for the first three Pursuit Rotor blocks of trials to the second three blocks. (One block = five 20-second trials) A significant difference between the two was accepted as an indication that learning had occurred. The mean contact time for Blocks I-III was 2.999 (s.d. = 1.216); mean contact time for Blocks IV-VI was 4.544 (s.d. = 1.001). The difference between the two was significant: $t(9) = 5.639$, $p < .0003$.

Attention. The digit cancellation task was used only as a distractor in this experiment because some of these young subjects were not familiar with numbers.

Discussion

Contact time scores on the motor skill-learning task were low, but significant differences across blocks indicated that learning had occurred. Similar to the results in Greenbaum and Graf (1988), recognition memory in these subjects was near ceiling, but given the verbal difficulties experienced by children with Down syndrome, difficulty level was not increased. As expected for subjects of this age, recall scores were low but there were few incorrect answers or intrusions. Consistent with other implicit memory research, these preschoolers demonstrated priming.

It was concluded that the tasks and instructions were manageable for four- and five-year-old children, and would therefore be suitable for the developmentally disabled populations for which they were designed.

Experiment 2: DS and NDS Pilot Study

Method

Subjects. Subjects for this pilot study were contacted through the Pilot Parent Program in Cochise County, Arizona. Six children with Down syndrome and four with other developmental disabilities (two unknown etiology, one William's syndrome, one head injury) participated. Subjects ranged in age from four to twenty years of age and were not matched for any characteristic for the pilot study. Some subjects did not complete all tasks.

Materials. Same as Experiment 1.

Procedure. Same as Experiment 1 except that subjects were accompanied by parents/guardians to the reference room of the Sierra Vista Public Library where investigators brought them individually to private testing rooms.

Results

Recognition Memory. DS: $n = 4$; NDS: $n = 2$) The mean Target score for the DS group was 12.500 (s.d. = 1.732); for the NDS group it was 14.500 (s.d. = 0.707). No significant difference was found using a single factor (groups) randomized design ANOVA, $F = 2.246$, $p < .2084$. The mean Distractor score for the DS group was 12.250 (s.d. = 4.193); for the NDS group the mean was 10.000 (s.d. = 5.657). There was no difference in performance, $F = 0.319$.

Free Recall. Mean recall score for the DS subjects ($n = 2$) was 4.5 (s.d. = 0.707); for the NDS subjects ($n = 2$) it was 5.00 (s.d. = 5.657). Results of a single factor (groups) randomized design ANOVA indicated that groups did not differ, $F(1,2) = 0.015$.

Priming. (DS: $n = 5$; NDS: $n = 2$). No significant difference was observed between groups using a 3 (phase) x 3 (groups) mixed design ANOVA, $F = 0.219$, and there was no interaction, $F = 0.477$. But differences between phases approached significance: $F(2,10) = 3.384$, $p < .0754$. Scores were collapsed across groups. The mean Train score = 5.790 (s.d. = 0.642); Old = 4.726 (s.d. = 1.332); New = 5.447 (s.d. = 0.836). A single factor repeated measures ANOVA indicated a difference between phases. A Tukey HSD test revealed only a significant difference between Train and Old scores, $F(2,12) = 6.094$, $p < .0149$.

It was noted that one child in the NDS group had difficulty identifying some stimuli even at the complete stage, leaving only one other NDS subject who completed the priming task. When the former subject was eliminated from the analysis (n = 6), the mean Train score = 5.800 (s.d. = 0.713); Old = 4.450 (s.d. = 1.196; New = 5.350 (s.d. = 0.871). A single factor (phase) repeated measures ANOVA resulted in a difference between phases. A Tukey HSD test identified differences only between Train and Old scores, $F(2,10) = 12.751$, $p < .01$, and Old and New scores, $p < .05$.

Motor Skill-Learning. (DS: n = 4; NDS: n = 3). (One block = five 20-second trials) A 6 (blocks) x 2 (groups) mixed ANOVA failed to reveal any significant within- (F = 0.605) or between-group (F = 2.698, $p < .1614$) differences, although mean contact time was slightly higher in the DS group: 4.632 (s.d. = 0.620) vs 2.212 (s.d.= 0.143). Subjects in the DS group appeared to improve and then tire or lose attention. It was decided to measure improvement across three sessions in the next experiment rather than doing all PR testing in one session. This modification was made in order to avoid confounds due to attention and motor deficits.

Attention. The digit cancellation task was used only as a distractor task in this experiment.

Discussion

It appeared that both developmentally disabled groups had statistically equivalent cognitive skills, but the subjects in the DS group tended to have slightly lower scores on the two explicit memory tasks (recognition and recall). Both groups exhibited priming. And despite motor impairments, subjects in the DS group were able to manage the pursuit rotor task, performing slightly better than those in the NDS group. It should be noted though that subjects in this experiment were not matched, so that conclusions could not be drawn about group comparisons. This experiment was only run to ensure that children with developmental disabilities would be capable of understanding directions and performing on all tasks, and to determine whether or not modifications would be necessary.

Based on these results it was decided to proceed with the next experiment with matched DS, NDS and NH groups.

Experiment 3: DS, NDS and NH Study

Method

Subjects. Three groups of ten subjects each participated in this experiment. Only children with no known visual, auditory, speech or motor deficits which would interfere with performance were included. Subjects for the DS and NDS groups were contacted through the Tucson Unified School District, Tucson, Arizona. In order to examine as closely as possible the effects of Down syndrome versus other developmental disabilities without the effects of profound mental handicap, and to avoid confounding variables such as severely restricted vocabularies or inadequate comprehension of instructions, only students in the educable or trainable range were included.

Children in the NH group were contacted through the Fort Huachuca Latchkey Program, Fort Huachuca, Arizona, a day care program primarily for the military population, and were tested at the latchkey center.

Down Syndrome Group. Chronological ages ranged from twelve to twenty-one (mean = 17.81, s.d. = 2.87); mental ages from 6 to 13 years (mean = 9.015, s.d. = 2.73). Full-scale IQs ranged from 40 to 64 (mean = 48.6, s.d. = 9.09). A single factor (groups) ANOVA resulted in a significant between-group difference for chronological age: there was no difference between the DS and NDS groups, but a Tukey HSD test indicated a difference between these two groups and the NH group. This difference is unavoidable due to mental age matching of subjects in the nonhandicapped group to those in the DS group. There was no difference between groups in mental age, F = 0.008, and no difference between the DS and NDS groups in full scale IQ, F = 0.099.

Data from one subject had to be eliminated from the pursuit rotor tracking (PR) task due to failure to complete the task. Subjects in the control groups matched to this individual were also eliminated from the PR analysis.

Non-Down Syndrome Group. Subjects in the NDS group were matched individually to those in the DS group as closely as possible by chronological age and by verbal and nonverbal/performance scale scores of the Wechsler Adult Intelligence Scale - Revised (1981), the Wechsler Intelligence Scale for Children - Revised (1974), or the

Stanford-Binet intelligence test administered by school district psychologists. Chronological ages ranged from 13 to 21 years (mean = 17.48, s.d. = 2.85); mental ages from 6 to 14 (mean = 8.91, s.d. = 3.02). IQs ranged from 40 to 67 (mean = 49.9, s.d. = 9.41).

Nonhandicapped Group. NH subjects were matched individually to subjects in the DS group by mental age. Mental ages of experimental group members were estimated by converting full-scale IQ scores: IQ multiplied by chronological age in months, the product of which was divided by one hundred. Chronological age of the NH group members ranged from 6 to 13 years (mean = 8.87, s.d. = 2.50).

Materials. Same as Experiment 1.

Procedure. Same as Experiment 1 with the addition of the fluency tasks. Testing was conducted in unoccupied school office space.

Session I. It was explained that the student and investigator would be playing some games together and that stickers and a certificate would be offered as rewards. The order of tasks for this session was: Pretest, PR I, Fragpix I, PR II, Fragpix II, PR III, Recognition, PR IV.

Session II. Order of tasks: Semantic Task, PR I, Phonemic Task (letter 'C'), PR II, Phonemic Task ('F'), PR III, Phonemic Task ('L'), PR IV, Phonemic Task ('H'). The initial phonemic task was preceded by a practice trial using the letter 'S'. Data from that trial were not included in the analysis. Instructions for the semantic test were as follows:

> Now we are going to play a word game. I would like you to name as many animals as you can think of.

Instructions for the phonemic tasks were as follows:

> We are going to play a word game. First I would like you to tell me all the words you can think of which begin with the letter 'S' (give the sound). (If successful:) Very good! Let's play that game again. Tell me all the words you can think of which begin with the letter 'C' (or F, L, or H in successive tasks).

Subjects were given two minutes to generate as many words as possible. They were encouraged to continue naming on both the semantic and the phonemic tasks if they stopped.

<u>Session III</u>. Order of tasks: Free Recall Training, PR I, distractor task, PR II, Digit Cancellation, PR III, Free Recall, PR IV. During Free Recall Training, subjects were instructed once before presentation of stimuli to remember the pictures, twice during presentation, and once after training.

<u>Results</u>

<u>Recognition Memory</u>. Data were analyzed using a single factor (groups) randomized design ANOVA. Target means: DS = 11.90; NDS = 13.90; NH = 12.00. Distractor means: DS = 14.70; NDS = 13.40; NH = 13.50. Groups did not differ significantly on either targets, $F(2,27) = 1.604$, $p < .22$, or distractors, $F(2,27) = 1.553$, $p < .23$. One DS subject answered "no" to every stimulus, both targets and distractors. When the data from this subject and the matched controls were eliminated from the analysis, a single factor ANOVA revealed a

significant between-group difference for targets, $F(2,24) = 3.952$, $p < .05$. A Tukey HSD test indicated that the NDS group recognized significantly more targets (mean = 14.00) than the NH group (mean = 12.00). There was no difference between the DS group (mean = 13.222), and either control group. There were no significant differences between groups regarding distractors with or without the outlier.

Free Recall. Mean free recall Target scores were as follows: DS = 4.100 (s.d. = 1.663); NDS = 4.500 (s.d. = 2.121); NH = 4.600 (s.d. = 1.075). Mean number of Intrusions (stimuli from previous tasks): DS = 2.200 (s.d. = 1.549); NDS = 1.900 (s.d. = 2.183); NH = 0.700 (s.d. = 0.675). Mean number of Incorrect responses: DS = 1.000 (s.d. = 0.943); NDS = 0.200 (s.d. = 0.632); NH = 0.300 (s.d. = 0.949). A single factor ANOVA failed to find a between-group difference for free recall memory on targets, $F(2,27) = 0.249$, incorrect answers, $F(2,27) = 2.604$, or intrusions, $F(2,27) = 2.480$.

Priming. Group means were as follows: DS = 5.151; NDS = 4.853; NH = 4.813. Phase means: Train = 5.551; Old = 3.951; New = 5.315. A 3 (groups) x 3 (phases) mixed ANOVA produced a significant priming effect, $F(2,54) = 22.38$, $p < .00001$, and a groups x phases interaction,

$p < .0135$, but no between-group differences, $p < .2920$. (See Table 1 [Appendix B] & Figure 1 [Appendix C])

Mean Train scores by group: DS = 5.627; NDS = 5.473; NH = 5.554. Mean Old scores: DS = 4.361; NDS = 3.933; NH = 3.560. Mean New

scores: DS = 5.466; NDS = 5.154; NH = 5.326. Planned pairwise comparisons using the Tukey HSD post hoc test revealed significant differences at the .01 alpha level for all groups between Old and New scores, and between Old and Train, but not between Train and New scores, indicating a priming effect with no skill-learning. There were no group effects, $F(2,27) = 1.289$, $p < 0.29$, but analysis resulted in an interaction, $F(4,54) = 3.474$, $p < .01$. Tukey HSD post hoc tests resulted in a significant difference between subjects in the DS and NH groups, $F(2,27) = 4.285$,
$p < .0242$, on Old scores: subjects with Down syndrome required more complete stimuli to identify primed (Old) targets than nonhandicapped subjects (means = 4.361 vs 3.560 respectively). (See Figure 2 [Appendix D]) Mean identification thresholds for NDS subjects fell between the NH and DS groups with no significant differences.

Difference scores were calculated by subtracting the mean Old score from the mean New score for each individual as a measure of the amount of priming demonstrated. These scores were analyzed using a single-factor (Group) ANOVA which yielded a significant main effect, $F(2,27) = 4.151$, $p < .0268$. A Tukey HSD indicated that there was a significant difference between the DS and NH group. Again scores of the NDS group were intermediate to the NH and DS groups, and NDS scores were not significantly different from either of the latter groups' performances.

Motor Skill-Learning. One DS subject refused to complete the task: this subject's data plus the data of her matched NDS and NH subjects were dropped from the analysis. (One block = five 20-second trials; one sessions = 4 blocks) Mean scores by group: DS = 4.521 seconds (s.d. = 1.28); NDS = 4.027 (s.d. = 1.05); NH = 5.375 (s.d. = 1.29). Using a 3 (groups) x 3 (sessions) mixed ANOVA, a main effect for session was observed, $F(2,48) = 49.95$, $p < .00001$, indicating that learning had occurred across sessions. There were no significant differences between groups and no interactions. (See Table 2 [Appendix E] and Figure 3 [Appendix F]) Single factor (sessions) repeated measures ANOVAs were performed for each group independently and a Tukey HSD was used to detect differences between sessions which indicated learning. The DS group demonstrated learning between session 1 vs 2, and 1 vs 3, but no difference between 2 and 3. The NDS group showed improvement between sessions 1 and 3 with no other differences. There were significant differences between all sessions for the NH group. The difference between the number of subjects who performed at 7 versus 14 revolutions per minute approached significance, $F(2.24) = 3.167$, $p. < .06$. More of the NH subjects operated at 14 RPMs than DS subjects.

Word Fluency. Single factor randomized design ANOVAs indicated there were no group differences in fluency for animal names (semantic category) nor for words beginning with the letters 'F' and 'C' (phonemic category). But the analysis and Tukey HSD did indicate differences between the DS (mean = 3.400, s.d. = 2.319) and the NH (mean = 6.900, s.d. = 2.331) groups on the 'L' test, $F(2,27) = 4.406$, $p < .02$. Similar differences were observed between the DS (mean = 3.700, s.d. = 2.452) and the NH (mean = 6.800, s.d. = 2.150) groups on the 'H' test, $F(2,27) = 3.599$, $p < .04$, phonemic tasks. ('L' and 'H' are the more difficult of these four phonemic fluency tasks [Borkowski, Benton, & Spreen, 1967]).

Digit Cancellation. A single factor (groups) ANOVA was used to analyze results of this task. A between-group difference approached significance on the digit cancellation (vigilance) task using either hit or miss scores, $F(2,27) = 3.101$, $p < .06$. The mean Hit scores were: DS = 35.7; NDS = 45.7; NH = 45.8. Subjects in the DS group circled fewer targets than those in the control groups. Given these results, it is predicted that a more demanding test would have produced significant group differences at the .05 alpha level. Data sheets were divided into quadrants and Miss scores were compared for selective attention deficits across groups and quadrants. Using a 3 (groups) x 4 (quadrants) mixed design ANOVA, differences between groups again approached significance, $F(2,27) = 3.013$, $p < .0659$, and a difference based on quadrants was found. A Tukey HSD test indicated a difference between the DS and NDS groups only on the lower right quadrant, $F = 3.836$, $p < .0342$.

Discussion

Several interesting patterns emerged from this study. First, a task which was expected to present one of the greatest challenges to the DS group produced surprising results. Unlike the subjects in both the Frith and Frith (1974) and the Kerr and Blais (1985) studies, these subjects with Down syndrome demonstrated a learning curve on the pursuit rotor task which was equivalent to both the NDS and NH subjects despite known motor deficits associated with DS. However, a between-group difference for task speed (7 vs 14 RPMs) approached significance with a greater number of subjects in the DS group operating at 7 RPMs than in the NH group.

There were differences in the learning curves which deserve further investigation. Members of the nonhandicapped group improved performance from session to session. On the other hand, there was no significant improvement for either of the handicapped groups between Sessions 2 and 3. Perhaps with further training, the groups would have become further dissociated as subjects in the NH group continued to improve at a more rapid pace than those in the DS and NDS groups. In future studies, motivation and attention factors should be examined in conjunction with this task, perhaps offering rewards chosen specifically for the individual for maximum motivation. The fact that the subjects with DS were able to manage this task on a microcomputer and to demonstrate a learning curve is encouraging in terms of the potential use of computers for the education, communication and employment of individuals with Down syndrome.

The recall skills of both handicapped groups were similar to the nonhandicapped group demonstrating visual memory appropriate for mental age on this task, but performance was near floor for all groups. Further investigation is needed in order to adequately compare these populations. In future studies, difficulty levels should be compared by varying the number of target stimuli and length of study periods.

There were differences between the NH and NDS groups in recognition memory when the data for the perseverative DS subject and her controls were eliminated. Interestingly, significant differences were only found for targets, not distractors. In other words, all three groups were able to accurately remember what they had not seen, but the NH group had the greatest difficulty identifying targets which had been presented previously. The Recognition test was given during the same session as the fragmented pictures task. It is possible that members of the NH group, who were significantly younger than those in the other two groups, suffered greater interference when attempting to recognize targets. Again, the handicapped groups performed similarly and above mental age on this task whereas their free recall scores were equivalent to mental age controls. Although differences were observed, recognition scores in all three groups approached ceiling. A test with longer latency and/or an increased number of targets might further differentiate the groups.

The most interesting effect concerns the priming task. Members of the DS group demonstrated preserved recall and recognition (explicit memory) relative to both control groups. But like Alzheimer's disease patients (Bondi & Kaszniak, 1991), they required more information than normal controls to identify primed (Old) fragmented pictures. If diminished priming is exhibited on alternative tasks, this pattern of performance will provide an additional link between Alzheimer's disease and Down syndrome. In that case, perhaps subgroups can be identified by relative success on tasks such as these. Poor performance may serve as a marker for those individuals with Down syndrome who will later become demented and those who will not. In this study, there was no evidence of a correlation between mental age or IQ and the demonstrated amount of priming (measured by subtracting Old from New scores). Only one DS and one NDS subject failed to prime (indicated by at least a 0.415 difference between Old and New scores). However, this was a relatively small experimental group. It may be necessary to study a larger segment of the population in order to identify subgroups.

Diminished priming in the DS group may provide evidence of qualitative differences between these individuals, those with other developmental disabilities and nonhandicapped children. An alternative explanation is that the deficits were an artifact of this particular task, and that several factors contributed to the relatively poor performance of the experimental group. Visual processing and memory for simple, complete figures was relatively intact on the recall and recognition tasks. But subjects with DS in previous studies seemed to have difficulty processing complex visual stimuli. Whereas the complete drawings used in the recall and recognition tasks are simple figures, fragmented stages are more visually demanding, requiring additional analysis and integration of features which may have put the DS group at a disadvantage if there is a syndrome-specific visual processing deficit as hypothesized. At initial presentation (Train & New phases), all three groups in this study required at least the fifth stage of completion (5/8) before being able to identify a stimulus. At this stage, stimuli might have been complete enough so that even with a deficit in visual processing, identification of common objects would be relatively preserved. But when viewing more fragmented stages, individuals with Down syndrome may have been less capable of synthesizing the stimulus fragments into a gestalt image and therefore, showed less improvement than controls on second presentation. This may result from the nature of the computerized fragmentation whereby critical features appear at a particular stage making the object disproportionately easier to identify at that point. Results of this priming task are consistent with impaired visual processing for complex stimuli and with the hypothesized inferotemporal lobe lesions. However, further investigation is certainly required. First, the control groups in this study were mentally handicapped or significantly younger subjects matched for mental age. Comparisons with normal control subjects matched for chronological age is necessary in order to make additional comparisons of implicit memory capabilities of individuals with Down syndrome and other memory-impaired populations. In addition, future investigations should include a variety of implicit memory tasks (e.g., word completion or lexical decision tasks; elaborative vs nonelaborative processing) to determine if there is an impairment in priming per se or if the pattern identified in the current investigation is an artifact of the task.

Subjects in the DS group showed marginal attention deficits, particularly neglecting the lower right quadrant of the digit cancellation stimulus. This may have resulted, for example, from a tendency of subjects to work from left to right, top to bottom, and abandoning the task prematurely. A directed version of this task in which subjects are told where to begin, balancing starting points across quadrants, subjects and groups, or tasks such as line cancellation might be used to address this question. If a selective spatial neglect exists, it would almost certainly have an adverse effect on visual task performance. This could at least partially account for the priming deficit demonstrated by the DS subjects on the fragmented pictures identification task in this study. Although differences between the DS group and control groups did not reach significance on the digit cancellation (vigilance) test, the fragmented pictures task is a more difficult one requiring sustained attention and memory which may have put the DS group at a disadvantage. Controls for attention were possible on the recognition and recall tasks because subjects were required to name the pictures during the encoding phase. This control is not possible on the fragmented pictures task. Without some control for attention, the DS group may have failed to encode the fragmented patterns as rapidly as the other groups. Therefore, impairments in both the processing of complex visual stimuli and in attention may have contributed to between-group differences. Use of alternative priming tasks (e.g., word completion or lexical decision) in which words or letter strings can be presented in the middle of the visual field might eliminate potential problems with neglect. Use of elaborative vs nonelaborative tasks such as the preference rating vs searching for vowels paradigm used by Graf, Mandler, and Haden (1982, see above) would permit control for attention by requiring a response from the subject for each stimulus.

Judging from fluency scores, production of target names on the recall and priming tasks may also have been more difficult for the DS group, and the requirement for a verbal response may have depressed explicit memory scores somewhat. But fluency deficits were minimal, and did not lead to significant group differences on the recall and recognition scores so it is not likely that they produced the curious pattern of results on the priming task. Future exploration of implicit memory abilities associated with Down syndrome should include tasks tapping different modalities and response types (e.g., verbal vs written vs sign language), which may reveal a different pattern of results than that of the fragmented pictures task.

Further examination of visual processing and memory skills should help identify strengths and weaknesses in this modality. In the current investigation, control for visual complexity (except, perhaps, in the fragmented pictures task) and color of stimuli seems to have resulted in better performance in the experimental group than has been observed in previous studies in which the recall and recognition skills of subjects with Down syndrome was often inferior to that of mentally handicapped controls. Between-group comparisons of performance using identical stimuli while manipulating color (e.g., black-and-white vs one color vs multi-colored) will determine the impact of this factor on both normal and mentally handicapped populations. Manipulation of color variables and visual complexity will help address the issue of inferotemporal lobe involvement in individuals with Down syndrome.

This study was designed to eliminate as many confounding variables as possible in order to better evaluate visual memory and motor skill-learning of subjects with DS in comparison to those with other developmental disabilities. Therefore, due to the nature of the tasks and the controls employed, the potential for observing qualitative differences between groups was limited. For instance, all but the fluency tasks included only visual stimuli, and most tasks required verbal responses. The only possible exception concerns differences on the Priming task and this might have been simply a quantitative difference. The results of this study provide a baseline for more careful examination of qualitative differences suggested by Nadel.

Summary

The current investigation was designed to identify strengths and attempt to define weaknesses in the cognitive abilities of individuals with Down syndrome. It was determined that, under carefully controlled conditions (e.g., for attention, stimulus complexity, color), the performance of children with Down syndrome on standard explicit memory tests (free recall and recognition for simple visual stimuli) is equivalent to that of MA-matched NDS and NH children. But further study is required to eliminate floor and ceiling effects, and to examine the impact of varying visual complexity of identical objects (e.g., color vs black-and-white; line drawings of toys vs more realistic representations).

Subjects in all three groups included in this investigation demonstrated priming abilities for fragmented pictures. However, priming in subjects with DS was inferior to that of controls. Future comparisons of DS and NDS groups on this and alternative implicit memory tasks should further define the priming abilities of MH populations.

Participants in the experimental group were as successful as controls in acquiring a motor skill (demonstrated in a pursuit rotor task) despite known motor deficits. Examination of learning over a greater number of trials is required to determine whether or not subjects in the MH groups would continue to improve.

Poor word fluency in subjects with DS may result in depressed scores on tasks requiring verbal responses. Use of alternative response demands in educational programs and in future investigations of cognition in this subject population may improve performance.

Analysis of the digit cancellation scores suggests that attention would be problematic on more difficult tasks demanding vigilance over a more prolonged period of time, and that neglect of portions of a stimulus array may occur. This issue warrants further investigation with tasks varying in demands on selective attention and vigilance.

The results of this study provide a more optimistic outlook for individuals with Down syndrome than was indicated in previous investigations of explicit memory. It seems that visual memory skills can be facilitated by controlling for factors such as attention, stimulus complexity and color. Presentation of learning material in the preferred modality with appropriate controls, improvement of educational materials designed for the needs of these children, testing of subject matter in more than one modality, and varying response requirements when appropriate should lead to enhancement of learning and memory, and more accurate assessment of the abilities of individuals with Down syndrome.

APPENDIX A

Human Subjects Approval

The University of Arizona
Human Subjects Committee
1690 N. Warren (Bldg. 526B)
Tucson, Arizona 85724
(602) 626-6721 or 626-7575

21 December 1988

Mary C. Newman
6026 West Lazy Heart Street
Tucson, Arizona 85713

RE: A88.169 EXAMINATION OF THE MEMORY SKILLS OF CHILDREN WITH MENTAL RETARDATION

Dear Ms. Newman:

We received all of the necessary items concerning your above cited project. The procedures to be followed in this study pose no more than minimal risk to participating subjects. Regulations issued by the U.S. Department of Health and Human Services [45 CFR Part 46.110(b)] authorize approval of this type project through the expedited review procedures, with the condition(s) that subjects' anonymity be maintained. Although full Committee review is not required, a brief summary of the project procedures is submitted to the Committee for their endorsement and/or comment, if any, after administrative approval is granted. This project is approved effective 21 December 1988.

The Human Subjects Committee (Institutional Review Board) of the University of Arizona has a current assurance of compliance, number M-1233, which is on file with the Department of Health and Human Services and covers this activity.

Approval is granted with the understanding that no changes or additions will be made either to the procedures followed or to the consent form(s) used (copies of which we have on file) without the knowledge and approval of the Human Subjects Committee and your College or Departmental Review Committee. Any research related physical or psychological harm to any subject must also be reported to each committee.

A university policy requires that all signed subject consent forms be kept in a permanent file in an area designated for that purpose by the Department Head or comparable authority. This will assure their accessibility in the event that university officials require the information and the principal investigator is unavailable for some reason.

Sincerely yours,

Milan Novak

Milan Novak, M.D., Ph.D.
Chairman
Human Subjects Committee

MN/ms

cc: Departmental/College Review Committee

APPENDIX B

Table 1: Source Table for Priming Task - Experiment 3

Between/Within Design   Data file: fragpix

PRIMING - EXPERIMENT 3

Records read: 30
Missing data: 0
Useable records: 30

Source	SS	df	MS	F	p
Between Groups					
GROUP	2.0465	2	1.0233	1.289	.2920
Error	21.4346	27	0.7939		
Within Groups					
SSN	44.7614	2	22.3807	175.311	.0000
GROUP SSN	1.7738	4	0.4435	3.474	.0135
Error	6.8938	54	0.1277		
Total	76.9109	89			

GROUP SSN	ds TRN	ds OLD	ds NEW	nds TRN	nds OLD	nds NEW	nh TRN
n	10	10	10	10	10	10	10
mean	5.627	4.361	5.466	5.473	3.933	5.154	5.554
s.s.	1.949	2.055	1.445	4.757	4.025	4.124	3.078

GROUP SSN	nh OLD	nh NEW
n	10	10
mean	3.560	5.326
s.s.	4.041	2.852

Effect: GROUP

ds	nds	nh
5.151	4.853	4.813

Effect: SSN

TRN	OLD	NEW
5.551	3.951	5.315

APPENDIX C

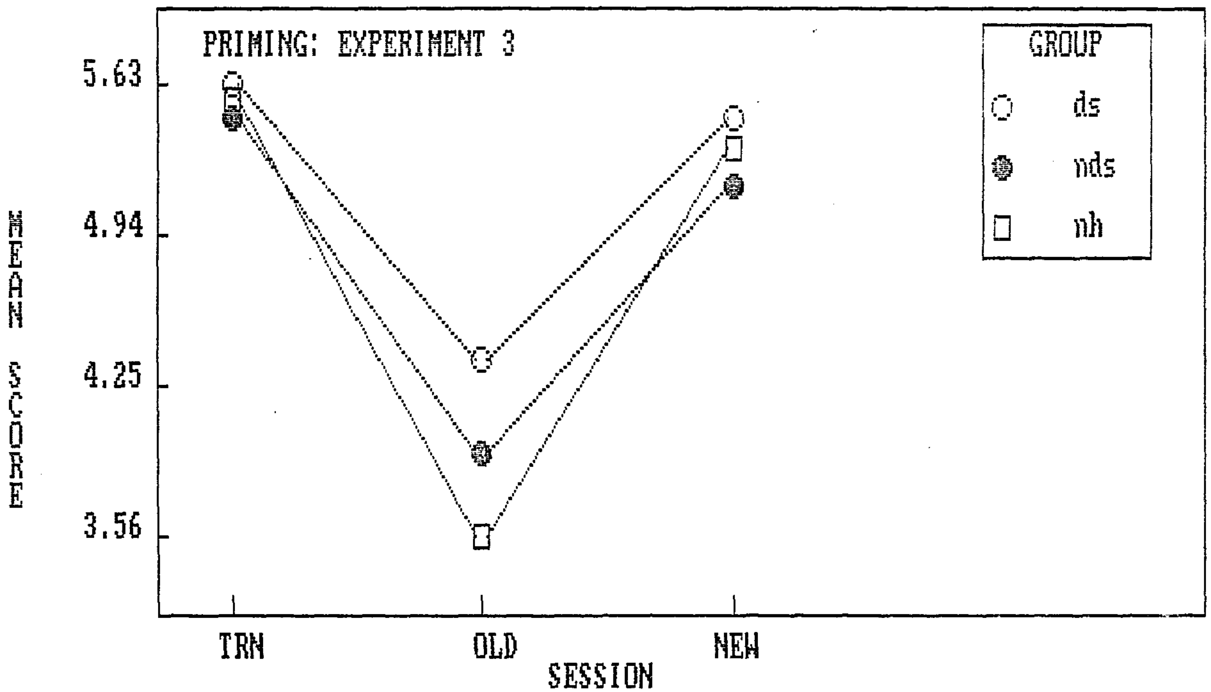


Figure 1: Graphed Results of Priming Task - Experiment 3

APPENDIX D

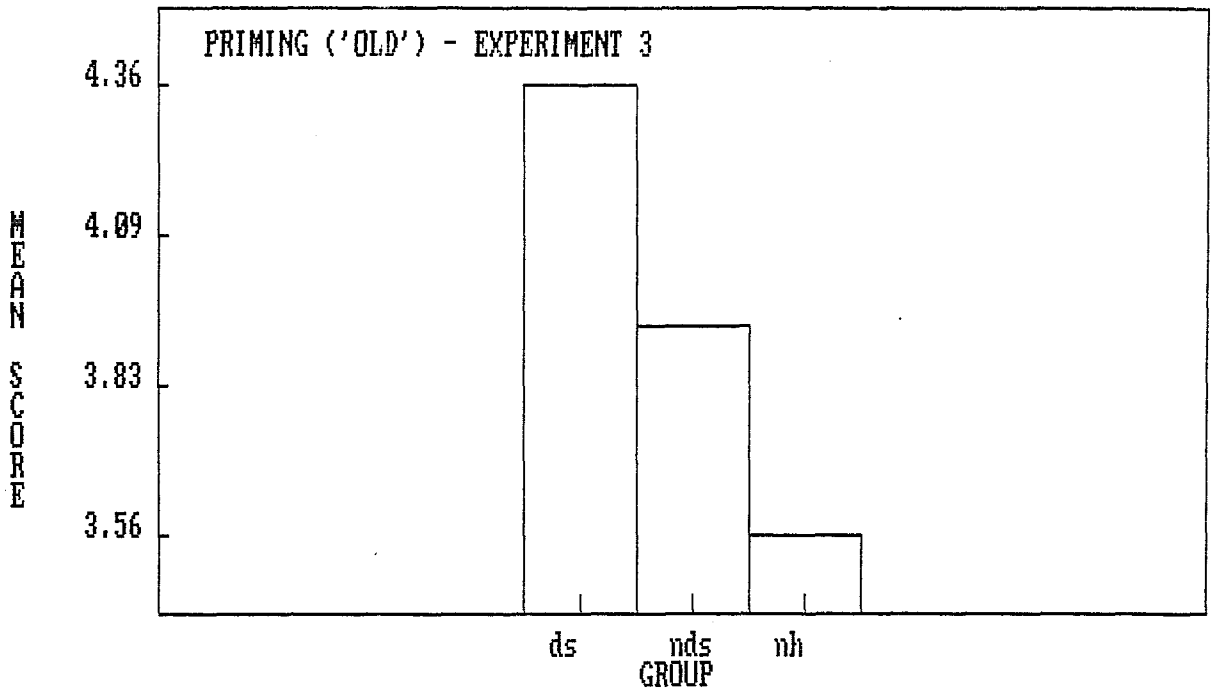


Figure 2: Graphed Results of Priming Task ('Old') - Experiment 3

APPENDIX E

Table 2: Source Table for Pursuit Rotor Task - Experiment 3

Between/Within Design   Data file: prst-rtr

PURSUIT ROTOR TASK - EXPERIMENT 3

Records read: 27
Missing data: 0
Useable records: 27

Source	SS	df	MS	F	p
Between Groups					
GRP	25.0707	2	12.5353	0.878	
Error	342.5950	24	14.2748		
Within Groups					
SSN	77.7092	2	38.8546	50.057	.0000
GRP SSN	1.8114	4	0.4528	0.583	
Error	37.2582	48	0.7762		
Total	484.4445	80			

GRP	ds	ds	ds	nds	nds	nds	nh
SSN	SSN1	SSN2	SSN3	SSN1	SSN2	SSN3	SSN1
n	9	9	9	9	9	9	9
mean	3.120	4.821	5.622	2.953	4.071	5.061	4.149
s.s.	9.030	29.926	43.523	24.013	37.885	56.051	44.439

GRP	nh	nh
SSN	SSN2	SSN3
n	9	9
mean	5.250	6.727
s.s.	55.706	79.278

Effect: GRP

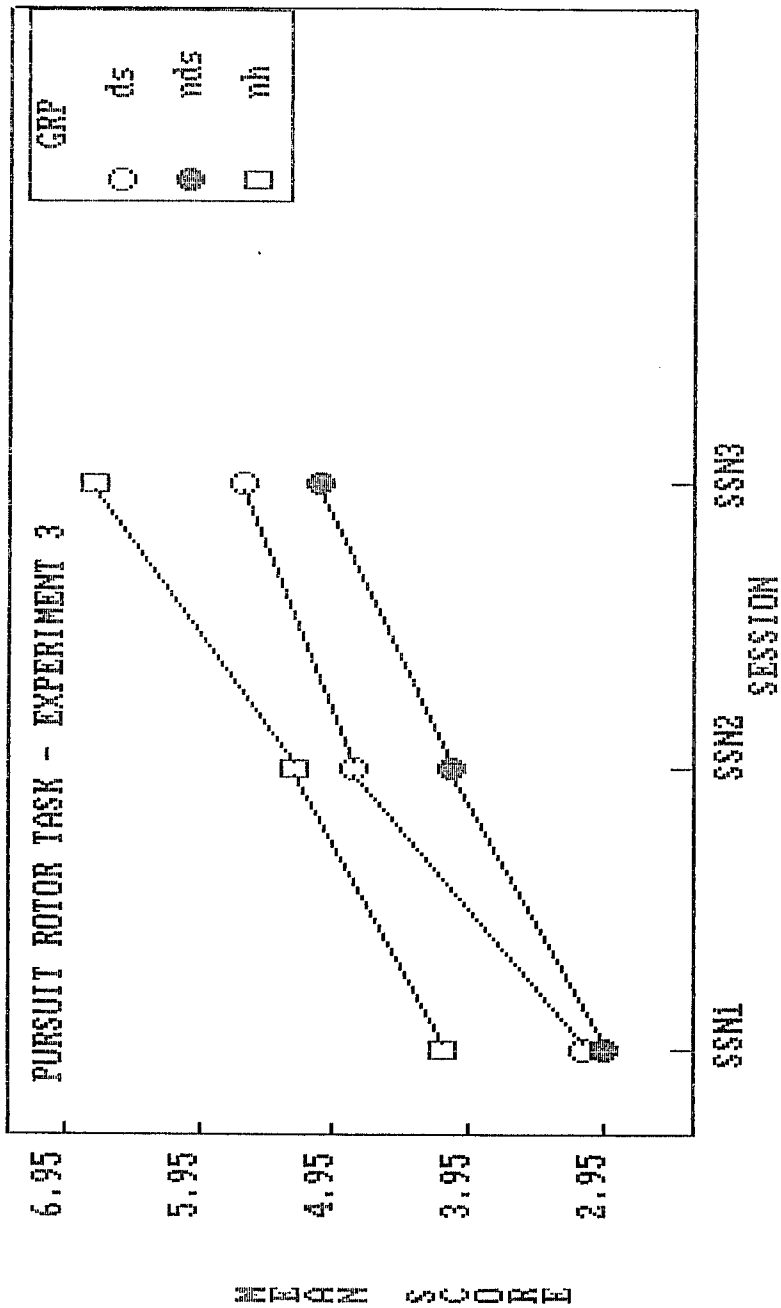
ds	nds	nh
4.521	4.029	5.375

Effect: SSN

SSN1	SSN2	SSN3
3.407	4.714	5.803

APPENDIX F

Figure 3: Graphed Results of Pursuit Rotor Task - Experiment 3



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