Savant Syndrome: processes underlying extraordinary abilities

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Summary

Examples of individuals who demonstrate extraordinary abilities despite low general levels of functioning have been thought by some theorists to pose a dilemma for the construct of general intelligence. Such individuals, often referred to as "savants", are the focus of this thesis. "Savant Syndrome" refers to observable behavioural characteristics rather than to a diagnostic classification and the term therefore incorporates all types of intellectual disability, including autism.

Abilities demonstrated by savants include; musical precocity, arithmetical and calendrical calculations, verbal representations, highly developed sensory discriminations, artistic ability, mechanical dexterity, mathematical skills, and memory for facts. The levels of these abilities demonstrated by savants vary considerably. Those cases who demonstrate levels of ability beyond the accomplishments of most people in the general population are referred to as "prodigious" savants, whereas those whose skill is less highly developed although still beyond the range predicted by a generally low level of intelligence are described as "talented" savants (Treffert, 1989, pxxv).

This thesis has six chapters. The first presents a detailed account of recent research in the field of savant syndrome, discussing existing terminology, incidence levels, types of disabilities associated with the syndrome, the representation of these abilities, the difficulties posed by such individuals for models of general intelligence and the extent to which these abilities reflect intelligent behaviour.

Chapter 2 presents a single-case study of a male autistic-savant with prodigious abilities in music. Specifically assessed was his ability to play two unfamiliar piano pieces after listening to a tape-recording. Other components of his musical ability assessed were pitch recognition, improvisation and ability to provide harmonic accompaniment. His musical precocity was examined in relation to his general level of intellectual functioning as indexed by a battery of standardised tests of intelligence, memory, reading, visual organisation and creativity. His parents and two male siblings also completed tests of intelligence. Results from psychometric testing indicated that this person has diverse and idiosyncratic levels of cognitive functioning, with

difficulties in verbal reasoning but high levels of concentration and memory. His speed of information processing, as indicated by Inspection Time, was better than average. He demonstrated perfect pitch recognition and other family members also demonstrated excellent relative pitch. His ability to recall immediately and perform music unfamiliar to him but structured within both the diatonic and whole-tone systems was exceptional. Analysis of errors suggested that his skill was dependent upon his familiarity with musical structure and was therefore organised and rule-driven. He demonstrated competence in improvisation and composition, by adhering to structural representations of familiar musical rules.

Chapter 3 focuses on calendrical calculation - the capability to state correctly the day of the week upon which any given date fell or will fall. Analyses of the response times to dates presented for nine subjects suggested that they were aware of rules and regularities associated with the calendar, including knowledge of the 14 different calendar templates, one of which describes any calendar year. In each case strategies were rigidly applied and could not be modified easily, even when to do so would have facilitated performance. Although speed of responses provided the primary measure for making inferences about the operations involved in the calculation of dates, number of errors and other behaviours associated with calendar features were also considered, as were reports from savants and care-givers relating to calendar performance. Results suggested that each subject had a long-standing, strong interest in calendars and had devoted considerable time and extensive practice to the study of calendars and dates. It is concluded that these savants were not reliant on mathematical algorithms but instead used knowledge-based strategies. Moreover, results indicated a limited range of dates for which each person could calculate days. Thus, results suggested that a well-developed, associative long-term memory is critical to the development of savant skills associated with calendrical calculations.

Chapter 4 presents cognitive profiles of 51 savants, examining which cognitive structures underlie and sustain their skills and whether there are commonalities between the cognitive strengths of savants with similar and different kinds of skills.

To this end, the possible relevance to the development of savant skills of factors like attention, memory and practice, as well as familial tendencies indicative of predispositions, has been considered. The conclusion proposed is that the existence of savants is consistent with a theory that some skills are based on relatively well-differentiated neurological capacities; but that these skills do not pose a dilemma for the construct of general intelligence as has been proposed by Gardner (1983) or Howe (1989). This is because the skills developed by savants are generally rule-based, rigid and highly structured, lacking critical aspects of creativity and the cognitive flexibility generally considered to reflect intelligence.

Chapter 5 describes results from a questionnaire presented to the care-givers of the subjects involved in the study in Chapter 4. Questions which developed as the result of the author's experience in working with savants have been specifically addressed. Areas of interest were:

i) Early life-histories of savants.

ii) The extent to which savants demonstrate autistic characteristics and other neurological, psychological and behavioural abnormalities.

iii) The incidence of high intelligence and specific abilities among family members.

iv) The extent to which savants demonstrate more than one skill.

Chapter 6 provides an overview and general discussion of the research presented in the first five chapters. It is concluded that, although many savant do demonstrate autistic characteristics, all savants are not autistic. Nevertheless, there may be commonalities between autism as clinically defined and in the development of savant personalities, such as language abnormalities and delay; preoccupation and persistence with area(s) of interest; idiosyncratic, divergent profiles of cognitive abilities but always with well-developed memory, particularly associative memory; and the presence of savant-type skills and higher levels of intelligence among family members, to a higher extent than would be expected from normative data. Although no single factor has been isolated which predicts the development of precocious skill in disabled individuals, it is suggested that a combination of these four common tendencies is necessary for such development to occur. The ability of models of intelligence to accommodate highly developed specific abilities, while allowing for the existence of a discrepancy between these and a general mental capacity is also discussed.

Statement

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University and, to the best of my knowledge and belief, the thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

I consent to the thesis being made available for photocopying and loan if accepted for the award of the degree.

Robyn Young

June 1995

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Chapter 1

Savant syndrome - an introduction and past research.

1.1. Intelligence

A widely debated issue relating to intelligence is whether intelligence is a unified ability reflecting some general mental capacity, additional to but sustaining specific abilities (Spearman, 1927), or whether there is no general controlling factor (Howe, 1989a, 1989b) but, instead, several relatively independent intelligences (Gardner, 1983; Thurstone, 1938). The argument for intelligence as a unitary concept is based on the well-established existence of positive correlations between most cognitive functions (Brody, 1992) - Spearman's "positive manifold". To accommodate more specific abilities, advocates of this approach have developed hierarchical models (Carroll, 1993; Cattell, 1971; Vernon, 1950, 1969). Opponents of this view, however, have emphasised that intelligence is multifaceted and therefore more appropriately represented by a group of abilities, each developing independently and supported by a specialised neural system (Gardner, 1983). Gardner and others who support a multi-faceted approach account for the positive manifold by arguing that it reflects test-taking ability rather than general ability. That is, the relatively consistent performance of individuals on tests of different abilities is held to reflect common attributes or component skills, such as performing well under pressure, but these do not necessarily generalise to other tasks in different settings (Scribner, 1986; Scribner & Beach, 1993). According to Gardner and Howe, examples of individuals who demonstrate extreme variations between abilities present a challenge to a unified view of intelligence. Such individuals, often referred to as "idiot savants", are the focus of this thesis.

This thesis presents a detailed account of recent research in this field. Cognitive profiles of savants presented in the literature, combined with new data, have been evaluated to determine what cognitive structures underlie and sustain their skills and whether there are commonalities between the cognitive strengths of savants with similar and different kinds of skills. To this end, the possible relevance to the development of savant skills of factors like attention, memory and practice, as well as familial tendencies indicative of predispositions, have been considered. The conclusion proposed is that the existence of savants is consistent with a theory that some skills are based on relatively well-differentiated neurological capacities; but that these skills do not pose a dilemma for the construct of general intelligence as has been proposed by Gardner (1983) or Howe (1989b). This is because the skills developed by savants are generally rule-based, rigid and highly structured, lacking critical aspects of creativity and cognitive flexibility - abilities generally considered to reflect intelligence.

1.2. Terminology: Idiot savants, autistic savants, savant syndrome

Although individuals demonstrating exceptional skills despite an overall low level of general functioning have been referred to as "idiot savants", the term "idiot" is misleading because it misrepresents levels of general functioning as indicated by IQ scores most frequently found among savants. Such individuals are rarely of the lowest grade of mental ability implied by the obsolete category "idiot" (i.e., IQ<25). In fact, reports in the literature suggest that a minimum IQ level (possibly IQ greater than 50-60) is necessary for savant skills to develop (Hoffman, 1971).

Savants occur in less than 1% of the intellectually disabled population (Hill, 1977) but their incidence is much higher within the autistic population (approximately 10%; Goodman, 1972; Rimland, 1978a, 1978b) and hence the term "autistic savant" has more recently been preferred by some authors. All savants, however, are not autistic and, in fact, O'Connor and Hermelin (1991b) found savants almost evenly divided between those with a clear diagnosis of autism and those with an intellectual disability to whom this diagnosis did not extend. Therefore the term "savant syndrome" is preferred by the present author (following Treffert, 1989), or simply "savant".

Savant syndrome is an extremely rare condition with males significantly outnumbering females (ratio = 6:1, Hill, 1977). A savant is a person with a disabled level of general functioning who nevertheless displays isolated and exceptional skills. Savant syndrome refers to observable behavioural characteristics rather than to a diagnostic classification and the term therefore incorporates all types of intellectual disability or mental retardation[1] including autism.

Not only do the type and degree of intellectual disability differ among savants but so does the degree of talent and skill. Rarely, individuals develop skills not only remarkable in contrast to their low general level of functioning, but also to levels beyond the accomplishments of most people in the general population. Such cases are referred to as "prodigious" savants (Treffert, 1989, pxxv). For others the skills are beyond the range predicted by a generally low level of intelligence, but are not exceptional in the "prodigious" sense because they might be expected to occur at similar levels among nondisabled persons. These cases are more frequent and are described as "talented" savants (Treffert, 1989, pxxv). However, although this distinction can be a useful one, the two categories are not discrete and there is at present no agreement about what levels exceptional skills must reach before they are regarded as prodigious, or what minimum skill level is required to warrant classification as a talented savant. Moreover, among the autistic population "splinter skills" (i.e., levels of interest and competence appreciably

[1] Mental retardation refers to a "significantly sub-average general level of intellectual functioning existing concurrently with deficits in adaptive behaviour and manifested during the developmental period" (Grossman, 1977 p11). While this is the terminology accepted by the American Association of Mental Deficiency, the term Intellectually Disabled is preferred by the Australian Psychological Society to describe such individuals. The latter term is therefore used in this thesis to describe individuals who might elsewhere be referred to as mental retarded or developmentally delayed.

above the general level of functioning) are common. Although these skills are often noticed due to poor performance in all other areas of functioning, they are not developed to "talented" levels and would not be considered at all remarkable in nondisabled individuals and therefore individuals with only "splinter skills" are not regarded as savants. Furthermore, because autistic characteristics may appear at any level of intellectual ability, in some cases where, despite being autistic, intellectual disability is minimal, the splinter skills demonstrated can be consistent with the overall level of functioning.

It is therefore important to be aware of the degree of variation in cognitive performance found among savants, not only between different kinds of skills but also within a particular area of ability. Rimland and Fein (1988) rejected 30 cases brought to them as possibly representing examples of savant syndrome because the levels of ability did not warrant "savant status" (p478). However, these authors did not adequately explain how they made these determinations. Although quantification of savant skills would enable more reliable classification of savants, measures to quantify these skills do not yet exist (Fein & Obler, 1988). Therefore, while the terms "prodigious savant" and "talented savant" provide a useful distinction, it is likely that a prodigious savant represents an extreme instance within a continuum of skills rather than a discrete category.

Regardless of whether a savant is considered to be prodigious or talented, there is also confusion about whether these abilities reflect "skill" or "talent". The former is usually taken to involve learning and practise while the latter is considered to reflect inherent capability. Although an inherent predisposition may be involved in the development of savant abilities since, even with practice, savants ordinarily do not develop skills outside their area(s) of interest and specific areas of abilities (Jensen, 1990), savant abilities are fostered with practice (Treffert, 1989), making the term "skill" more appropriate. Therefore, the term "skill" is hereafter adopted within this thesis to refer specifically to performance in a particular area of ability. Consistent with Treffert's interpretation, the term "talent" will be reserved in this thesis to indicate a specific level of performance in a particular area (i.e., above the level of "splinter skills" but not "prodigious").

1.3. Savant syndrome, autism and IQ.

1.3.1. Autism and Exceptional Ability

Autistic individuals account for only a small percentage of the disabled population, but more savants have autism than any other form of intellectual disability (Rimland & Fein, 1988). This suggests that there are characteristics common to both exceptional ability and autism (O'Connor & Hermelin, 1988).

Parents of gifted children have sometimes voiced concerns relating to autistic characteristics in their young child and Rimland (1978b) claims that savant syndrome and giftedness can be indistinguishable at a young age. It has been suggested that some well-known exceptional individuals have displayed autistic tendencies such as social withdrawal and indifference as well as an obsessive pre-occupation with their area of expertise (e.g., Bobby Fisher, suggested by Rimland, 1978a; Albert Einstein, suggested by Howe 1989a). In Kanner's (1943) initial description of 11 children with autism, three showed good musical ability, while two demonstrated a skill for numbers. Among his subjects Kanner (1943) also noted passion for maps, exceptional memory for names and calendar dates and exceptional reading ability. If a link exists between autism, savant syndrome and giftedness, it may provide important information relating to the cognitive structures necessary for these skills to develop.

Although many savants do not fit the diagnostic criteria for autism, all savants demonstrate at least one of the characteristics critical for a diagnosis of autism; namely a near-obsessive preoccupation with an area(s) of interest (O'Connor & Hermelin, 1991b). This preoccupation may provide a necessary but not sufficient condition for the development of savant syndrome (Hill, 1975; Hoffman, 1971; Rimland, 1978b) and this matter will be investigated in this thesis.

1.3.2 Autism and IQ

An interesting feature of autism is that many autistic individuals demonstrate marked discrepancies across specific levels of intellectual abilities (McDonald, Mundy, Kasari & Sigman, 1989), with the majority demonstrating better performances on tasks involving perceptual-motor organisation or rote memory skills, compared with verbal ability (Lincoln, Courchesne, Kilman, Elmasian & Allen, 1988). Furthermore, some areas of cognitive functioning remain largely unimpaired (Freeman, Ritvo, Yokota, Childs & Pollard, 1988).

The task of determining an overall level of functioning for an autistic individual from standardised tests is difficult; and perhaps inappropriate because of discrepancies commonly found between subtests within a test like the Wechsler Scales (often four or more standard deviations; Rutter, 1966a), as well as instability between concurrent IQ levels obtained using different tests. For example, Hermelin and O'Connor (1990b) reported one savant who had an IQ of 70 on the Columbia Mental Maturity Scale yet 128 on Raven's Progressive Matrices. Such reports force one to question the validity of standardised tests of intelligence to derive a global score of intelligence in such cases, because this is assumed to reflect unity of function for the individual.

1.4. Types of Ability, Early Interest and Recent Research

The skills demonstrated by savants are remarkable, not only because they occur within a generally dull individual but also because, despite the vast array of skills available to humans, those skills developed to savant levels among the disabled population are limited to a discrete range of abilities; musical precocity, arithmetical and calendrical calculations, verbal representations, highly developed sensory discriminations, artistic ability, mechanical dexterity, mathematical skills, and memory for facts. The development of these skills, although certainly more pronounced among those persons recognised as savants, is also noticeably the areas within which splinter skills develop in the autistic population. When recruiting subjects for the research described in this thesis, the present author therefore encountered many false positives - that is, despite claims that the individual was a savant, the skills when assessed were not sufficiently developed to meet criteria defining "prodigious" or "talented" categories. For some individuals, the skills were not especially well-developed. In other cases, individuals demonstrated well-developed skills but, this was consistent with their overall level of functioning because, although they were autistic, their degree of intellectual disability as indicated by IQ was minimal. Notwithstanding, the skills evident in these individuals were the same types of skills usually associated with savant syndrome. Apparent ESP was also reported as a skill among a couple of the subjects, consistent with reports in the savant literature (eg Rimland, 1978b; Treffert, 1989) but, because support for this assertion has generally been found to lack substance and most such accounts can be plausibly explained by other means (McMullen, 1991), this matter was not investigated further here.

Interest in savant syndrome is recorded in the literature as early as 1751 when a German magazine article reported on a farmhand with exceptional memory (Foerstl, 1989). Many reports on savants have been largely anecdotal, containing many inconsistencies about the level of ability, age at which the skill became apparent, formal instruction, amount of practice, medical history and intellectual ability (e.g., Anastasi & Levee, 1960; Duckett, 1976; Hill, 1975; LaFontaine, 1964, 1974; Monty, 1981; O'Connell, 1974; Scheerer, Rothman & Goldstein, 1945; Southall, 1979, 1983; Viscott, 1970; Zsako & Urban, 1938). Recent research in the 1980s and 90s has been more scientific and systematic, involving formal assessment of the cognitive processes underlying savants' abilities, skill levels and general levels of functioning (e.g., Hermelin & O'Connor, 1986a, 1990a; O'Connor & Hermelin, 1984, 1987a, 1987b, 1989, 1990, 1991a, 1991b; Miller, 1989; Treffert, 1988, 1989).

Review articles and books have begun to emerge, providing an overview of the skills involved, together with possible explanations for their development in terms of a wide variety of contributing factors - for example, eidetic imagery, inherited abilities, hemispheric localisation, compensation for sensory deprivation or social isolation, reinforcement, pre-occupation and practice. A number of studies have attempted to evaluate the implications that the nature of savant skills hold for an understanding of brain functioning in general and more specifically intelligence (e.g., Goldsmith & Feldman, 1988; Hermelin & O'Connor, 1983; O'Connor, 1978,1987a, 1987b, 1989; O'Connor & Hermelin, 1991a; Rimland & Hill, 1984; Rimland & Fein, 1988; Treffert, 1988, 1989). Howe (1989a) cites the existence of savants to support his view that intellectual abilities are essentially multi-faceted and that the concept of a unitary intelligence does not provide a valid scientific explanation for individual performances. O'Connor and Hermelin (1988, 1991a; O'Connor, 1987a, 1987b), however, accept the notion of a general ability but suggest that savant abilities are supported by cognitive functions that are independent of general intelligence, even though general intelligence may determine the manner in which the skills develop. They conclude that such skills represent the modular nature of some cognitive functions, despite the importance of general intelligence to other cognitive processes supporting thinking and imagination. For example, O'Connor and Hermelin (1990) have concluded that copying and reproduction tasks which underpin graphic art skills by savants are dependent on cognitive or perceptual factors other than intelligence. Similarly, Hagen (1985) suggested that there was only a minimal relationship between some aspects of drawing ability and childhood cognitive development, even among the nondisabled population. Other investigations of savants have also concluded that some cognitive processes involved in savant skills are independent of general intelligence. These skills include; linguistic talent (O'Connor & Hermelin, 1991a); artistic quality (Hermelin & O'Connor, 1990a); calendrical calculation (Hermelin & O'Connor, 1986a); and specific mathematical abilities (Furneaux & Rees, 1978).

Many studies have attempted to provide an explanation as to how and why these skills develop (Kehrer, 1992; Goldsmith & Feldman, 1988; White, 1988) and why they do not develop in all intellectually disabled individuals. Kehrer (1992) has offered a neurological explanation , in terms of an abnormal ability to perceive and store information, together with a behaviourist one - the focussed reinforcement by others of the emerging skill under circumstances where the individual shows inadequacies in other abilities. However, as yet there has been no consistent physiological evidence to support either of these hypotheses.

The obsessional involvement typically demonstrated by savants toward their area of expertise has sometimes been perceived as detrimental to an individual's overall development because it is held to interfere with social and academic development (Tsatsumi, 1969). According to this theory, the prognosis for savants' general development and adaptive functioning is poor unless the obsessional behaviours are prevented. Some evidence is counter to this view. For example, Miller and Monroe (1990) have discussed the extent of maladjustment among their savant sample (16 intellectually disabled individuals with musical skills) and, despite showing more eccentricities, these persons appeared to engage in no more maladaptive or obsessively compulsive behaviour than other intellectually disabled persons.

While the studies listed above have involved the study of savant syndrome in general, others have focussed on the development and manifestation of specific skills. These different areas of ability are addressed in the sections which follow.

1.4.1. Music

Musical precocity is one of the most frequently exhibited skills among savants, with Rimland and Hill (1984) reporting its occurrence in 53 % of their sample of "autistic-type" individuals with savant skills (N=119). Recent formal documentation of the abilities of musical savants indicates that these abilities are comparable to those shown by normally skilled, intelligent musicians (e.g., Miller, 1987a; Sloboda, Hermelin & O'Connor, 1985), reflecting acquired cognitive structures for encoding conventional musical systems, rather than some specialised, domain-specific mechanism capable of literal sensory encoding and reproduction. However, the quality of savant musical performance may be mechanical and rigid, lacking feeling and expression (Charness, Clifton & MacDonald, 1988; Judd, 1988; Miller, 1987a; Sloboda et al., 1985).

As yet there is only limited knowledge about the development of musical skills among the intellectually disabled. Early anecdotal reports of musical savants (e.g., LaFontaine, 1974; Minogue, 1923; Rife & Snyder, 1931; Sequin, 1971) referred to the emergence of musical abilities as untutored and sudden. Such reports are best regarded with cautious scepticism, however, because closer scrutiny has commonly revealed not only that tuition has been involved but also there has been opportunity for extensive practice. Initial investigations of the musical ability of Leslie Lemke, a well-known modern musical savant, indicated that one evening, at the age of 14, Leslie simply began playing Tchaikovsky's Piano Concerto No 1. This account, provided by his mother, suggested that this was Leslie's first performance on the piano. However, recent interviews between Treffert and Leslie's family (reported in Rimland & Fein, 1988) reveal that Leslie played folk songs prior to that evening and had a piano installed in his home at age 8 (Miller, 1989). Furthermore, because Leslie had been learning music for at least 13 years before he made his first public appearance (Treffert, 1989) his initial competence will never be known. However, doubts about the sudden appearance of full-blown competency notwithstanding, many musical savants have apparently demonstrated an early interest in music together with an exceptional musical memory for tonal and rhythmic relationships, and an understanding of technical concepts such as chord formation and more elusive talents like absolute pitch, without formal training (Judd, 1988; Treffert, 1989).

Musical savants have often had physical and/or language impairment, with either blindness or echolalia being the most common. More than half of the 18 reasonably well-documented savants listed by Judd (1988) were blind. This is consistent with speculation that development of musical skills may reflect compensation for sensory deprivation (Hill, 1977). Most cases have also involved language disorders, consistent with left hemispheric damage, and this has resulted in speculation that musical competence reflects intact functions in the right hemisphere. However, current neurological evidence does not support the longstanding theory that developed musical performance is primarily a right cerebral hemispheric function (Charness, et al., 1988; Judd, 1988; Lucci, Fein, Holevas & Kaplan, 1988), although it is possible that more elementary musical functions are. The incidence of physical and linguistic disabilities among savants will be investigated in this thesis.

Miller (1989) has investigated six musical savants, comparing their musical ability with nondisabled musically trained adults and children. In addition, he has reviewed findings about savants of the past, discussing associated developmental deficits, the origins and the development of musical ability, as well as the ways in which this ability affects other areas of development. Miller has pointed out that, because musical performance is notably rule-based, savants with musical skills must be able to observe, abstract and induce the rules and structures of music.

Miller's (1989) research is consistent with single-case studies of musical savants which have focussed on specific aspects of musical ability. These aspects have included musical competence, recall and representation (Charness, et al., 1988); sensitivity to aspects of diatonic music structure (Miller, 1987b); ability to access relevant rules (Sloboda et al., 1985); abilities in pitch discrimination, tonal memory, rhythm and comprehension of complex patterns (Lucci et al., 1988); and memory, reproduction and generation of music (Hermelin, O'Connor, Lee & Treffert, 1989). The consensus from this work is that reproduction skills and the memory organisation of musical savants are comparable to those demonstrated by normally intelligent musicians, although musical savants have generally been judged to demonstrate only low levels of musical expression and emotional involvement (Sloboda, et al. 1985).

Hermelin et al. (1989) suggested that some aspects of musical ability, such as input analysis, decision making, and output monitoring, are independent of general levels of intelligence, supporting earlier results by Sloboda et al. (1985). Findings from studies by Miller (1989) and Hermelin, O'Connor & Lee (1987), based on comparisons of musical abilities among larger numbers of savants (six and five respectively), have been consistent with these conclusions.

Charness et al. (1988) noted that, despite divergent aetiology, there are common characteristics and common areas of cognitive functioning found among musical savants. Firstly, musical savants have all been reported to have absolute pitch (i.e., the correct identification of the pitch of notes and melodies without reference to an external source), something which is rare among the nondisabled population (Bachem, 1955). Thus, the high incidence of absolute pitch reported among musical savants appears to be an important component underpinning the development of wider musical skills. However, while absolute pitch may be an important precondition, it cannot be sufficient for the development of musical precocity because it has been noted both in autistic children with no demonstrated musical ability and also among savants who demonstrate other skills but lack musical ability. Secondly, another common aspect is that musical savant skills usually involve the piano or a piano-type keyboard, although why this is the case remains uncertain. Thus, Miller's (1989) review of 13 published cases of musical savants indicates that all played the piano.

1.4.2. Calendar calculation

Calendrical calculation refers to the ability to state correctly the day of the week upon which any given date will or has fallen. The span of dates may vary between individuals, ranging from a year to several centuries. This ability, first documented by Langdon Down (1887), is intriguing because, while it is prevalent in savant populations throughout the world including the United States, England, Japan and Australia, and is displayed by savants with precocious skills in other areas, it is rarely observed in nondisabled individuals. This is an interesting observation, given that it is not a skill universally acclaimed, taught or studied. The term "calculation" implies that the skill involves using some type of mathematical algorithm but, since most savants with this skill lack the rudimentary mathematical abilities involved in such algorithms (Sacks, 1985), this is unlikely. The terminology may therefore be somewhat misleading, although its use is widespread and it is therefore employed in this thesis

To date, savants have themselves been unable to provide testable explanations as to the methods which they employ when making these calculations. Recent explanations for the manifestations of these abilities and the processes used have included the use of the 14 calendar templates (Ho, Tsang & Ho, 1992; Young & Nettelbeck, 1994[2]); enhanced visual imagery or eidetic recall (Howe & Smith, 1988); inferred rules from calendar structure and knowledge (Howe & Smith, 1988; O'Connor & Hermelin, 1984, 1992); rote memory and arithmetic (Hermelin & O'Connor, 1986b); rote memory and ability to concentrate for extended periods (Hill, 1975); low-level processes (Norris, 1990) and long- term memory (Rosen, 1981).

As most studies involving calendrical calculation have been based on single cases (Burling, Sappington & Mead, 1983; Dorman, 1991; Ho et al., 1992; Howe & Smith, 1988; Hurst & Mulhall, 1988; Nelson & Pribor, 1993; Smith & Howe, 1985), generalisations about the ability are difficult because the proficiency of the skill and the level of disability of the individual are often difficult to determine from the literature. Contrast in performances of calendrical calculators within the available literature is evident when one compares the calendrical calculations of Dorman's (1991) subject (a 28 year-old male whose responses to dates, although better than chance, were nonetheless frequently incorrect) with the error-less and almost instantaneous responses of the twins reported by Sacks (1985).

It is also possible that the strategies employed by those whose skills appear to be more automatic may be different from those whose responses are more laborious, in view of Shiffrin and Schneider's (1977) differentiation between two fundamental processing modes described as "automatic" and "controlled". According to Shiffrin and Schneider, automatic processing proceeds without the subject's conscious control and without stressing capacity limitations, whereas controlled processing requires attention and is capacity limited. A theory investigated in this thesis is that, although controlled processing may be involved initially in the acquisition of calendrical calculation, as savants develop

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[2] This article was based on part of the data presented in Chapter 4.

their skills, by familiarising themselves with the calendar and by continually practicing the skills involved, the processes underpinning these skills become more automatic.

A number of recent investigations have tried to establish predictable patterns in the responses of calendrical calculators. Although Hurst and Mulhall's (1988) study of an autistic male with calendrical skills failed to establish any consistency in responding, Rosen (1981) found, for his two subjects, significant correlations between their reaction times to provide responses to dates, these correlations reflecting predictable relationships between the year and the month of the date presented. Rosen concluded that his savants used an anchor date (possibly December 1), from which they based their calculations. so that longer reaction times were recorded for dates further removed from the anchor point.

However, a difficulty when drawing conclusions from early studies of calendrical calculators is that these were virtually all based on results from a single subject. Recent studies have involved larger samples of savants. Thus, Ohtsuka, Miyasaka and Kamizono (1991) attempted to determine if the calendrical skills of four Japanese autistic male adolescents were based on general memory abilities or on familiarity with unique mathematical algorithms[3]. In studies involving eight calendrical calculating savants, O'Connor and Hermelin (1984; Hermelin & O'Connor, 1986a) concluded that their subjects were aware of some of the rules of the Gregorian calendar - for example, some months within the year and across years have identical configurations of days and dates. However, even eight subjects were insufficient to permit reliable conclusions about independence between IQ and calendar skills, although no correlations were found between IQ scores and response times when calculating days from dates. Norris's (1990) success in simulating calendrical skills on a computer, using an algorithm which required only knowledge about

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[3] The author's interpretation of this study (published in Japanese) remains uncertain, despite personal communication with the senior author (December 1994). Interpretation has been based largely on the contents of the abstract, which was provided in English.

days and dates, and the ability to add simple integers, suggests that the calculations involved are low-level processes and, given enough learning trials, a simple network architecture can be trained to calculate days from dates. In a more recent study, O'Connor and Hermelin (1992) have compared the ability of two young calendrical calculators with the same IQ (90), one nondisabled and the other autistic, with eight savant calendrical calculators with IQs between 48 and 88. Levels of skill across all participants were markedly similar, irrespective of IQ, and results supported earlier findings, indicating the use of calendrical rules as the basis to correct responses. O'Connor and Hermelin concluded that calendrical calculation is a skill, independent of IQ, which is developed by extensive practice but which , once the skill has reached a high level of proficiency, does not develop further with age or additional practice. They offer no suggestions as to the basis for this ability or the processes underlying it.

Despite the recent increase in research in this area (Dorman, 1991; Hermelin & O'Connor, 1986a; Ho et al., 1992; Howe & Smith, 1988; Hurst & Mulhall, 1988; Norris, 1990; O'Connor & Hermelin, 1984, 1992; Ohtsuka, et al., 1991), how and why savants learn and develop this skill remains unclear. Perhaps the best explanation (cited in Dalphonse, 1993) has recently been provided by Peter Guthrie, a calendrical calculator and one of the savants upon whom the fictional character Raymond in the film "Rain Man" was based. Until his involvement in the film, Peter had always responded to queries about how he performed his calculations with "I don't know". However, when questioned about his ability at a recent meeting about the movie, he unexpectedly provided detailed information about his knowledge of the 14 different calendar configurations. Calendar knowledge is an issue which is addressed further in experiments described in Chapter 3.

1.4.3. Artistic Talent.

Although artistic dimensions such as creativity and abstraction have been recognised in the artwork of savants, savants are generally respected for their abilities in reproduction and perspective. Hermelin and O'Connor (1990a; O'Connor & Hermelin, 1990) have concluded from their comparison of eight artistic savants with IQ-matched controls that, in general, artistic ability is of two kinds which may operate somewhat independently of each other; representational accuracy and artistic merit. Representational accuracy involves the ability to draw, paint or sculpt subjects in a way which fully presents the precise details, location and orientation of the subject being reproduced. Artistic merit, however, involves the presence of personal style and composition and therefore reflects abstract qualities. The detailed representation of the subject is not as important as the artist's impression. Hermelin and O'Connor's conclusion is that savants typically demonstrate high levels of representational accuracy and that these may be IQ independent; but that savants lack many of the more creative qualities which define artistic merit and which may depend on general levels of intelligence.

There are, however, reports of some savants demonstrating artistic merit in addition to representational accuracy. The original paintings of cats and other topics by the idiot-savant Gottfried Mind and sketches of famous architectural landmarks by the autistic-savant Stephen Wiltshire, both well-known for their attention to detail, have also been judged by experts to be creative and imaginative (see Treffert, 1989). Nevertheless, the most striking quality of the work of both of these artists lies in their ability to reproduce rather than create. However, the subjective nature of artistic merit makes the level of creative and aesthetic content difficult to evaluate. This is an issue discussed in Chapter 4 of this thesis.

Other research has focussed on the reason for the development of savant artistic ability, offering explanations in terms of socialisation (White, 1988) and facilitation of development because of deficits in other areas (Stevens & Moffitt, 1988). Such explanations are therefore essentially the same as those put forward to account for musical abilities, as already discussed in section 1.4.1 above. White's (1988) discussion of a female artistic savant focussed on the cognitive structures presumably utilised for the development of such skills, concluding that processes usually required by language and long term memory may be involved in the development of artistic skills. O'Connor and Hermelin (1987a, 1987b, 1990) have also concluded that memory is involved in the development of the abilities required for artistic expression.

1.4.4. Verbal Skills: Representation without Comprehension:

This ability involves the recall or reproduction of material presented visually or aurally without understanding the content of the material. Examples of this involve the reproduction of words in any language, perfect spelling and pronunciation, the ability to translate languages easily and reading ability superior to one's ability to comprehend; commonly known as hyperlexia. Hyperlexia, the most common verbal skill reported among savants, is also often reported in children with autism (Cobrinik, 1974, 1982; Elliott & Needleman, 1976; Goodman, 1972; Healy, Aram, Horwitz & Kessler, 1982; Huttenlocher & Huttenlocher, 1973; Silberberg & Silberberg, 1967) and is found occasionally in the intellectually disabled population (Fontenelle & Alarcon, 1982; Lebrun, Endert & Szliwowski, 1988).

Because most adults learn to read, even high levels of word recognition are not usually sufficient to be regarded as a savant skill among older individuals. Nevertheless, the ability to read technical and difficult literature despite very poor verbal skills in all other areas including comprehension has, on occasion, been so remarkable that it seemed to be qualitatively commensurate with other kinds of skills found among talented savants (Patti & Lupinetti, 1993).

Hyperlexia, like other savant skills, is reported to emerge suddenly, with no formal instruction, frequently appearing between the age of 2½ and 3½ years. Unlike the emergence of precocious reading ability in a normally developing child, reading becomes a total obsession for a hyperlexic child, replacing most other play and social activities (Healy et al. 1982). Recent research in this field has generated speculation that hyperlexia is an integral feature of autism (and therefore of autistic savant syndrome) (Patti & Lupinetti, 1993). This is supported by studies that have cited the co-existence of hyperlexia with other savant skills such as musical ability, calendrical calculation and exceptional memory (Cobrinik, 1982; Goldberg, 1987; Goodman, 1972; Lucci, et al., 1988; Scheerer et. al., 1945). Furthermore, hyperlexia is almost always associated with a developmental disorder where verbal skills are impaired and language is not communicative, with autism being the most common. Consistent with earlier work, Patti and Lupinetti (1993) suggest that hyperlexia may result from making specific associations with visual information.

Goldberg (1987) has discussed the development of hermetic reading (a term used specifically to describe an isolated word reading ability within a context of other language impairments) among the autistic population and compared it to the development of other savant skills. He has proposed that, despite deficits in procedural memory and behaviour, including difficulties with patterned daily activities and tasks involving some perceptual motor-skills, other areas of memory may remain intact and may be influential in the development of the skill. One such function is declarative memory, which incorporates the storage and retrieval of distinct units of verbal and visual-spatial information (e.g., rote-memory, cognitive mapping or list-learning). Because the neuroanatomical substrate for declarative memory is allegedly distinct from other memory structures, this may be possible, although the theory is not yet substantiated.

Another manifestation of the development of specific verbal skills, despite other verbal deficits, is fluency in a number of languages, with limited exposure to them and the lack of formal training. O'Connor and Hermelin (1991a) cite the case of a brain-injured man who had the ability to translate French, German and Spanish into English. His abilities were, however, consistent with his Verbal IQ despite having a much lower PIQ. Consistent with reports concerning the acquisition of other savant skills, the skill developed quickly and in the absence of any formal training. The authors suggest that the achievements of this man were the result of a natural endowment, defined by them as a modular ability and therefore IQ independent. They base this conclusion on the fact that others with similar levels of verbal-IQ do not demonstrate the same facility in language development. Lebrun et al. (1988) report exceptional linguistic skills in a female hyperlexic who could read in three languages. Her pronunciation when reading words aloud, in Dutch and French, was superior to that of her spontaneous speech. Inconsistent with reports of the sudden emergence of ability among savants, Lebrun et al. (1988) believe that, in this case, the mother's encouragement was instrumental in the development of the subject's verbal skills. Furthermore, although the subject's reading ability could not be predicted from her overall level of general ability, it was consistent with her chronological age.

1.4.5. Sensory Discrimination

Special senses such as acute smell, vision that can detect slight differences in form or size, acute hearing and extremely fine tactile ability have occasionally been reported in intellectually disabled persons, particularly those with autism. Although on rare occasions this ability has been sufficiently developed to warrant savant classification on its own, it can also accompany other savant skills. For example, Horwitz, Deming and Winter (1969) claim that the savant twins studied by them and others (e.g., Horwitz, Kestenbaum, Person & Jarvick, 1965; Sacks, 1985) were hyperosmic, constantly sniffing and smelling people, a peculiarity not infrequently observed among autistic people and also outlined in behavioural observations of other savants (e.g., Tredgold, 1923).

1.4.6. Mathematical Ability

Mathematical skills demonstrated by savants typically involve rapid calculation almost always involving multiplication. Other mathematical skills reported have involved the ability to recognise and generate prime numbers and factorisation (Rimland, 1978b, Hermelin & O'Connor, 1990b). Steel, Gorman and Flexman (1984) presented a case-study of a 28 year-old intellectually disabled male with mathematical skills. They believed that the existence of such individuals supports the idea that isolated, highly complex skills can be developed and preserved in an otherwise damaged brain. Stevens and Moffitt (1988) support the idea of an isolated ability, hypothesising that an intact verbal memory function may have been responsible for the mathematical skills demonstrated by their mathematical savant with Asperger's syndrome.

1.4.7. Mechanical Ability

These skills involve preoccupation with mechanical objects and generally reflect the widespread availability of appliances like washing machines, vacuum cleaners, televisions and radios. These skills also include repairing and modifying mechanical and electrical equipment and knowledge of technical concepts in mechanics, electronics and astronomy. An interest in mechanical objects is frequently observed in the autistic population but, while for the majority who show this interest it remains relatively undeveloped, for a few their skills become highly developed and reach savant level (e.g., Brink, 1980; Hoffman & Reeves, 1979). Brink (1980) has provided a detailed account of a man who, despite receiving brain-damage from being shot in the left temple when he was 9 years-old, demonstrated "outstanding" mechanical abilities. He was able to modify and manipulate multi-gear bicycles, design a punching bag and had excellent carpentry skills. The level of his abilities prior to the accident compared with those after the accident are not discussed but it can be assumed, given his age at the time of the accident, that there would have been little opportunity for the development of complex mechanical skills. What is clear is that the development of the skills involved motivation, intense practice and reinforcement from family members. This case-study provides a good example of the co-existence of precocious ability together with intellectual disability which has resulted from trauma, as opposed to developmental cognitive deficiencies which are generally considered to apply to most savants. The origins of these skills, and whether skills characteristic of "acquired" savancy, or precocious skills within normal levels of general functioning, are similar to those savant skills which can accompany developmental disabilities and low general intellectual functioning, will therefore be considered further in this thesis.

1.4.8. Memory

The most frequently observed skill in this category is the memorisation of relatively trivial facts such as post-codes, telephone numbers, capital cities, street names and dates. Although this ability is frequently observed in the autistic population, and hence among savants, on occasion the skill reaches a level so highly developed that it is appropriately described as prodigious. Recent research suggests that certain aspects of memory may remain intact, despite deficits in general intelligence (e.g., Duckett, 1976; Steel et al., 1984; Stevens & Moffitt, 1988; Dorman, 1991; White, 1988). O'Connor and Hermelin (1989) administered a battery of standardised tests to six autistic-savant mnemonists. Factor analyses of the tests isolated a verbal memory factor, which loaded highly on tests measuring verbal paired associates and general information, but was independent of general intelligence levels and measured verbal-IQ. They suggested that this factor may be unique to savants because it was not extracted from similar analyses involving IQ-matched controls.

The involvement of prodigious memory has often been suspected as essential to the development and performance of other savant skills, although the functions are not necessarily the same as that identified by O'Connor and Hermelin (1989). Thus, exceptional memory has been linked with the skills of music (Hermelin et al., 1989), mathematics (Stevens & Moffitt, 1988), artistic ability (O'Connor & Hermelin, 1987a), calendrical calculation (Hermelin & O'Connor, 1986a), and hyperlexia (Goldberg, 1987). The frequency with which savants demonstrate abilities in memory in addition to other savant skills, and the type of memory involved, is evaluated in the study presented in Chapter 4 of this thesis.

Despite the ability of many savants to recall trivia as well as the perceived role of memory in other savant abilities, poor performances on standardised tests of memory are common. Because of this, Howe (1989a) discounts memory as an explanation for savant abilities. It seems more likely, however, that the poor memory performance of most savants reflects inadequate content validity of the tests used because the type of memory involved seems to be highly specific and associated with only a very narrow range of behaviours. Such abilities would therefore not necessarily be revealed in available standardised tests of general memory. Tasks which better test the skills involved are therefore required.

1.4.9. Multiple Skills.

It is often assumed that most savants develop only one skill. However, results from some previous research (Duckett, 1976; Rimland, 1978a) suggest that the development of more than one skill is widespread, although the skills may be associated and perhaps involve similar cognitive processes. Multiple skills appear to be more frequent among autistic savants and Rimland (1978a) has suggested that one of the main differences between savants with autism and those with other forms of intellectual disability is the relatively high frequency of multiple skills among the former. Furthermore, it has been suggested that certain skills often accompany each other to form common groupings, with the combination of musical and memory skills being the most common, followed by mathematical and musical skills (Rimland, 1978b). If skills are found to be consistently grouped, it may be that they require the same cognitive structures but that these structures are insufficient to support other areas of intellectual functioning. However, if the skills do not form common clusters, it may be assumed that where multiple skills co-exist, the supporting cognitive structures are not linked. Therefore, all savants in this study have been tested in all areas reflecting savant ability, and questionnaires have been distributed to parents and guardians of savants to determine, among other things, if savants demonstrate additional skills that have previously been overlooked. It seems plausible to suggest that, in many instances, relatively isolated abilities may be broader and more diverse than has previously been envisaged. Moreover, it is possible that diversity in abilities is related to IQ, since a greater range in skills among higher functioning savants has been detected (Allen, Lincoln & Kaufman, 1991). This possibility has also been explored.

1.5 Are savant skills intelligent?

The existence of savants demonstrates that some apparently complex cognitive processes can develop and function, to an extent, independently of general intelligence. It is not clear, however, whether these processes include qualities such as to permit flexibility in cognitive functioning, or creativity and reasoning - qualities generally considered to reflect intelligent behaviour. From investigations reviewed in this chapter, it is evident that most savant skills are well-practiced, highly developed activities that are rule-based and follow predictable patterns or processes within a structured framework. In general, savants do not initiate new styles of expression or extend their skills outside their narrow range of interest. For example, no mathematical savant has to date shown insight into new mathematical strategies or extended his or her mathematical knowledge to involve complex intellectual strategies such as those involved in physics. Typically, the mathematical ability of savants has been limited to the function of multiplication. Furthermore, the production of original material by most savants is rare and the quality is not at the level achieved when they simply copy material (O'Connor & Hermelin, 1987a). Nevertheless, there is some indication that the abilities of a few prodigious savants may extend to generative processing which demonstrates flexibility, creativity and sophisticated cognitive processes (Hermelin et al., 1987, 1989). This thesis considers whether a minimum level of general intelligence is required for the development of savant-type skills and whether the further extension of these skills to levels indicative of intelligent behaviour is restricted by low levels of general intelligence. Furthermore, it examines the extent to which some cognitive processes can develop independently of general intelligence, and what these processes may be and whether these skills can be considered intelligent.

1.6 Representation of Abilities

Because savants display high levels of ability, despite low levels of general intelligence, and often with little formal training, it has been hypothesised that the manner in which savants achieve these feats may be qualitatively different from the path followed by people displaying similar skills but who have normal levels of general intelligence. For example, Sloboda, et al., (1985) suggested that musical savants may possess an enhanced ability for recall of diatonic material compared to most pianists with normal IQ. Recent research, however, suggests that the manner in which the skills and associated cognitive processes are represented among savants are the same as those employed by high-IQ experts. For example, analyses of savants' musical abilities suggest that, although there may be differences in their expression or overt performance, the cognitive processes involved are the same as those of normally intelligent musicians (Charness et al., 1988; Miller, 1989). This is supported by the observation of savant-type abilities occurring among the nondisabled population (Hoffman, 1971; Laber, 1992). Even the skill of calendrical calculation is found in nondisabled adults, albeit rarely. Treffert (personal communication, October 14, 1993) believes that by extending our observations to include the development of savant-type skills and other highly developed abilities among the nondisabled population, we may gain a broader understanding of what processes are involved in the manifestation of skills and brain functioning in general. Howe (1989a) also emphasises that commonalities between the development of abilities among the disabled and nondisabled populations are important to our understanding of savant syndrome. Although this thesis does not address abilities in the nondisabled population, it includes individuals who represent varying levels of general functioning, some of whom, although autistic, are within the normal IQ range.

1.7. The role of practice in the development of ability

Research supports the role of substantial practice in the development and maintenance of savant-type abilities (e.g. Anastasi & Levee, 1960; Charness et al., 1988; Comer, 1985; Hoffman & Reeves, 1979; O'Connor & Hermelin, 1991b; Shiffrin & Schneider, 1977; Tredgold, 1923). Charness et al. (1988) cites the example of a musical savant JL whose obsession was so intense that he used to practice even throughout the night. Prior to substantial practice, JL's musical skills were reported to be quite poor. Another musical-savant was taught music for thousands of hours by a psychiatric nurse (Comer, 1985) and the savant reported by Anastasi and Levee (1960) practiced nine hours a day, Monday to Saturday and six hours on Sundays.

The importance of practice in the development of savant skills has been demonstrated by researchers who have trained nondisabled individuals to develop savant-type skills through practice alone. For example, a college graduate with no experience in calendrical calculation was, as the result of much practice, able to duplicate the calendrical calculation skills of the famous twin George (Rimland, 1978a). This suggests that the acquisition of savant-type skills can be achieved as the result of persistent, repetitive practice. Arguably, this enables the individual to achieve an optimum level of capability, independent from the overall level of intellectual functioning. The role of practice in the development of savant abilities has therefore been investigated in this thesis.

1.8. The purpose of these skills.

Many of the skills that savants develop are not considered to be useful or productive and as a result may be seen as interfering with more important areas of development such as language and socialisation. Tsatsumi (1969), for example, questioned the value of the development of savant skills within individuals who were unable to take care of themselves. It is possible, however, that in order to produce more sociable and universally appreciated behaviour, we may underestimate the importance of these skills in the overall development and well-being of savants. A notable feature when watching a savant is the enjoyment that they receive from their skills. Sacks (1985) noted that "numbers" for the twins described by him were their "friends" and the emotional centres of their lives. It seems, however, that by being forced by care-givers to focus on more socially acceptable activities, the twins lost their skills and thus their greatest joy in life - arguably an unacceptable sacrifice in return for social acceptability and a degree of independence. Others argue that such skills enable savants to cope with a world that is often incomprehensible while providing them with identity, self respect, and discipline (Miller, 1989; Scheerer et al., 1945). Furthermore, the skills may provide a means by which savants can communicate and, rather than being detrimental to "normalisation", they may actually assist it (Treffert, personal communication, October 14, 1993).

It has been proposed that savants develop their skills to compensate for deficits in other areas (Hermelin et al., 1987). For example, Howe (1989a) suggested that savants, like all other individuals, need mental stimulation - but they lack the inner resources to find solace in their own thoughts.

The skills evident among the autistic population, and hence savants, are commonly associated with the functioning of the right hemisphere of the brain, while areas that are dysfunctional such as language, are frequently held to have a left hemisphere association (Rimland, 1978a). Although mathematical abilities are often associated with the left hemisphere, Restak (1984) believes that it is not the overt behaviour that indicates which side of the brain is involved; what are more important are the processes involved. The left hemisphere is commonly associated with sequential, logical and symbolic processes whereas the right hemisphere is more commonly associated with simultaneous, intuitive and non-verbal tasks. Therefore the mathematical skills demonstrated by savant which are usually spontaneous and highly practiced may reflect simultaneous processing and therefore right hemisphere processing. Consistent with this hypothesis, Treffert (1989) argued that, when practiced, skills may become automated and transfer from a sequential format (left brain) to a simultaneous format (right brain). It is not clear however, how these skills can be practiced to a level sufficient for this transition to occur if the ability for sequential processing is damaged or impaired from the outset. Therefore, it remains unclear as to what cognitive processes are involved in the development of savant skills. Nevertheless, a preserved ability to process information simultaneously may account for the processes underlying the ability once it is well-developed. Furthermore, as the simultaneous processing by autistic children has been found to be less impaired than their sequential processing (Allen et al. 1991), this would also account for the over-representation of such individuals among the savant population. Simultaneous and sequential processing by savants is therefore investigated in this thesis.

1.9. The effect of savant skills on other abilities

As the social and academic abilities of savants develop, the level of expertise demonstrated in their skill area has sometimes been reported to decline. Therefore, it has been suggested that the development of savant skills may be detrimental to the development of other skills, most noticeably adaptive functioning. Support for this argument comes from accounts of well-known savants such as Nadia (Selfe, 1977), whose drawing ability, presumed to be associated with the right hemisphere, dramatically declined coincident with improvements in her social skills and language development, associated with the left hemisphere of her brain (Selfe, 1977). Similarly, Hope (1987) reported that the highly skilled calculating ability of his subject with normal intelligence deteriorated as she was taught conventional mathematical algorithms at school. One explanation offered for this change is that the decline in ability occurs because the new skills require the same neurological "hardware"(Hope, 1987). However, this conflicts with neurological evidence suggesting that the skill and language are associated with opposing hemispheres of the brain. An alternative explanation is that the introduction of new skills provides another form of communication and socialisation and consequently lessens the need for, and the time to practice, the skill. However, it has been suggested that the expression of savant skills may increase positive social interaction and general cognitive performance, rather than the reverse (Miller, 1989). In the case of Nadia it may be that her interest in art enabled her to communicate more effectively and that this extended to her communication skills in general.

The notion that an indulgence by savants in their area of expertise is detrimental to adaptive functioning was an explanation offered by several institutions for their refusal to allow their clients to participate in this study. The adaptive functioning of savants has been assessed in this thesis, to determine whether it is in fact worse among savants whose abilities are better developed and more frequently practiced.

1.10. Family Characteristics

1.10.1. Intelligence

Treffert (1989) has noted that in his experience the parents of children with Early Infantile Autism have higher education levels than the parents of children with other psychiatric disorders. Rimland (1978a) also noted that children with symptoms of classical Early Infantile Autism were almost invariably the offspring of parents with exceptional intelligence and he consequently hypothesised that these children have a genetic predisposition toward higher intelligence. That is, had these children not been autistic one might expect them to have a high level of general ability. Howe (1989a), on the other hand, disagrees with these suggestions, inferring that the intelligence levels of the majority of parents of intellectually disabled savants are only average. The disparity between Howe's (1989a) and Rimland's (1978a) positions may be because Howe's estimates of IQ levels were based on the parents of intellectually disabled savants apparently free from autism, whereas Rimland was referring to the parents of individuals with autism. Therefore, high parental IQs may be associated with autism rather than savant syndrome per se. However, because neither researcher formally tested the IQ of parents, inferences about their IQ-levels were based on socio-economic status and education levels. In fact, the present author was unable to find any evidence in the literature of formal intelligence testing among family members of any savants. Intelligence tests have therefore been administered to family members of the savants involved in this thesis.

1.10.2 Special Abilities of Family Members

Many case studies of savants have been accompanied by reports of similar abilities among family members (Brink, 1980; Duckett, 1976; Hermelin & O'Connor, 1990b; Rife & Snyder, 1931; Rimland, 1978a). For example, Brink's (1980) investigation of a mechanical savant revealed that the savant's father was well-known in his town for designing his family home as well as his ability to repair mechanical devices. Similarly, both parents of the autistic mathematical prodigy in the study by Hermelin and O'Connor (1990b) had degrees in mathematics, which led Hermelin and O'Connor to propose that individuals can inherit a special ability independent of IQ. Not all studies support these findings. LaFontaine (1974) found only one family member with similar abilities among 23 relatives of five different savants. Furthermore, Tredgold (1923) stated that similar tendencies have rarely existed in ancestors of savants. However, since investigations such as these have relied on self-reports of developed skills, without assessing abilities or the potential for their development, it may be that many of the relatives had the potential to develop skills but did not have the inclination or the opportunity to pursue them. Furthermore, the influence of the parents on the development of abilities should not be limited to genetics (Sarason & Gladwin, 1958). Evidence for environmental influences comes from accounts such as that of Viscott (1970), who reports that one savant could recite the first three pages of the Boston telephone directory which her father had read to her at age 7. While this feat of memory is remarkable, what may be more interesting is why her father had read this particular material to her. Was the telephone directory chosen by the father to accommodate his interests or his daughter's? It is therefore of interest to determine if the more unusual skills developed by savants are also pursued by family members or whether they have developed independently. This study has therefore also investigated the interest areas of family members.

Chapter 2

The Abilities of a Musical Savant and His Family.[1]

2.1. Introduction

Traditional views of musical ability suggest that general levels of intelligence govern its development. This conclusion is supported by low to moderate correlations between intelligence and musical skills (Seashore, 1938). A radically different perspective is that musical ability represents a distinct type of "intelligence", with its development independent of, and not restricted by, general intelligence (e.g., Gardner, 1983). Support for this position comes from individuals who demonstrate precocious musical ability which is inconsistent with their general level of functioning. In some cases high musical skills coexist with otherwise low general levels of cognitive abilities. These persons are commonly referred to as musical savants and they form a subgroup among "idiot" and "autistic" savants. The existence of musical savants was outlined in Chapter 1 and this type of savant skill is the focus of this chapter.

Musical ability, generally exhibited on a piano-type keyboard, is the most frequently exhibited skill among savants, with Rimland and Hill (1984) reporting its occurrence in 52% of their "autistic-type" individuals with savant skills. There have been a number of reported cases of musical savants in the literature but most have focussed on the musical ability, with little objective consideration of assumed low general ability (Charness, Clifton & MacDonald, 1987; Rife & Snyder, 1931; Thaut, 1988; Viscott, 1970). This study therefore examined the level of musical ability shown by an autistic savant, in relation to his general ability. It also explored the origins of his musical ability, including the extent of practice, because anecdotal accounts of savants have often suggested that the talent together with competent performance suddenly emerges, without substantial practice. Most such reports have not withstood closer scrutiny although many musical savants have

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[1] An article based on this chapter by R, Young and T. Nettelbeck and titled "The Abilities of a Musical Savant and His Family has been accepted for publication in the American Journal of Autism and Developmental Disorders (in press).

apparently demonstrated absolute pitch and an understanding of technical concepts, like chord formation, without formal training (Treffert, 1989).

As noted above in Section 1.4.1, reports of absolute pitch are common for musical savants yet rare among the normal population, even for musicians. A common speculation is that absolute pitch is a relatively rare innate capacity (Bachem, 1955). Alternatively, Takeuchi and Hulse (1993) have argued that everyone is born with the potential to acquire absolute pitch, with appropriate environmental circumstances determining its development. Absolute pitch and other aspects of musicality were therefore examined in available members of the savant's family, on the premise that evidence for shared absolute pitch, but without common musical experiences, would favour genetic involvement.

Memory was investigated in this study because unusual feats of memory have often been associated with savant skills. Spitz and LaFontaine (1973) found that the digit span of savants was within normal limits, despite overall lower IQs. However, this finding has not always been confirmed and it was therefore decided to test memory span for digits. In addition, memory span for randomly generated sequences of notes was tested, permitting a comparison between the common form of memory span based on highly familiar materials and an analogous form based on specifically musical materials.

Finally, as foreshadowed in Section 1.10.1, above, Rimland (1978) has observed that children with symptoms of classical Early Infantile Autism, from among whom many savants emerge, are frequently the product of parents with higher abilities. As Treffert (1989) and others have speculated, this could mean that a foetus with a potentially higher level of functioning is somehow more at risk for such damage. Although this issue was beyond the scope of this study, it was considered sufficiently interesting to warrant relevant data collection; the abilities of family members and other demographic data were therefore collected. Included in the analyses were tests of cognitive functioning reflected in various standardised tests; and Inspection Time (IT), assumed to index speed of information processing. The objective of these analyses was to investigate cognitive structures associated with musical ability.

The study described in this chapter was made possible and encouraged by the parents of an autistic boy (TR) aged 12 years-11 months, whose musical ability was apparently equal to anything reported in the savant literature. The experimental design and the materials used were derived from an experiment by Sloboda, Hermelin and O'Connor (1985), to enable comparisons with the musical performance of their subjects; a savant (NP) and a professional musician (AS). One objective was to document and analyse the memory processes utilised by TR – specifically to investigate whether diatonic material was encoded more efficiently than chromatic material. Another objective was to map the extent to which TR's performance of previously unfamiliar music changed with repeated exposure and consequential opportunities for rehearsal. Also evaluated was the extent to which aspects of musical ability noted by Hermelin, O'Connor and Lee (1987) were affected by TR's autism. These involved competence in composition and improvisation, for example by extending unfamiliar material while maintaining an appropriate melodic style and harmonic accompaniment. Finally, several aspects of the intellectual functioning of TR and family members were assessed, firstly to investigate whether TR possessed specific cognitive functions which might be supporting the development of his musical skills and, secondly, to determine the extent to which such abilities were common within the family.

2.2. Method

2.2.1. Subjects

The main subject for this study was TR, a prodigious musical savant who is autistic. He is the middle sibling of three boys and was aged 12 years 11 months when testing began. No other member of the immediate family had autism or highly developed musical competence, although the younger brother played the violin.

Other family members participating were; TR's elder brother, aged 15 years 6 months at the time of the study. He had a high IQ and from an early age was recognised as having exceptional mathematical abilities. Subsequent to this investigation he has begun studying for his PhD in mathematics at Princeton University. His precocity is recognised as exceptional even compared with other precocious mathematicians (J. Stanley, personal communication, 1990). At age 8 he scored 760 out of a possible 800 on the mathematical section of the Scholastic Aptitude Test (SAT-M), something achieved by less than 1% of college entrants in the United States. His score on the verbal component of this test, while still well above-average, was more than 3 SDs below his mathematical score. The younger brother, aged 11 years 3 months at testing, was also highly gifted in general terms. At age 9 years 7 months he scored 163+ on the Slossen Intelligence Test. At that time he scored 520 on SAT-M, above the mean for 17 year-olds preparing for university entrance. He recently won a national mathematics competition and was selected to represent Australia in an International Mathematical Olympiad. The younger brother was the only other family member who played an instrument although the older brother formerly received some training. Their mother had a Bachelor degree in mathematics and has continued to teach the three boys; their father was a paediatrician. The parents' first language was Chinese but they spoke English fluently. Although the three boys understood Chinese, their first language was English.

2.2.1. i) Early Psychological / Medical Evaluations (TR).

TR was diagnosed as autistic at age 2 years 8 months although his father, a paediatrician, had previously suspected this. Throughout his early development TR showed many obsessions typical of autistic people; ritualistic behaviours, including lining things up, finger tapping, inappropriate smelling, touching noses, resistance to change, head banging and drawing anything that involved lines - like telegraph poles, roads, signs and musical notation. His speech was holophrastic and repetitive and his eye contact and social awareness were poor. Psychometric testing revealed wide variation across different ability areas. At age 4½ TR was tested on the Illinios Test of Psycholinguistic Ability, scoring in the borderline retarded range of mental ability. However, from an early age his teachers noted an excellent near-literal memory. For example, at age 4 using toys he assembled a miniature but accurate road plan, complete with stop signs, of the route from his home to kindergarten. At age 6 his reading skills were beyond those of a normal 8 year-old although his comprehension remained poor. At age 7 years 11 months TR's Full Scale IQ (FSIQ) on the Wechsler Intelligence Scale for Children - Revised (WISC-R) was 100. His Verbal IQ (VIQ) was 102 and Performance IQ (PIQ) was 98. At that time he scored poorly on the Picture Arrangement and Comprehension subtests yet produced the maximum score possible for Block Design. British Ability Scales were recorded three times at that age during six months of Fenfluramine trials, the IQ scores being 120, 127 and 134 respectively but with scaled-scores differing by up to 47 points (eg., Visual IQ 145, Verbal IQ 98; cf. standardised M=100 for both). In contrast, social quotient scores on the Vineland Social Maturity Scales recorded during the same period were 69, 80 and 83 (cf. standardised M=100) and scores on the Test of Language Development - Primary were 72, 78 and 88 (cf. standardised M=100). Results of a magnetic resonance scan at age 13 showed a mild degree of bilateral dilation of the lateral ventricles but medical opinion considered this to be of little significance in either the understanding or treatment of his autism. He had no physical disabilities.

2.2.1 ii) Education

TR began special education on a one-to-one basis from age 2 ½. At age 4 he was gradually integrated into a local kindergarten, followed by local primary school at age 5 ½. He entered secondary school at age 13 and, within a school environment that catered for his autism, he has been able to take all subjects at his age-appropriate year level. His musical skills were already apparent at age 4. His technique was then judged to be extraordinary, despite showing poor rhythm and dynamics, but an early teacher predicted that he would never be more than a recreational performer. Despite this poor prognosis, TR has developed as a musician. At the time of this study he could sight-read and play from memory and his pianistic interpretation had been commented on very favourably by adjudicators in local Eisteddfod competitions in which he has regularly participated.

2.2.1 iii) Other skills.

TR has also demonstrated prodigious skills in mathematics and chess. He was invited to take part in Mathematical Olympiad training programs after winning prizes in national mathematics competitions. He was recently the National Junior Chess Champion and at the time of writing has accepted an invitation to compete internationally in the near future. TR had a good sense of direction and excellent practical spatial skills. He seemed hypersensitive to sound and could, for example, tell if the oven bell was ringing when he was playing the piano in another room, on another level of the family home. TR also engaged in word puzzles like anagrams and cryptic crosswords. From a very young age he had received tuition for chess, maths and music from the best local teachers available.

2.2.2. Apparatus and Procedure

2.2.2 i) Psychological Assessment.

All testing took place in the family home. TR completed the WISC-R and Stanford-Binet (fourth edition), and to test nonverbal reasoning he completed the Raven's Standard Progressive Matrices (PM). The Wechsler Memory Scale- Revised (WMS-R) was used to measure verbal, visual and delayed memory. This test was included because it is the most appropriate in content, despite inadequate normative data for TR's age-group. The Schonell Graded Word Reading Test and the Neale Analysis of Reading Ability-Revised (Form 2) provided comprehensive measures of reading accuracy within context, rate of reading and comprehension. Creativity was investigated using pictorial materials from the Torrance Test of Creative Ability (Thinking Creatively with Pictures: Figural Booklet A). The Bender Visual Motor Gestalt Test and the Hooper Visual Organisation Test assessed visual organisation and integration.

TR's working memory for musical notes was tested by playing a series of notes selected randomly without replacement from the 24 notes in the chromatic scale over two octaves and requiring that he subsequently play them. He did not see the notes played, so that recall was dependent upon pitch recognition. Presentations were of increasing number, with two trials at each length. The procedure was therefore the same as that used for Digit Span in WISC-R (both forwards and backwards). Thus, presentations ceased when TR made errors on both trials of the same number. This procedure was then repeated but using verbal representations of the names of these notes which TR was asked to repeat.

TR's two brothers completed WISC-R and WMS-R and both parents completed the Wechsler Adult Intelligence Scale - Revised (WAIS-R). The younger brother was also tested for musical memory with the procedure used for TR.

Inspection Time (IT) was estimated using a two-choice procedure. (See Nettelbeck, 1987 for a detailed account of the rationale and methods upon which this measure is based.) Essentially, the IT measure requires a judgement as to which of two-vertical lines 22 mm and 27 mm, joined by a horizontal line 12 mm long and presented on a computer screen, was shorter. A small dot displayed for 400 ms preceded the target figure as an attentional cue. The target figure was followed by a "flash mask" (see Evans & Nettelbeck, 1993) - a particular configuration for a backward pattern mask which lasted 360 ms. Subjects attempted to identify the side on which the shortest line was presented, with chance likelihood being equiprobable. Response-stimulus interval was 2000 ms. Subjects were familiarised with the cue - target - mask sequence and response requirements and then presented with 30 trials at exposure durations of 1000 ms, 500ms and 300 ms (10 at each with replacement if an error occurred). Nine correct responses were required at 300 ms to begin the task. Subjects were instructed that accuracy of performance was more important than speed and that as trials became more difficult due to reductions in exposure duration, it was permissible to guess which line was shorter. IT was estimated as the time required to make correct discriminations of the stimulus 90 percent of the time, using an adaptive staircase procedure derived from Wetherill and Levitt (1965). The initial exposure duration was 300 ms; with subsequent exposures automatically adjusted in response to performance accuracy. The program was designed to incorporate eight reversals to direction of adjustment (i.e., longer or shorter), requiring six correct responses at each exposure duration before reducing exposure duration by 20 ms (i.e., the duration of the screen refresh cycle) but only one error to increase exposure duration. An IT measure required approximately 10 minutes to make.

2.2.2. ii). Musical assessment

Musical assessment took place in TR's home, using his piano. The two pieces were those used by Sloboda et al. (1985); Op. 47 No 3 ("Melodie") from Grieg's Lyric Pieces, which has a conventional diatonic harmony, and an atonal composition based on the whole-tone scale from Book 5 of Bartok's "Mikrokosmos"[2]. It was first confirmed that both pieces were unknown to TR.

The procedure was similar but not identical to that employed by Sloboda et al. (1985), with the Grieg piece attempted first, followed by Bartok after a short delay. Both pieces were heard in their entirety before being presented in segments of 8 bars which TR was then requested to play. The amount of material presented was not dependent upon his accuracy, as had been the case in the experiment by Sloboda et al. (1985). TR heard the first segment and played it. He then heard the first segment again, followed by the next segment, and played both. This part-whole combination continued until he had heard and attempted to play the entire piece. The full session was recorded on video and audio tape, the former being preferred for transcriptions because fingering could be observed. Transcriptions were made by a music student not involved in data collection and subsequently checked by Dr. Nettelbeck who is a trained musician and who has supervised this thesis. At no time during testing did TR see a printed score, or receive any help with fingering.

TR's pitch discrimination, tonal memory, chord analysis, and rhythmic memory were tested using the Measures of Music Abilities (Bentley, 1985). In addition to testing his memory for sequences of notes, as outlined above, his pitch identification was assessed using the procedure outlined by Miller (1989, p49), whereby he was presented with all 24 notes from two consecutive octaves. The order of presentation was random, with the constraint that successive notes were not an octave apart. After hearing the note TR was asked to name it (see Appendix 2.1). This procedure was then replicated for 24 chords; two each in root position on every note of the chromatic scale procedure(see Appendix 2.2). These chords included major, minor, augmented, diminished, half-diminished and dominant versions, chords with added 6th, 7th and 9th degrees, all in either open or closed versions, but were otherwise not balanced. The younger brother and mother were also tested for pitch identification, but not chords, using the same procedure.

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[2] These pieces were provided by Dr. John Sloboda on high fidelity audio-tape

2.3. Results

2.3.1 Psychometric Assessment

A full record of TR's performance on all tests is included in Appendix 2.3, On many tests the outcome was in the average to above-average range. His reading rate, accuracy and comprehension of written material was at the ceiling level (i.e., > 12 years) on both tests. Scores for Peabody Individual Achievement subtests (i.e., mathematics, reading recognition and comprehension, and general information) were between 101 and 107 (cf. standardised M=100, SD=15). His spelling score of 126 placed him at the 96th percentile for his age group. His overall achievement score (113) placed him on the 80th percentile. He identified 25 out of a possible 30 pictures on the Hooper Test of Visual Organisation (within the normal range) and showed no errors of distortion, perseveration, integration or rotation on the Bender Visual Motor Gestalt Test. On materials relevant to creativity his ideas reflected originality and flexibility but lacked elaboration and fluency.

Results for TR and family members from WAIS-R, Stanford-Binet and PM are shown in Table 2.1. Consistent with TR's earlier IQ tests and those of other autistic cases in the literature (Lockyer & Rutter, 1969), there was marked variability in the WISC-R subtests, with five subtests deviating by more than 2 SDs from his subscale means. These results, together with discrepancies between overall scores on the three different IQ tests, make an interpretation in terms of a general intellectual level inappropriate.

The subtests for which TR's scores were in the average range are influenced by cultural opportunities and recreational reading – areas in which, despite a limited scope of interests, TR has been well stimulated. His high performance on Block Design could indicate superior spatial skills but this conclusion is weakened by his average score on Object Assembly, also held to reflect this ability. More plausibly, the Block Design score is consistent with TR's expertise in areas that involve pattern recognition (i.e., chess, music, mathematics), whereas Object Assembly involves construction of social objects, an area that causes difficulty for people with autism. Moreover, his autism probably reduced his performance on the Arithmetic subtest which, although above-average, did not suggest his demonstrably precocious skills (see Section 2.2.1 iii), above). This could be because the test's verbal format requires comprehension and TR did appear to experience difficulty with transferring his mathematical skills to this format, even though he had no problem with the calculations required. His Quantitative Reasoning score of 140 on the Stanford Binet (cf. standardised M=100, SD=16) better demonstrated his aptitude in this area. This observation, that verbal comprehension may mask mathematical ability, may be of general relevance to the assessment of mathematical skills in autistic individuals.

Table 2.1

Individual scaled scores and IQ on Wechsler scales and PM.

TEST	TR	Older brother	Younger brother	Other savant[a]	Father	Mother
WISC-R / WAIS-R[b]						
Information	10	15	19	07	15	14
Similarities	11	16	18	09	18	16
Arithmetic	15	16	18	17	15	17
Vocabulary	10	19	19	07	14	12
Comprehension	04	16	15	04	18	18
Digit Span	19	16	19	16	12	13
Picture Completion	07	10	14	08	17	17
Picture Arrangement	03	14	15	06	17	15
Block Design	19	19	19	13	14	19
Object Assembly	10	17	18	08	11	14
Coding / Digit Symbol	19	19	19	06	12	15
Verbal IQ	100	141	150	94	138	134
Performance IQ	111	141	149	89	140	149
Full Scale IQ	105	145	154	91	143	147
PROGRESSIVE MATRICES	136	117	136	95th percentile[c]		
PM Raw Scores	56	56	56	34/35		
STANFORD BINET IQ	119					
Verbal Reasoning	91					
Quantitative Reasoning	140					

a WAIS results of an autistic mathematical idiot-savant aged 29 years from a neuropsychiatric evaluation by Steel et al. (1984).

b Scaled subtest scores on Wechsler tests can range from 1 to 19 (M=10; SD=3). A score of 8 or less places the subject in the lower 25%; 5 or below defines the least able 5%.

c Coloured Progressive Matrices - Norms not appropriate for the calculation of an IQ.

TR correctly solved 56 of the 60 PM items, placing him at the 99th percentile for his age group. This outcome translates as an IQ of 136. As may be seen from Table 2.1, nonverbal reasoning ability was also unaffected in the savant tested by Steel et al. (1984), who correctly identified 34 of the 35 items presented to him on the Raven's Colored Progressive Matrices, placing him on the 95th percentile.

IQ data from TR's family indicated that, consistent with their occupational success and academic achievements, all had superior levels of general mental ability (see Table 2.1). TR and both brothers performed well on WMS-R, particularly in areas requiring short-term memory (subtests for Figural Memory, Visual Memory Span and Digit Span). Other family members demonstrated superior levels of ability in all areas tested and the Wechsler tests provided no indication about what may contribute to their precocious numerical ability or, conversely, their lack of development in the area of music.. Nevertheless, the very high general performance of family members, as well as their enthusiasm for academic success, suggested that TR may have had a predisposition for well-developed abilities.

Memory, particularly near-literal figural imagery and enhanced short-term memory, has been linked to the achievements of savants. TR correctly recognised all 10 figures in the Figural Memory subtest (WMS-R) which demonstrated a well-developed and accurate visual memory, at least for figures. This results supports the suggestion that an enhanced level of ability in this area may underlie savant skills. His Digit Span (identical to his WISC-R performance) and Visual Memory Span (8 forwards, 7 backwards)on the WMS-R were also beyond normal levels. However, both brothers also correctly identified all 10 figures, and since their Digit Span and Visual Memory Span scores were equivalent to TR's and neither brother has well-developed musical skills, TR's musical talent must obviously depend on more than superior memory. TR's aural recall of musical notes played on the piano (sequences of 11 notes forwards, 9 backwards) was superior to his memory for equivalent arrangements for names of notes presented verbally (9 forwards, 7 backwards). However, both were well above what one might expect from the normal population (6±1 "chunks" or units of information, Spitz & LaFontaine, 1973). This outcome was remarkable when one considers that accurate absolute pitch recognition, in addition to memory, was required for the former task. Overall TR's digit span (10 forward, 9 backwards), as shown by his performance on WISC-R and WMS-R (extended until he made two-consecutive errors) and his recall for individual randomly generated musical notes, suggested that specific aspects of TR's memory were well above normal limits. TR's performance for recall of musical notes was superior to his younger brother's who managed 6 notes forward and 4 backwards; cf. 8 forwards and 6 backwards for digits.

Inspection Time (IT) for TR was 77 ms and 57 ms for two successive estimates. These were comparable to those from his older brother (80 ms and 57 ms) and superior to those for his younger brother (97 ms and 95 ms) and to those typically obtained for normal adults; (recent experiments conducted by Dr. Nettelbeck and students with the identical procedure to that followed here have resulted in M=83.8 ms, SD= 21.3, n=87. Personal communication, T. Nettelbeck, June, 1994). These results suggested that TR's speed of information processing, as indexed by IT, was not affected by his autism.

2.3.2 Musical Assessment

Pitch Discrimination on the Measures of Musical Ability (Bentley, 1985) requires subjects to discriminate between two sounds so as to indicate whether the second sound has risen or fallen in relation to the first. TR responded correctly on 18 out of the 20 trials, also correctly naming 38 tones out of the 40 as musical notes, which is not a test requirement. However, consideration of the two incorrect trials clarified that the slight variations involved could be interpreted as two musical notes -both As - with the second note on two of the trials slightly (3hz) out of tune. This test therefore poses more difficulty for trained musicians than persons untrained, because musicians are likely to try to identify the note if they possess good pitch recognition. Untrained listeners with equivalent abilities in pitch discrimination are not going to be confused by trying to relate the tones to notes. This interpretation was confirmed by seeking the responses to this test from other trained musicians. The outcome clearly demonstrated that those able to identify the absolute pitch of the musical notes applied this strategy (e.g., "different - but both A").

TR made no other error on any of the Bentley subtests involving note or chord recognition, identification of the difference between two tunes, and recognition of the variations in rhythm. In the chord recognition subtest, he not only identified the number of notes played in each chord (as required), but also correctly named all notes involved. Furthermore, he correctly identified all 12 notes of the chromatic scale in two consecutive octaves and 22 of the 24 chords presented. It was therefore concluded that TR did have absolute pitch (see Appendix, 2.4).

TR's younger brother correctly named 19 of the 24 notes played on the chromatic scale while their mother identified 11. She did, however, have difficulty in naming the notes due to a lack of formal music training. Nevertheless, both can be assumed to have at least good relative pitch - some evidence that the ability may run in families.

A primary objective in this study was to determine how TR's musical performance on both the unfamiliar Grieg and Bartok pieces changed with repeated exposure and rehearsal and to make comparisons between his performance and that of the subjects in Sloboda et al.'s (1985) study. To this end, his initial performance on both pieces was evaluated in detail by comparing the transcriptions (checked against the video record) with the original score. (A bar-by-bar record of this analysis is included in Appendices 2.5 and 2.6). However, this analysis found that TR's initial attempts at each 8-bar segment were essentially fully formed, with few errors other than those involving embellishments and dynamics. There was therefore very little margin for improvement beyond the initial performance. He was able to play the initial 7 bars of Grieg after one hearing with only one incorrect note. This error (substituting a D for a B in bar 6) was, however, harmonically consistent. Three embellishments in bars 2, 4 and 6 were also omitted. He heard these seven bars 10 times in total because they were repeated in bars 41-48 and, with the exception of one missed embellishment in the fourth reproduction of the second bar, his performance was perfect. In addition, rhythm was preserved and the melody was correctly reproduced throughout the performance, except that on occasion he played different inversions of the written chord (i.e., he retained harmonic identity but not a literal rendition).

TR's musical abilities easily transferred to the atonal Bartok piece although he obviously found this piece to be more difficult. He was able to reproduce the first six bars of Bartok after only one hearing - accurately, except that a note properly held throughout was not sustained. He made seven reproductions of these bars, with only one error; on the fourth reproduction he omitted an E. The errors that TR did make over the entire piece were predominantly due to the interpolation of material consistent with the whole-tone scale but which was not present in the original recording. In this composition, the two voices are separated by a minor third, with both consistently within a whole-tone scale, based on C in the right hand and simultaneously on A in the left hand. Because his performance was accurate, without deviation into a diatonic system, he was clearly aware of how the whole-tone scale operates. His representation of musical structure was therefore superior to that by NP who had four times the error rate of AS (see Sloboda et al., 1985). On this piece TR's performance was more akin to that of the professional musician AS, because his errors were structure preserving, therefore indicating familiarity with this style of music. However, once again the amount of material recalled by TR was superior to AS, reflecting TR's better aural acuity for nondiatonic material. Furthermore. when first hearing the piece he immediately recognised the whole-tone scale and named it, and his excellent sense of pitch enabled him to play the two versions involved. Familiarity with the whole-tone structure of the Bartok piece therefore facilitated TR's performance.

2.4. Discussion

TR's idiosyncratic levels of ability were consistent with previously published assessments of savants. Comparisons between TR's psychometric evaluation and a mathematically precocious autistic-savant presented in Steel, Gorman and Flexman (1984) showed that the profiles from IQ data from the Wechsler Scales for these two individuals were remarkably similar. Thus the correlation between the 10 subtests was high ($r=.87$. $p<.01$ $n=10$). As seen in Table 2.1, both profiles had peaks on Arithmetic, Digit Span and Block Design, consistent with higher levels of concentration, but low scores on Comprehension, Picture Completion and Picture Arrangement, consistent with poor social maturity and verbal reasoning. Profiles available from other savants have suggested reduced functioning in these latter areas (e.g., Anastasi & Levee, 1960) although similar deficits are common among autistic persons who do not demonstrate savant skills (e.g., Lockyer & Rutter, 1969). While it would be inappropriate to draw firm conclusions based on these data, they do at least suggest that focussed concentration may underlie all savant skills. However, other variables must also be involved in the development of savant skills because all autistic cases do not become savants.

Memory as a foundation of savant ability has often been discounted because of unexceptional performances on standardised tests of memory. However, TR's ability to recall notes suggests that memory capacity may be enhanced when the information to be recalled is associated with a field of expertise. This is consistent with previous findings (e.g., Charness, 1991; Chase & Simon, 1973; Ericsson & Smith, 1991). Furthermore, superior memory has been shown to increase as a function of degree of expertise or knowledge (e.g., Chiesi, Spilich & Voss, 1979). Therefore, although memory tests may not always reveal superior memory, the role of memory and musical knowledge is critical in musical reproduction, which requires access to familiar relevant rules.

Although absolute pitch is not essential for the development of musical ability among the normal population, where it is in fact rare, the frequency with which it has been demonstrated among musical savants suggests that it is critical in the development of musical ability in this population. Unlike normal musicians who typically play from written scores, musical savants always play initially by ear, unless actively encouraged to do otherwise.

Overall, TR's performance on the Grieg piece was comparable to the autistic savant NP and certainly superior to AS, the professional pianist engaged by Sloboda et al. (1985). Subsequent testing of other musicians by Sloboda et al. (1985) found that none could perform as well as NP, indicating that savants may have an enhanced ability for recall for diatonic material compared to pianists with normal IQ. Because virtually all of TR's errors were structure preserving, even on the atonal Bartok piece, the results suggest that TR's memory for music was well organised and structurally based, consistent with that of an expert pianist with normal IQ - or, indeed, an expert in any other field.

Sloboda et al. (1985) found for AS and other professional musicians that their performance was adversely affected by retroactive interference; but NP was not. TR also was not affected by this type of interference; his recall for later bars was equally as impressive as his recall for earlier bars. This outcome was therefore consistent with psychometric evidence that savants may have a well-developed ability to focus attention with little interference.

Our initial intention was to compare TR's errors with those of NP and AS but because TR made very few errors of any kind in either piece and played with high polish, without hesitation or stumbling, this became unnecessary - he obviously out-performed these cases. Other aspects of his musical ability were therefore evaluated. He had a limited ability to improvise an appropriate passage and a conclusion to a fragment of music within certain style constraints (e.g., the Baroque "classical" style). This extended to atonal music, as evidenced by his initial attempts to play the Bartok piece when he completed the piece in a style consistent with the musical context, albeit inaccurately. TR was invited by Dr. Nettelbeck to play together on the one instrument and, on the basis of a single example of a jazz blues composition (melody and harmonic structure played simultaneously) he was instantly able to take the role of providing either an appropriate harmonic accompaniment or an improvised melody. TR's involvement with a jazz band at his present school was also observed. However, here as elsewhere, despite demonstrating high musical competence, TR showed little affect or indication of emotional involvement. The music he produced was stylistically appropriate but stilted, "wooden" and lacking essential jazz qualities. This lack of affect has been noted in other savants (e.g., Sloboda, 1985). However, while his attempts at improvisation were rhythmically stilted and melodically limited to scalar embellishments, this was no more so than would commonly be the case for classically trained musicians not familiar with jazz music. Moreover, in the school situation he demonstrated familiarity with the simple blues structure (key of F major) which the band was playing, without being told beforehand what was required.

The quality of TR's musical composition was undoubtedly above that produced by normal music students of his age, as evidenced by his success in competitions. His production of original music was, however, dependent on structural representations from familiar musical rules, conforming to familiar structure patterns and therefore dependent upon his musical knowledge.

TR's musical performance demonstrated a well-developed ability to access a representational system of relevant rules, and in this respect his playing was similar to the performances of NP and AS (Sloboda et al., 1985). With more familiar diatonic music TR (like NP) showed an enhanced ability for recall, clearly superior to the normal IQ musician AS tested by Sloboda et al. Further, TR's familiarity with the whole-tone structure permitted transfer of his abilities of superior recall to the Bartok piece. Overall, his performance with this system was less certain, with more errors, although not markedly so. Sloboda (1991) states that many of his musical colleagues have claimed that they once had better abilities of memorisation but that they lost this ability when they no longer rehearsed it. On this basis it seems likely that extensive practice in both diatonic and nondiatonic systems, linked to specific motivation and reinforcement but lack of socialisation in other regards, may have contributed to TR's skills of retention and to the development of his musical abilities.

As musical ability is known to develop in individuals with no formal musical training (e.g., NP) we can assume that the ability to recall music is acquired incidentally, from exposure and the type of learning which, for example, enables novices to recognise notes played incorrectly or detect an untuned violin In fact, studies of expertise reveal that most knowledge is the result of incidental learning (Charness, 1991). TR's success with the reproduction of both pieces depended upon familiarity with style and, although the structure of the Bartok piece is less common, he had certainly been introduced to this type of music through formal training. It may therefore be assumed that TR's apparently superior performance over that of NP resulted from his degree of training.

The origins of TR's musical abilities were difficult to isolate, given musical understanding and appreciation among family members, his formal musical training from a very young age and the fact that he was also the child of exceptionally talented and supportive parents. Furthermore, TR's parents have encouraged TR's musical ability and have engaged the best teachers available in music as well as in chess and mathematics. TR's devotion to music and his other skills has left little time for more social activities but this appeared to be of no concern to TR. In fact, when permitted, TR was and is almost always actively engaged in the development of his skills.

Although, it is unlikely that practice alone can account for precocious ability, this has been proposed (Ericsson & Faivre, 1988). However, the amount of time that TR has dedicated to his field certainly highlights the importance of practice in the development of a skill and supports other studies that have implicated practice as a major contributor (e.g., Anastasi & Levee, 1960; Charness, 1991; Hoffman & Reeves, 1979; Shiffrin & Schneider, 1977; Tredgold & Sody, 1956). Regardless of the origins of TR's abilities, his current level of skill was assuredly the result of much effort. Furthermore, in TR's case his perfect pitch appeared to have provided an important basis for the development of his musical skills and since both members of his family tested in this regard appeared to have a similar ability to recognise pitch, it may be that inheritance has been involved.

TR's abilities suggest that some cognitive functions may be independent from a general capacity. Irrespective of the generally high level of TR's musical achievements, his success was dependent on his ability to access predictable structure patterns. It is also possible that the extent to which he can develop his musical production and make abstractions in a creative and flexible manner may be dependent upon his general intellectual capacities. As indicated by the wide range of scores for different tests, some estimates TR's IQ may underestimate his broader capabilities, in so far as his autism poses a major problem for the valid measurement of IQ.

This research has raised a number of questions for the study of savant syndrome in general. Firstly, as found for TR, is memory structured and organised for savants in areas of ability other than music? Secondly, are all savant abilities based on patterns with a predictable structure and if so, do these patterns provide an alternative symbol system to language? Finally, do high levels of familial intelligence predict savant syndrome among the autistic population? These issues have been addressed in the chapters which follow.

Chapter 3

The "Intelligence" of Calendrical Calculators

3.1. Introduction

In their argument against a general theory of intelligence, advocates of a multifaceted approach to understanding intelligence have drawn heavily on biographies of individuals with isolated, exceptional abilities, despite those individuals having less than remarkable and even low levels of general intelligence (Gardner, 1983; Howe 1989a; Thurstone, 1938). The four experiments reported in this chapter, however, demonstrate that although some skills are relatively well-differentiated, these capacities do not pose a dilemma for the construct of general intelligence.

This chapter focuses on the skill of calendrical calculation, the ability to state correctly the day of the week upon which any given date fell or will fall. Among savants with this skill, the span of dates defining accurate performance varies between individuals, ranging from a year to several centuries, and may include the future as well as the past (Norris, 1990; O'Connor & Hermelin, 1984). There have been numerous reports of individuals capable of these calculations but until recently most accounts have been anecdotal, with little attempt to identify the mental processes involved.

Explanations offered by savants about the systems employed by them when making calendrical calculations have not resulted in a testable theory and there has been considerable speculation among researchers about the processes involved, with the involvement of specific memory processes being among the theories most often proposed. Because many savants have probably had access to either conventional or perpetual calendars, Hill (1975) concluded that the ability is associated with rote memory - that is the verbatim recall of information usually requiring little or no understanding of the content. Hermelin and O'Connor (1986a; O'Connor & Hermelin, 1984), however, found six of the eight calendrical calculators in their study, with IQs between 48 and 88, to be using strategies derived from knowledge about regularities within a calendar year and four subjects with higher IQs (50 to 88) were able to apply these strategies to analogous problems that did not involve the calendar. Hermelin and O'Connor concluded that processes other than rote-memory were involved because subjects' performance demonstrated understanding of the principles involved in calendrical calculation, together with knowledge regarding the rules and regularities of the calendar. Processes suggested by these authors included relatively more cognitively complex rule-governed strategies.

Other types of memory suggested as being well-developed among savant subjects and therefore involved in their achievements have included: eidetic imagery, that is the ability to retain an intense visual image for at least 40 seconds (e.g., LaFontaine, 1974; Roberts, 1945), semantically organised memory schemata (Pring & Hermelin, 1993), retention of information stored in the long-term (Rosen, 1981), auditory verbal memory (Stevens & Moffitt, 1988) and detailed memory for objects or events perceived- probably visually (Howe & Smith, 1988). No single theory of memory has, as yet however, been adequate to explain the development of calendrical skills across all cases. For example, although some calendrical calculators use eidetic imagery to facilitate their performance (e.g., LaFontaine, 1974), the necessity of its involvement is questionable given that blind subjects have also been reported with this ability (e.g., Hurst & Mulhall, 1988; Rubin & Monaghan, 1965). Similarly, studies that have suggested enhanced abilities on items assumed to measure short-term memory are offset by other empirical research which does not support this finding (e.g., Byrd, 1920).

Given that most calendrical calculators demonstrate recall for trivia and other associated feats of memory in addition to their calendrical skills, it is reasonable to suggest that the processes that underlie the ability of calendrical calculations do involve memory, despite the inability of researchers to identify consistently such processes. Comparisons with studies of experts in other fields, however, suggest that it may be unreasonable to expect these processes to be identified by standardised tests because it is unlikely that these memory processes will be extended to any other domain. For example, Ericsson and Faivre (1988) found that chess masters had knowledge, from the literature and their own experience, of large numbers of chess games and had acquired high level concepts relating to the interaction of chess pieces, which could be accessed when confronted with unfamiliar games. There was, however, no evidence to suggest that these experts had superior memory systems, nor that this knowledge could be applied to tasks outside their field. It is therefore plausible that the proficiency of calendrical calculation can be explained in similar terms. That is, savants acquire information relating to the calendar, its structure and regularities, and continued exposure to such information results in the storage of this knowledge which can be automatically accessed when calculating dates.

Although most calendrical calculators have been unable to verbalise their knowledge of the calendar or the strategy employed by them when making calculations, the experiments presented in this chapter have been designed to determine the extent of their knowledge - that is, their familiarity with internal consistencies within and between years, knowledge of other structural regularities, and whether such knowledge was utilised when making calendrical calculations. Although, standardised tests of memory were completed by each subject, superior performances in memory were not expected. Instead, such testing was aimed at identifying memory processes that may be functioning within normal limits among these subjects and hence underlie their calendrical skills. Identification of memory processes within normal limits would suggest that although superior memory processes are not necessary for the development of calendrical skills, preserved memory processes in some areas may be.

Evidently the methods employed by savants are different from those based on widely known numerical algorithms, since calendrical calculators are not limited to solutions that these algorithms allow. Thus many savants can identify calendars by year and name the date on which a specific day, like the second Saturday in July, will fall (e.g., Norris, 1990; Treffert, 1989). Moreover, all known algorithms rely on considerable mathematical fluency (e.g., adding integers corresponding to the century, the year, the month and the date in the month; Addis, 1968), yet most calendrical calculators have limited arithmetical skills (Norris, 1990). Norris (1990) was able to simulate calendrical abilities, using a connectionist-model of calendrical calculations that did not require sophisticated arithmetic knowledge or insight. Instead, the model was developed from knowledge about days and dates. The model used a multi-layer back-propagation network which was able to make calculations about days, then months and then years in a manner similar to the way in which people experience days and dates. The algorithm used essentially involved a three-step procedure, with each step producing an integer which was added together to determine the day of the week upon which any given date fell or will fall. Norris' demonstration suggests that the skill of calendrical calculation involved low level processes and, given enough learning trials, a simple network architecture was trained to calculate dates. However, although plausible, the model does not explain why, if the ability to calendrical calculate is so simple, it is not more common and found, in the nonretarded population. Norris argued that nonretarded individuals lack the intense interest that the savant has in the calendar; but this then raises a question as to why the calendar attracts such interest? This chapter therefore addresses the role of memory in the development of calendrical skills, the knowledge savants have relating to the calendar and its structural regularities, and the extent to which this knowledge is involved in the strategies employed by these individuals when making their "calculations".

3.1.1. Four experiments in calendrical calculation

Internal consistencies within the Gregorian Calendar are of three kinds. Firstly, certain months within a year are paired, so that a given date in those months will fall on the same week day. Secondly, any year conforms to one of only 14 configurations of the calendar; as a general rule the calendar repeats every 28 years, although there are restrictions and in some instances the repetition occurs after only six years. Thirdly, any date advances a day in the following year except for leap years when two shifts are necessary; and moves back a day in the preceding year.

Following Hermelin and O'Connor (1986a), the broad aim of the four experiments reported here was to explore further how and to what extent calendrical calculators make use of rule-based strategies focussed on structural regularities within the calendar. Speed of response provided the primary measure for making inferences about the operations involved in the calculation of dates but number of errors and other behaviours associated with calendar features were also considered, as were reports from savants and care-givers relating to calendar performance. Participants also completed several tests of cognitive functioning, to provide information about levels of functioning outside of the area of calendar calculation.

A description of the participants recruited with calendrical skills is provided in section 3.2.1 to follow. Section 3.3 includes the results of all psychometric testing.

An account of the general procedure followed throughout the calendrical experiments is provided in Section 3.4, together with a detailed account of the specific procedure followed for Experiment 1. Sections 3.5, 3.6 and 3.7 provide specific information relevant to the remaining three calendrical experiments.

3.2. Method

3.2.1. Subjects

Ten calendrical calculators fitting a description of at least "talented savant" (Treffert, 1989) were located from several institutions for autistic and disabled persons; four from Australia and a further six from the United States[1]. Five were diagnosed as having Early Infantile Autism, although examination of the medical histories of all others suggested the presence of autistic-type tendencies. All subjects were semi-independent and could take care of their personal needs. All subjects except one (JS; who chose not to participate) received a psychometric assessment and one Australian subject (FC) did not participate in the four experiments relating to the skill of calendrical calculation due to his accidental death. All four calendar experiments were administered to the remaining three Australian subjects (BL, DB and TM) and two from the United States (DS and GF) while a further four from the United States (CT, TS, MR and JS) were involved in Experiment 2. Although individuals of both sexes attended the institutions from which the subjects were recruited, all ten subjects located with calendrical skills and subsequently involved in this study were male.

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1. The results from the four Australian subjects were published in:

Young, R.L., & Nettelbeck, T. (1994). The "intelligence" of calendrical calculators. American Journal of Mental Retardation, 99(2), 186-200.

Subject 1 (BL).

BL was an Australian male, 20 years of age, the youngest of three children. He had been formally diagnosed as autistic at age 7. He had attended a special school for autistic children but was now attending a daily work-training program for persons with disabilities. He lived with his parents. They reported noticing his calendrical skills at a young age. He owned a perpetual calendar and claimed to spend up to two days a week examining it.

Subject 2 (DB).

DB was an Australian male, 36 years of age and the second child in a family of four. He had lived in an institution for the intellectually disabled from age 8 and had attended a special school there, graduating in his late teens to a special adult work program. He currently lived in a group home and worked in a dairy supervised by the institution. His parents believed that he had calendar skills even before he saw his first calendar. DB reportedly told his mother what day of the week she was born on when he was 8 years old. He owned a perpetual calendar and had extensive knowledge of when holidays occurred and the dates when recordings of popular songs had first been released. His younger brother also had extraordinary memory of sporting events. If permitted, DB's conversation focussed on dates. He enjoyed asking about birthdates and although he may forget a name he seemed not to forget birthdates.

Subject 3 (TM).

TM was an Australian male, 22 years of age, formally diagnosed as having autistic tendencies and he had been at an autistic centre most of his life. He was living in a semi-independent home supported by the local autistic centre and worked as caretaker for the school there. He ate most meals with the school children and participated in many school outings. When shown a perpetual calendar his familiarity with it was evident, although it was unclear whether he owned one. Along with his calendrical skills, TM demonstrated extraordinary ability to spell and tended to focus on the correct spelling of names of towns. TM also demonstrated outstanding memory for all kinds of music, singers and the year songs were recorded. He was exceptionally slow, being very careful to do things correctly. He was not as overtly obsessive about the calendar as many of the other subjects, although he did like to talk about the dates of important events such as birthdays and outings.

Subject 4 (FC).

FC was male, Australian and 42 years old. He talked excessively, repeating himself often. He did not take part in the calendrical experiments because of his accidental death immediately before they began, although he had completed all tests in psychometric assessment and his results have therefore been included in the account of this in section 3.3. Little was known about his education, other than that he had attended schools within the mainstream system for about 11 years, but had been principally located in remedial classes. He had lived independently for most of his adult life, apart from periods of psychiatric institutionalisation for severe depression. FC's calendar calculations were not as automatic as most of the other participants. He was familiar with many of the rules of the calendar and could verbalise regularities such as month pairings and identical year configurations, although he claimed not to own a perpetual calendar. He could be heard verbally working things out, appearing to start from anchor dates and explaining rules about calendar regularities as he proceeded. He had an excellent memory for the weather and the dates of important events like his admission and release from various institutions and his commencement and cessation of employment. He also had excellent knowledge about all the premiers of each state in Australia (within his lifetime), including when they came to and vacated office.

Subject 5 (CT)

CT was an American (US) male aged 30. He had been diagnosed with mental retardation with autistic characteristics when he was 5 years old. He owned a perpetual calendar and demonstrated familiarity with its usage. From parental reports, his interest in calendars occupied a lot of his time. CT had a keen interest in trains and train tracks which he would constantly draw, although his artistic ability was not noteworthy. In addition, he was familiar with all types of trains and their routes. His father reportedly had an exceptionally high IQ and had a double major in electrical and mechanical engineering. His mother, from her own reports, had some musical ability.

Subject 6 (DS)

DS was American, male and 25 years of age. He had been diagnosed as autistic although it was unclear when this diagnosis was first made. He had excellent skills in music, perfect pitch, was a good speller and could name the states of the US apparently in any order requested; e.g., largest to smallest, entry into the constitution etc. He also had a good memory for other facts; such as Presidents of the United States and musical compositions and composers. He had two sisters and lived at home with his mother. When asked how he performed his calendrical calculations he said "I look at the calendar". He was able to cite the numbers which corresponded to each version of the 14 calendar configurations on a perpetual calendar and has spent considerable time studying such calendars.

Subject 7 (GF)

GF was 53, male, American and one of two twins with similar abilities. The other twin was unwell at the time of testing and therefore unable to be involved in the study. GF has had considerable media attention (e.g., the television program "60 Minutes") and several publications have discussed and analysed his abilities (e.g., Sacks, 1985; Treffert, 1989). From a young age GF spent hours examining an Almanac which contained a perpetual calendar and his calendrical calculation skills were noticed as early as 6 years of age. He could associate the correct number with any of the 14 calendar configurations on a perpetual calendar. In addition to his calendrical skills GF had exceptional memory for the dates of events and the weather for most days. Although autism has also been suspected for GF this has not been formally diagnosed. Mental retardation commonly associated with the visual defect chorioretinitis has also been proposed to explain his disability (Holstein 1964; cited in Treffert, 1989). Treffert (personal communication, October 14, 1993) also suspects that autism is not an appropriate diagnosis for GF. Nevertheless, early reports of the twins have indicated the prevalence of autistic characteristics such as rocking, swaying, acute smell, and hand-biting, although none of these characteristics is specific to autism rather than any other form of retardation. GF now resides in a group home with other individuals with intellectual disabilities. Since being separated from his twin in 1977, to encourage more "socially acceptable" development, his skills have reportedly declined and are not now as precocious as when first noticed (Treffert, 1989). Precocious mathematical ability and knowledge of prime numbers, which have been demonstrated by GF in the past, were no longer apparent when he was tested on this occasion, supporting Treffert's observations.

Subject 8 (TS)

TS was 48 years of age and diagnosed with "cretinism", although he too demonstrated autistic tendencies. He was an American male. TS had ability in musical production and perfect pitch. He had other skills such as the ability to say the alphabet backwards. He could associate any calendar year with the correct version of the 14 configurations available from published perpetual calendars; and was also able to verbalise calendar rules and had extensive knowledge and understanding of calendars. Although he was unsure when he had first developed his interest in calendars he remembers scanning an Almanac that contained a perpetual calendar when he was about 8 years old. TS attended a centre for talented musicians with intellectual disabilities and he was interested in astronomy.

Subject 9 (MR)

MR was American, male and 37 years of age. He was autistic and was bought to the author's attention initially because of his artistic ability. However, it was immediately evident that he also demonstrated skills in calendrical calculation and he was able to identify calendar configurations corresponding to particular years although his familiarity with a perpetual calendar was unclear. MR typically talked about events referring to the day of the week upon which they occurred; (for example, "I started painting on Thursday, September 12, 1977"). His ideas were repetitive and talked about events that had occurred in the distant past as though they had taken place only yesterday. For example, during an interview in 1993 he spoke enthusiastically about a friend's birthday, although in fact he hadn't seen this person or contacted him since 1970. MR attended a centre for disabled individuals where his artistic needs were well catered for. His artwork was of a very high standard and he has sold many paintings throughout the US. MR lived at home with his parents, one of whom has a PhD.

Subject 10 (JS)

JS was male, American, and 32 years of age. He had been formally diagnosed as autistic at age 2. In addition to his calendrical skills he had excellent skills in addition, multiplication, perfect pitch, knowledge of floor plans, and he had been hyperlexic when younger. He currently had an interest in prime numbers, squared numbers, telephone numbers and licence plates. He was particularly interested in certain licence plates (e.g., DT-5153) and he knew where they were located. As a reward for good behaviour he was taken out to find the cars with the plates that fascinated him. He had a keen sense of humour and often when making calculations he would answer one number below the correct one just to ensure that you were paying attention. JS was one of two savants used by the actor Dustin Hoffman as a model for the film "Rain Man". Although JS remained socially isolated he graduated from high school and now works in a library. He engaged in bizarre rituals such as rolling up his trousers to brush the hairs on his legs or wiping each book on his trousers before shelving it. He also ate certain food items with a toothpick. His father was a Professor in English and his mother had a PhD. JS was willing to participate in only one of the calendar experiments and did not wish to participate in any of the psychometric testing. In order to test JS on the calendar he required advance notice, together with detailed information relating to the testing procedure and assurances from his mother. This notwithstanding, the disruption to his normal routine created by testing about the calendar still caused him considerable distress.

3.2.2. Procedure for Psychometric Assessment

Nine of the 10 subjects completed the following battery of eight psychological tests. The Schonell Graded Word Reading Test provided a screening test of general reading accuracy and the Neale Analysis of Reading Ability-Revised (Form 2) provided a more comprehensive measure of accuracy within context, rate of reading and comprehension. The Bender Visual Motor Gestalt Test and the Hooper Visual Organisation Test were included to assess visual organisation and integration, on the grounds that if difficulties were found in these areas, this would exclude these abilities as influencing calendrical calculation. Since a lack of creativity has often been reported for savants, this was investigated using the subtest utilising pictorial materials from the Torrance Test of Creative Ability (Thinking Creatively with Pictures: Figural Booklet A). The Wechsler Adult Intelligence Scale- Revised (WAIS-R) provides a profile of both verbal and performance subtests and has been widely used among savant populations; Raven's Standard Progressive Matrices (PM) was included to test nonverbal reasoning; Wechsler Memory Scale -Revised (WMS-R) was given in its entirety because it is not clear from the literature what significance different aspects of memory may have for understanding savant performance. This test provides Memory Quotients for information presented and recalled verbally and visually which form separate memory quotients (i.e., Verbal Memory and Visual Memory) and together these yield a General Memory Quotient. Other subtests which measure memory span, orally, and logically constitute an Attention and Concentration Quotient. Scores from the recall of paired associates, visual presentations and logical information tested after a delay combine to form a Delayed Memory Quotient.

Sessions required to complete these tests ranged from 1 to 14 depending on the concentration of the subject. Regular breaks were given - at least every hour. No more than two weeks lapsed between sessions. Total testing of psychometric measures for each subject was approximately five hours.

3.3. Results and Discussion - Psychometric Assessment

Raw scores for all psychometric tests are presented in Tables 3.1 to 3.4 or are otherwise included in Appendix 3.1.

3.3.1. Reading and Comprehension (Schonell, Neale).

Reading rate and accuracy were at ceiling for three subjects (i.e. > 12 years) and all other subjects were able to read at a level equivalent to at least that of a 6 year-old child. All subjects had poor understanding of materials read except FC (reading age > 12 years for rate, accuracy and comprehension). Poor comprehension was therefore the only commonality relating to the reading ability of all subjects whose calendrical skills were formally tested, with five subjects (i.e., BL, TM, MR, TS and DS) tending to read very quickly, whereas DB, CT and GF were very slow and deliberate. These results suggest that only minimal reading ability is necessary for calendrical skills to develop.

3.3.2. Visual Organisation and Integration (Hooper, Bender).

All subjects, except TS, obtained between 22 and 24 out of a possible 30 on the Hooper test, within the normal range for visual organisation. These results were qualified, however by seven subjects making either two or three errors on the Visual Motor Gestalt Test, slightly more than would be expected among adults in the normal population. TS scored 13 on the Hooper, clearly identifying difficulties with visual integration; and this was further supported by his five errors on the Visual Motor Gestalt Test (Bender). These results therefore suggested that TS had neurological impairments which affected visual integration and therefore impairments in addition to the other subjects with autism. Taken together, the results on these tests showed that a preserved ability in the area of visual organisation and integration is not essential to calendar calculation. Thus, even if the performance for visual integration was taken to be in the normal range for most subjects, one subject clearly performed poorly in this area, but still had the ability to make calendar calculations. It was noteworthy too that the calendar responses for this subject with the difficulties in this area (TS) were significantly slower and less accurate than were those of any of the other subjects. Thus, even if some preserved ability in this area is necessary for increased automatisation and development of the skill, visual organisation and integration is not essential for the acquisition of the skill.

3.3.3. Creativity (Torrance).

All subjects showed concrete thoughts, with poor flexibility and elaboration. Some ideas were original but no subject demonstrated an ability to elaborate on these. This result was consistent for all subjects, despite one subject having precocious ability in art. Because all subjects were fairly accurate, their differences in calendrical abilities were predominantly determined by speed of answers (i.e., mean response times to the calculation of dates presented in subsequent experiments). The precocity of their calendrical skills was therefore determined by ranking the subjects in these terms. Correlations were then calculated between this speed-of-response variable (i.e., with rank 1 being the most skilled, 2 the next skilled and so on) and scores on the Torrance Test of Creativity. The only significant relationship found was between rank and creative fluency ($r = -.76$, $p < .05$; $n=9$), suggesting that fluency in thought may facilitate the subsequent development of calendrical skills. The subject DS who was ranked as the most skilled calendar calculator, also showed most fluency in his ability to produce items. Although savants may demonstrate some flexibility when tested in their skill domain (e.g., O'Connor & Hermelin, 1984a), at least in general terms, results from the present study suggested that flexibility in thought is not essential for the acquisition of savant skills.

3.3.4. Intelligence and Memory Testing.

WAIS-R, PM and WMS-R results are shown in Table 3.1. Overall, results were consistent with mild to borderline retardation, despite some subtests in the normal range, including occasional exceptionally high scores. DB performed poorly on all subtests but otherwise the scatter in the IQ profiles was wide for all other subjects.

Individual subtests within WMS-R showed diversity between areas of memory and, although some savants scored well on some tests (e.g., Figural Memory, Visual Paired Associates and Digit Span), superior performance in particular areas of memory was not uniform among all subjects. Correlations between subtests, although low, were consistent with those reported in the WMS-R Manual and reflected a common lack of unity in memory processes. The differences between selected indexes, however, were significant for some savants, suggesting that the diversity of abilities in memory may be more apparent among this population. Overall, results for the five WMS-R indexes were well below average for most subjects, supporting O'Connor and Hermelin's (1984a) conclusion that generally exceptional memory is an unlikely explanation for the calendar abilities shown by savants. Closer analysis of individual WMS-R subtests did identify an important relative strength common among all subjects, namely the recall after a time delay of information which had been encoded through paired associations. The performances of DS, MR and GF in particular on such tasks were exceptional as was their immediate recall of these paired associations. All three correctly matched the six visual association items after just one showing and DS and MR matched all eight verbal paired associations after just three presentations. All other subjects were slow when learning by association (see Table 3.2), consistent with Hill (1975). Nevertheless, given additional trials to master learning (as the WMS-R permits), all had good delayed recall of items requiring paired associations. All subjects with the exception of CT were able to recall the six items encoded in Visual Paired Associates after a delay. CT's poor recall

Table 3.1

Individual scaled scores and IQ on WAIS-R[a], PM and WMS-R.

Test Subject	BL	DB	TM	FC	CT	DS	GF	TS	MR
WAIS-R									
Subtests									
Information	07	02	06	09	07	06	06	07	06
Digit Span	06	06	07	06	05	16	08	13	08
Vocabulary	04	04	03	09	04	05	04	06	05
Arithmetic	07	02	04	04	04	12	03	06	08
Comprehension	03	02	01	11	03	03	04	05	05
Similarities	04	04	03	06	06	08	04	07	03
Picture Completion	07	05	05	07	06	05	04	06	06
Picture Arrangement	06	02	07	02	04	05	04	04	07
Block Design	09	05	10	03	08	11	05	08	10
Object Assembly	12	05	06	03	10	08	07	05	09
Digit Symbol	05	02	07	03	03	12	04	05	05
Scales									
Verbal IQ	74	65	67	82	70	88	74	87	78
Performance IQ	82	70	78	72	76	88	78	82	88
Full Scale IQ	76	65	72	76	72	86	75	84	82
PM	85	59	83	59	63	91	63	68	70
WMS									
Verbal Memory	69	59	62	77	59	64	63	87	97
Visual Memory	71	51	72	<50	66	106	70	89	100
General Memory	69	<50	54	57	50	74	55	86	96
Attention / Concentration	74	83	74	57	70	>138	95	116	86
Delayed Recall	84	77	78	76	69	81	71	73	83

[a] Scaled subtest scores on WAIS-R range from 1 to 19 (M=10; SD=3). A score of 8 or less places the adult in the lower 25% of adults and a score of 5 or below places the adult among the least able 5%. For WAIS-R scales, PM and WMS-R, scaled scores follow the conventions of mean=100, SD=15.

can be attributed to an inability to encode these associations during the initial presentation. Only three subjects made errors on the subtest which involved recall of Verbal Paired Associates after a delay, with the performance of the other subjects being errorless. BL and TS made two errors while CT made only one error. Once again CT's performance, after a delay, was affected because of his inability to encode the items during the six trials permitted by the WMS-R in the first presentations of these items in Verbal Paired Associates 1. However, he was able to recall seven of the eight items after some delay in Verbal Paired Associates 11, despite never achieving complete accuracy when the recall of items was immediate (see Table 3.3).

The standardised delayed recall scores shown in Table 3.1 were calculated by following the recommended procedure and were therefore markedly influenced by very poor initial recall of "logical memory" materials, on which most subjects scored poorly (DB, GF, MR, TS, DS and CT) to below-average (FC, MR, TS and CT; see Table 3.4).

Table 3.2

Raw scores for the recall of the six items presented in Visual Paired Associates after initial presentations and then after a delay[a]. Maximum score for each trial is 6.

Visual Paired Associates	BL	DB	TM	FC	CT	DS	GF	TS	MR
Trial 1: Initial Presentation	3	1	4	3	1	6	6	3	6
Trial 2: Initial Presentation	4	2	3	5	0	6	6	3	6
Trial 3: Initial Presentation	4	2	5	4	0	6	6	6	6
Trial 4: Initial Presentation	5	3	6	6	4				
Trial 5: Initial Presentation	5	5			3				
Trial 6: Initial Presentation	6	6			1				
Delayed Recall	6	6	6	6	1	6	6	6	6

[a] The procedure permits a maximum of six trials during initial presentation, with this phase ceasing after a minimum of three presentations - as soon as six items have been correctly recalled. Even if six items have been recalled during the first two trials each subject must be presented with three trials. There is only a single delayed trial.

Table 3.3

Raw scores for the recall of the eight items presented in Verbal Paired Associates 1 after initial presentations and then after a delay[a]. Maximum score for each trial is 8.

Verbal Paired Associates	BL	DB	TM	FC	CT	DS	GF	TS	MR
Trial 1: Initial Presentation	1	0	6	3	0	6	2	0	4
Trial 2: Initial Presentation	7	4	3	7	0	8	4	6	8
Trial 3: Initial Presentation	7	7	8	7	2		7	6	
Trial 4: Initial Presentation	6	5		8	5		7	7	
Trial 5: Initial Presentation	6	8			6		8	4	
Trial 6: Initial Presentation	8				5			8	
Delayed Recall	6	8	8	8	7	8	8	6	8

a The procedure permits a maximum of six trials during initial presentation, with this phase ceasing as soon as eight items have been correctly recalled but not before three presentations have been administered. . As for Visual Paired Associates each subject must receive a minimum of three trials. There is only a single delayed trial.

Table 3.4

Raw scores for the recall of Logical Memory after initial Presentation (i.e., Logical Memory 1) and then for recall after a delay (i.e., Logical Memory 2). Maximum score for each presentation is 50.

	BL	DB	TM	FC	CT	DS	GF	TS	MR
Logical Memory 1	12	6	6	23	24	5	7	21	25
Logical Memory 2	9	4	7	17	14	0	6	14	28

However, when comparisons were made between the initial recall of this test and that recalled after a delay, it was evident that little information had been lost. This might be expected, given that for many subjects there was little information to lose Nevertheless, the standardised delayed recall scores reflected poor initial encoding of story materials as tested by

Logical Memory, rather than poor long-term memory which, for paired associations between visual and verbal materials, was highly reliable. The relatively poor performance on Logical Memory by these savants suggests an inability to memorise information that requires semantic organisation and comprehension of the material presented. Instead, savants performed better on tasks that did not require logical comprehension of the material presented in order to facilitate recall, like items encoded and recalled using paired associations. As Jensen (1969) has pointed out, associative memory can be relatively independent from other forms of development and other cognitive processes. Jensen distinguished associative (Level 1) from cognitive (Level 2) processes and in these terms the savants had difficulties with Level 2 processes involving transformations of input; however, Level 1 abilities appeared to be largely intact.

3.4. Experiment 1: Range of Ability

The purpose of Experiment 1 was to test the range of subjects' abilities with respect to both past and future dates.

3.4.1. Method

Subjects

Following psychometric assessment, the three Australian subjects (i.e., all except FC) and two of the US subjects (DS and GF) described in Section 3.2.1 completed Experiment 1.

Apparatus

Calendar dates were presented on a 386 Acer lap-top computer with the monitor at a viewing distance of approximately 40 cm but with variation depending on the movement of the subject. Seven letters on the computer-keyboard (i.e. Q,W,E,R,T,Y,U) were used as response keys and labelled Sunday through to Saturday respectively. The speed and accuracy of the responses to dates were recorded by the computer.

Procedure

When a date appeared on the computer screen in the format date, month (in words), year, the subject identified the day of the week on which the date had fallen or would fall by moving the preferred index finger from a "home" key to the appropriate key in a response panel with seven keys labelled Sunday through Saturday from left to right. The dates presented over all experiments ranged form the year 1600 to 2215. The home key was immediately below the seven keys and was included to prevent quicker motor responding to repeated dates. Each trial began from the home key. The date remained on the screen until a response was made. Response time was measured from presentation of the date to the key press. The response-stimulus interval between trials was 5 seconds. Each subject received feedback on the screen about his performance (eg "Correct, the 18th of March 1982 was a Thursday"; or "Sorry, the 2nd of January 1991 was a Wednesday"). This mode of presentation was followed for the four calendrical experiments with each experiment lasting between 20 and 60 minutes, depending on subjects' response times to the presentation of dates.

Subjects were first presented with three blocks of 12 future dates beyond the current year 1991 and including the 21st, 22nd and 23rd centuries. There were 10 trials between 1992 and 1999, 21 trials between 2000 and 2099, and five trials between 2100 and 2215. Subjects were then presented with 36 past dates, completing 12 trials within each of three blocks representing the 19th, 18th and 17th centuries respectively. Past dates within the span of subjects' personal perpetual calendars (1901 forwards) were excluded. Thus, 72 dates were involved altogether. This experiment lasted approximately 30 minutes.

3.4.2. Results and Discussion

Subjects found this experiment difficult, with the five subjects making a total of 156 errors (M =8737.0 ms, SD=8875.7) from the total of 360 dates. Individual mean correct response times for the different epochs are set out in Table 3.5. Across all epochs, the overall mean response time for the correct dates from the five subjects combined was 7401.7 ms (SD=6142.4, N=204). Response times were standardised within subjects to eliminate between subject variability. The overall difference between correct and incorrect responses for the five subjects was highly significant, ($t(358)=2.96$, $p<.01$), with errors being slower. This is contrary to Rosen's (1981) finding, although he found very few errors in his study. Significantly slower errors were confirmed for BL, ($t(70)=2.57$, $p<.05$) and DB, ($t(70)=5.9$, $p<.01$) and GF ($t(70)=2.44$, $p<.05$). No significant difference was found for TM ($t<1.0$) and the incorrect responses were, in fact, faster for DS ($t(70)=-3.50$ $p<.01$; see Appendix 3.2.1). Errors ranged from 21 for BL and 22 for DS to 33 for TM, 37 for GF and 43 for DB.

Each subject was able to respond with high accuracy to the dates from the 20th and 21st centuries. BL and GF were most accurate across the widest range of dates but dates prior to 1800 presented considerable difficulty for all subjects. The other three subjects experienced considerable difficulty with dates from beyond those included on perpetual calendars which typically cover 1901 to 2100. That is they could not correctly respond to dates from the sixteenth, and seventeenth centuries and nor could they respond to future dates beyond this century (see Table 3.5). Thus, accuracy for all five savants was very high within certain limits, with errors contained to specific epochs and being markedly slower for four of five subjects, consistent with uncertainty. Although the responses of DS were also limited to specific epochs, the speed of his correct responses were unaffected by the duration the date presented was from the present year. This suggests limitations to whatever strategies subjects were using; and tends to eliminate arithmetic computations as a significant explanation because these can be applied to future and past dates equally and are not generally limited to specific epochs.

Table 3.5

Experiment 1: Mean correct response times (ms) and SDs to dates from different epochs for BL, DB, TM, DS and GF.

		Future Dates			Past Dates		
Subject		1992 - 1999 (n=10)[a]	2000 - 2099 (n=21)	2100 - 2215 (n=5)	1800 - 1899 (n=12)	1700 - 1799 (n=12)	1600 - 1699 (n=12)
BL	M	7376 (8)[b]	6673 (19)	7237 (4)	5751 (12)	8757 (6)	8325 (2)
	SD	3583	3399	1322	1672	5090	956
DB	M	4081(9)	4957(20)	(0)	(0)	(0)	(0)
	SD	653	1939				
TM	M	10084 (9)	14213 (20)	34792 (1)	10053 (3)	10214 (4)	2761 (1)
	SD	7400	12399		3077	6203	
DS	M	3787 (9)	4317 (17)	5349 (1)	3982 (5)	4081 (1)	1018 (2)
	SD	1215	2338		1134		282
GF	M	5353 (9)	7351 (21)	11390 (3)	8836 (11)	8777 (4)	13782 (2)
	SD	930	4453	10940	3259	4270	1124
Overall	M	6095 (44)	7552 (97)	11473 (9)	6977 (31)	8839 (15)	7001 (7)
	SD	4308	713	10593	3111	4854	5587

a) n= number of dates presented
b) number of correct responses are in parentheses

3.5. Experiment 2: Month, Leap Years and Familiarity

Given the results from Experiment 1, the dates selected for Experiment 2 were well within the range within which subjects could correctly respond (i.e., between 1991 and 1984 inclusive). The presentation of dates was structured to test the three hypotheses set out below.

Hypothesis 1. Subjects utilise the rule that the date in a given month may fall on the same day as the same date in another month. This hypothesis followed Hermelin and

O'Connor's (1986a) conclusion and the experiment was effectively a replication of their first experiment. In non-leap years, February, March and November constitute a common group, with April - July, September - December; January - October as pairs. In leap years the pairs February - August, March - November, September - December and group January - April - July have identical structures. Pairing common dates and presenting these successively would permit a subject to avoid reworking whatever algorithm was involved on these repeated instances. Thus, response times to the second date in each pair would be faster if the subject used the rule.

Hypothesis 2. Little attention has been given to differences in response times to dates from leap and non-leap years. Rosen (1981) found that leap years had little effect on response times, although there were other variables not held constant in his study, like day of the month, which may have influenced the result. In addition, less than half the dates he presented (48/192) were in leap years. Because leap years occur less frequently than non-leap years, it was predicted that, if subjects were less familiar with the structures within leap years, then responses would be slower to leap year dates.

Hypothesis 3. At issue was the extent to which savant abilities are relatively rigid. If subjects remembered dates previously encountered and had the flexibility to adapt processing accordingly without recalculation, then response times would be shortened.

3.5.1. Method

Subjects

All subjects outlined in Section 3.2.1 (except FC) were involved in this experiment.

Procedure

All nine subjects first completed eight blocks of 12 dates, with the month varying within each block but the date and the year remaining the same. The correct response to these dates (i.e. the day of the week) was the same as the response to follow, because of calendar structure. This arrangement permitted a test of hypothesis 1. Paired months followed each other, so that the correct response would be the same (see for example, the first three entries in column 1 of Table 3.6). According to the same logic as outlined for hypothesis 1, above, it was argued that, if subjects were aware of these pairings, then response times to replications (hereafter termed "Paired Showing" responses) would be significantly shorter, compared to initial presentations and dates not repeated (hereafter termed "First Showing" responses). In terms of the illustration in Table 3.6, shorter times should be found for those items not set in bold, compared with those set in bold.

Table 3.6

Order of presentation of dates for two blocks in Experiment 2.

Non-Leap Year	Leap Year
2nd March 1991 (Saturday)	**2nd August 1988 (Tuesday)**
2nd February 1991 (Saturday)	2nd February 1988 (Tuesday)
2nd November 1991 (Saturday)	**2nd March 1988 (Wednesday)**
2nd May 1991 (Thursday)	2nd November 1988 (Wednesday)
2nd August 1991 (Friday)	**2nd May 1988 (Monday)**
2nd April 1991 (Tuesday)	**2nd January 1988 (Saturday)**
2nd July 1991 (Tuesday)	2nd April 1988 (Saturday)
2nd June 1991 (Sunday)	2nd July 1988 (Saturday)
2nd September 1991 (Monday)	**2nd June 1988 (Thursday)**
2nd December 1991 (Monday)	**2nd September 1988 (Friday)**
2nd October 1991 (Wednesday)	2nd December 1988 (Friday)
2nd January 1991 (Wednesday)	**2nd October 1988 (Sunday)**

Note: Dates presented first in a group of repeated correct responses (i.e., Paired Showing responses) and dates which were not paired (termed First Showing responses) are shown in bold (see text). Correct responses are shown in parentheses.

Since there are different paired-month structures in leap and non-leap years, the first four blocks involved the non-leap years 1991 and 1982 and the next four involved the leap years 1988 and 1984, permitting a test of hypothesis 2. Two examples of these arrangements are set out in Table 3.6. Thus, the subject received 48 trials for both leap years and non-leap years. Because temporal remoteness has been found to affect response times (O'Connor & Hermelin, 1984), the dates of leap-years and non-leap years were approximately equally close to the current year (averaging 5 years for leap years and 4.5 years for non-leap years).

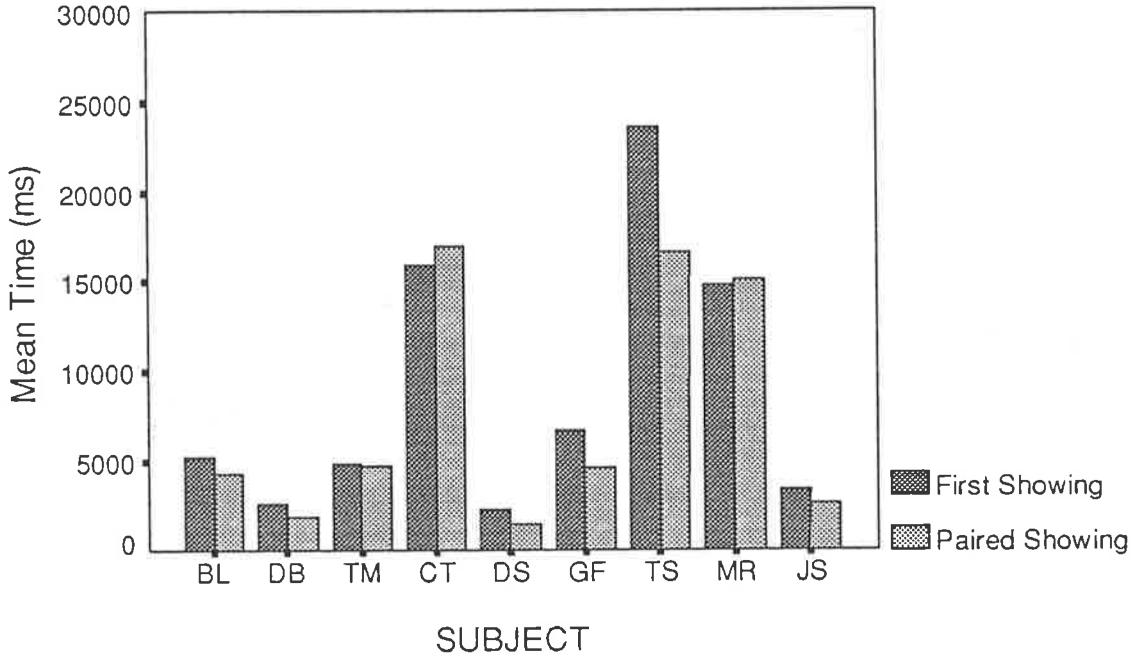
Subjects were then presented with a ninth block which replicated the first block, to test if subjects were quicker to respond to these dates, given that they had already encountered and answered them (hypothesis 3).

3.5.2. Results and Discussion

The accuracy (i.e., correct identification of the day corresponding to the date) of eight of the subjects was near perfect with errors ranging from 0 to 8 (M=2.5, SD=2.4, n=8) from the 108 dates presented to each subject. The accuracy of the other subject (TS), although better than the chance level of 15/108, was poor compared to the others. He made 50 incorrect responses, scoring 58 correct from the total of 108 dates presented to him. His response times were also slower then the response times of all other subjects as discussed further below. The responses of CT and MR were slower than those of the other subjects and therefore appeared to be less automatic . Incorrect responses for all subjects were excluded from the analyses. After excluding Block 9 because these dates were all repetitions, response times for First Showing and Paired Showing responses were separated. Individual performances are shown in Figure 3.1. For group analyses, each subject's response times were standardised (within subjects) to eliminate the effect of between-subject variability.

Figure 3.1

Individual mean correct response time (ms) to dates in First and Paired Showings from Experiment 2.



3.5.2. i) First showing and paired showing responses.

A two-way analysis of variance (ANOVA) using the variables Showing (i.e. First Showing *v* Paired Showing) and whether the year was leap or not revealed that correct Paired Showing responses were on average shorter than those in the First Showing (F (1,795)=7.4, $p<.01$; see Appendix 3.3.1). This was consistent within both leap and non-leap years. Although the interaction effect of subject was non-significant, post-hoc analyses using Newman Kuels revealed that the responses from CT, TS and MR were significantly slower than the responses from the other five subjects ($p<.05$). The responses of GF were slower than DS, DB and JS but not TM and BL, although significantly quicker than MR, CT and TS When the responses of the four slower subjects were compared with the five faster subjects the difference in combined response times was significant (t(794)=18.2, p<.01; see Appendix 3.3.2) It is therefore reasonable to suggest that the processes utilised by the slower individuals may have been different from those whose processing had become more spontaneous and automated, making group analyses somewhat inappropriate.

In support of this suggestion individual ANOVAs found that not all subjects were making use of Paired Showings under all conditions. Four subjects demonstrated faster responses to Paired Showings in non-leap years (i.e., BL, DS, GF and TS) with three (DB, DS and GF) showing the same outcome in leap-years. One subject appeared to only benefit from this strategy in leap years. Five subjects did not respond any quicker to the Paired Showings, two of whom actually had slower responses to such dates (see Appendix 3.3.3).

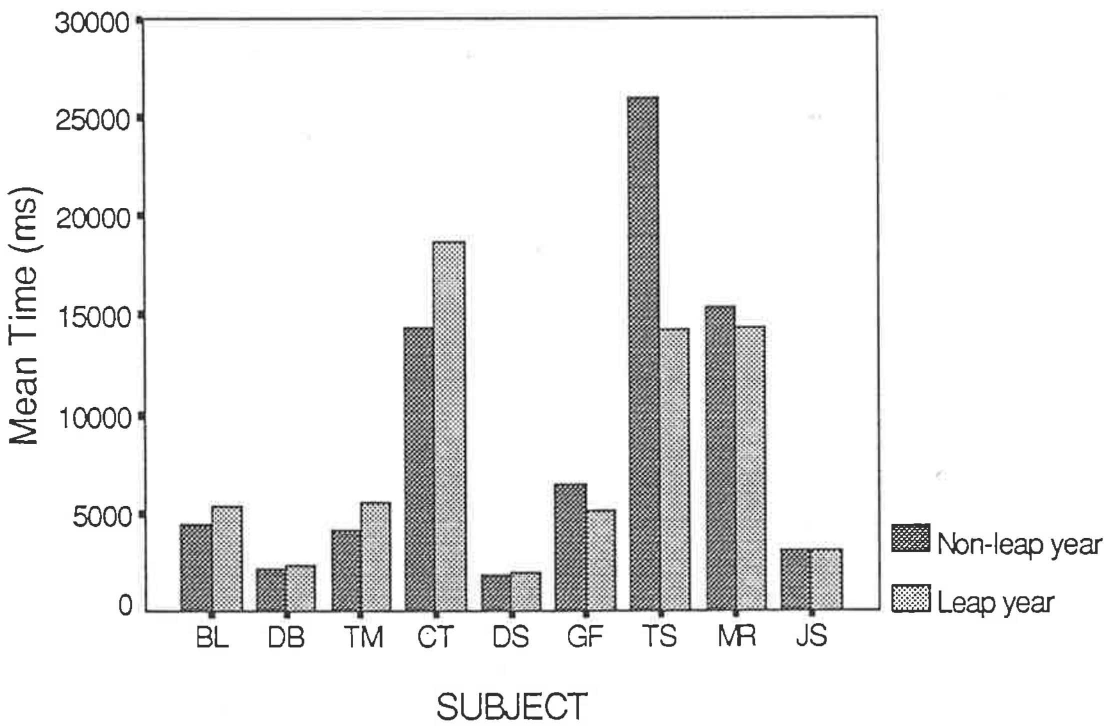
From verbal reports it was clear that some subjects were aware of month pairings because they could extend a sequence which began February, March by correctly stating "November" (see Table 3.6) and continue with identical months in the proceeding year. Nevertheless, this knowledge was not used by all subjects and, if used, it was not applied under all conditions. It was also clear that response times to Paired Showing presentations were not as quick as one might expect had subjects been utilising this rule extensively. Even among the seven subjects who overall were quicker for Paired Showing responses, the relative gain for the faster subjects was generally less than one second, although for TS it was eight seconds. Thus, presentation of the second month paired with the first month did not appear on the whole to result in subjects modifying their normal strategies. These findings suggest that although subjects may be aware of month pairings, and some may use this information under some conditions, it is not an integral component of their performance. Thus, the key to understanding processes underlying savant calculations must lie elsewhere than with the consistent use of knowledge about paired months.

3.5.2. ii)Leap and non-leap years.

Investigation of differences in response times between leap and non-leap year for the nine subjects combined showed no significant difference between year types. However, four subjects were quicker when responding to dates from non-leap years (i.e., BL, TM, GF and TS), consistent with greater familiarity with these (see Figure 3.2). One subject (TS) showed significantly faster response times to dates presented from leap years than non-leap years ($t(50)=2.6$, $p<.05$). This may, however, have been because leap-years were presented after non-leap years and this subject seemed to improve throughout the experiment as his familiarity with the procedure developed. In hindsight, these blocks should have alternated between leap and non-leap years, balanced for order across subjects, instead of the clustered arrangement followed (see Section 3.5.1).

Figure 3.2

Individual mean response time (ms) to dates in Non-leap and Leap-years from Experiment 2.



3.5.2. iii). Comparison of Block 1 with Block 9.

Only one subject (TS) responded more rapidly to the replication of Block 1 dates presented in Block 9 ($t(12)=2.4$, $p<.05$), although most commented that they had seen the dates in Block 9 before. The improved performance of TS, however, was consistent with his general improvement in response times as the experiment progressed. Significant correlations ($rs=.89$, .95., .93 and .66, $ps<.05$) between response times to Blocks 1 and 9 for BL, CT, TS, and MR respectively suggested that they were continuing with the same strategy without modification throughout the experiment, despite prior exposure to the dates as well as increased familiarity with the order of presentation. However, nonsignificant correlations for the other five subjects suggested that familiarity with the design of the experiment may have influenced their strategies. Although one might expect replication of dates to facilitate performance only the responses of TS were significantly faster in Block 9. For the other subjects the replication of dates only confused them, with several stopping to tell the author they had already been presented with these dates. Thus, despite evidence that subjects were aware that they had previously encountered the dates in Block 9, none clearly demonstrated flexibility when recalculating.

3.6. Experiment 3: Calendar Configurations

It was noted by chance that one of the subjects (BL) was aware of the numbers associated with each calendar configuration as presented on a perpetual calendar. There are only 14 configurations of the calendar, each year conforming to one of these. On a perpetual calendar each year is allocated a number from 1 to 14. Questioning determined that these savants were aware of these correspondences; all subjects with the exception of TM were able to give correct numbers (i.e. 1 to 14) for each year from a perpetual calendar within the 20th century. Although TM was not able to number years, he knew which years were identical in structure. Given that all these savants had this knowledge, it was tested to determine if this familiarity assisted their calculations. If so, then response times would be quicker within arrangements where years had the same configurations.

3.6.1. Method

Subjects

The five subjects involved in Experiment 1 again participated in this Experiment. The additional subjects recruited for Experiment 2 (i.e., CT, TS, MR and JS) were unavailable for this experiment due to the large personal commitment required by each subject (all of whom except JS were particularly slow when responding) and the associated disruption to their normal routine.

Procedure

Subjects were first presented with four blocks of 16 trials. The first eight dates in each block were from the same calendar configuration; seven of the eight were past dates and the final one a future date. The second eight dates were from different configurations of the calendar, with seven past and the final future. Month and date were constant within each block. Subjects were then presented with a fifth block of eight trials, involving leap years, with four dates from leap years of the same configuration and four from leap years of different configurations; three of four were past dates, with the final a future date. The total number of dates presented to each subject was therefore 72. Testing time for Experiment 3 was approximately 20 minutes.

3.6.2. Results and Discussion

Only 9 errors were made from the total of 360 dates presented to the five subjects and these were removed for subsequent statistical analysis. Correct responses were converted to standard scores within subjects and analysed for the blocks presented in the same calendar configuration compared with different calendar configurations.

ANOVA of combined data for the five subjects using the variables calendar configuration (same v different), year (non-leap v leap year) and subjects indicated that responses were significantly faster within same calendar configurations, ($F(1, 349)=19.9$, $p<.001$). Effects for subjects and year were not significant ($F<1.0$ for both; see Appendix 3.4.1). The configuration difference across all subjects was significant within both non-leap years, ($t(187)=4.9$, $p<.001$) and leap years, ($t(22)=4.51$; $p<.001$). Individual ANOVAs for each subject (configuration x year) confirmed that each individual was significantly quicker for responses to dates within the same calendar configuration (Fs between 2.9 and 7.8) except GF whose responses were quicker but not significantly so(see Appeddix 3.4.3). Nevertheless, GF was familiar with the consistency within calendar configurations. The responses of GF are questionable for this experiment and the following experiment, because he developed a ritual of touching each response pad from Saturday through to the correct date (i.e., working from left to right) before indicating his response. Results are summarised in Table 3.7; they suggest that each subject, even GF, was using his knowledge of identical configurations across years when responding and could do so for leap years as well as for non-leap years.

Table 3.7
Experiment 3: Mean response times (ms) to dates within the same calendar configuration compared to dates from years with different calendar structure, for leap and non-leap years. (N= number of dates presented).

		Non-leap year				Leap year			
Subject		N	Same Configuration	N	Different Configuration	N	Same Configuration	N	Different Configuration
BL	M	32	3087	32	5895	4	2887	4	10180
	SD		2229		2035		1994		7527
DB	M	32	3192	30	3890	4	2159	4	4914
	SD		2075		1617		379		1812
TM	M	32	4793	32	7256	4	2810	4	6557
	SD		4229		4384		1678		1789
DS	M	31	1953	28	2678	4	2484	3	5466
	SD		1045		1485		921		783
GF	M	32	4469	31	5524	4	5232	4	5961
	SD		2613		1955		4623		2924
Overall	M	159	3467	153	5056	20	3073	19	6375
	SD		3292		3068		2344		4104

3.7. Experiment 4: Rule Based Strategies

This experiment investigated use of the rules that in non-leap years the day of a date in one year will be the following day in the next year and the previous day in the preceding year; working forward from a leap year a day is skipped (e.g. Thursday to Saturday) but for the preceding year the rule is as for non-leap years. It is evident from Hermelin and O'Connor's (1986a) analysis that some of their subjects did know these rules since they could abstract them for transfer to an analogous arrangement of colours. However, it does not necessarily follow that knowledge about a rule will result in its application when making calculations. It was expected that, if dates presented conformed to these rules and subjects became aware of this and made use of them, then response times should become shorter. In the event that subjects did not adopt the foregoing strategy, it was possible to test Hill's (1975) observations that the day on which a date falls and the day of the week with which a year begins may be important cues.

3.7.1. Method

Subjects

All five subjects who participated in Experiments 1 and 3 were again involved in this Experiment (i.e., BL, DB, TM, DS and GF).

Procedure

All five subjects were presented with 40 dates. The date and the month remained the same for each presentation (i.e. January 13), the only variable being the year. The initial date was from the year 1991, with dates for successive trials being one year prior to that just completed. After the presentation of 20 past dates, 20 for future years were presented chronologically, beginning again at 1991. The years 1977 and 2007 were omitted, to check that subjects were not anticipating the correct response required before presentation of the date. Dates therefore ranged from 1971 to 2011). If subjects detected this invariant pattern and used it, then subsequent response times should be reduced.

3.7.2. Results and Discussion

Six errors (M=4589.5, SD=4199.0) made in this experiment were excluded from analysis. Every subject successfully skipped two days where 1977 and 2007 were omitted, confirming that they were not simply utilising the pattern without checking.

Regression analysis indicated no trend in the data to suggest that subjects were aided by the regularities in this experiment. As shown in Figure 3.3, there was considerable variability both within and between subjects but otherwise performance was generally uniform across the full span of years examined. There was no suggestion of a slower response on the first trial followed by an improved performance and subjects' mean response times to dates presented in this experiment, either for dates in the future or the past (see Figures 3.3 and 3.4), were consistent with response times for the first three experiments. These results suggested that the savants did not simply have a date in the current year from which they worked, as has been suggested by others (e.g. Rosen, 1981). Moreover, speed of responding generally suggested that their skills were in most instances more automatic, rather than based on the utilisation of this rule.

One-way ANOVA using the data from the five subjects combined showed no significant difference in response times, depending on which day of the week the response fell. However, individual one-way analyses of variance did demonstrate that BL responded more slowly to Thursdays ($F(6,33)=4.30$, $p<.01$), whether leap years were included or not. No other subjects responses differed significantly depending upon which day of the week the dates fell (see Appendix 3.5.1).

Figure 3.3

Response times (ms) to future dates presented in Experiment 4.

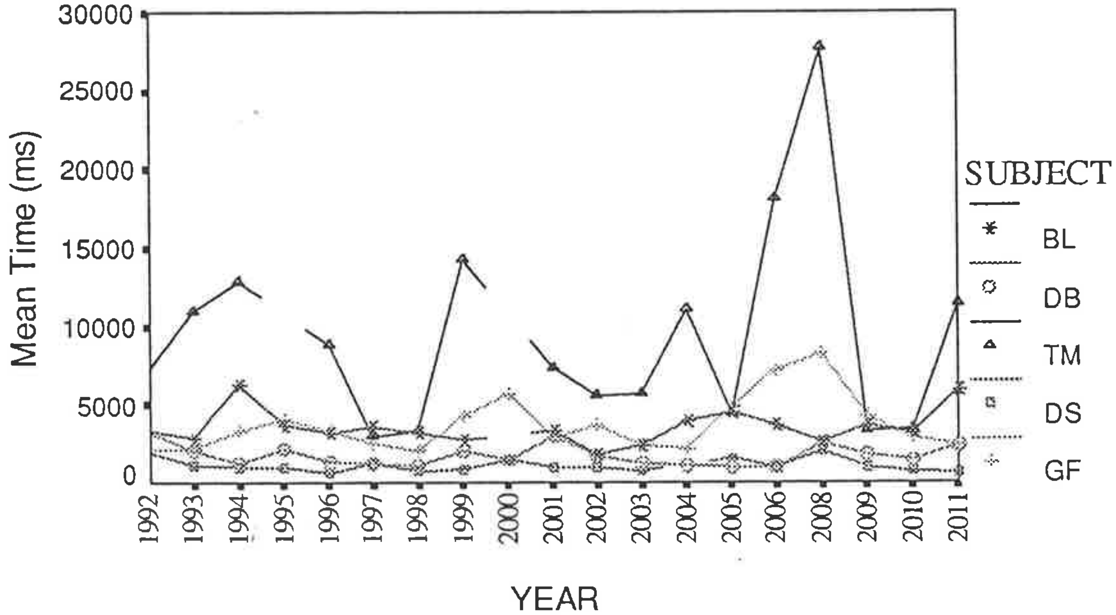
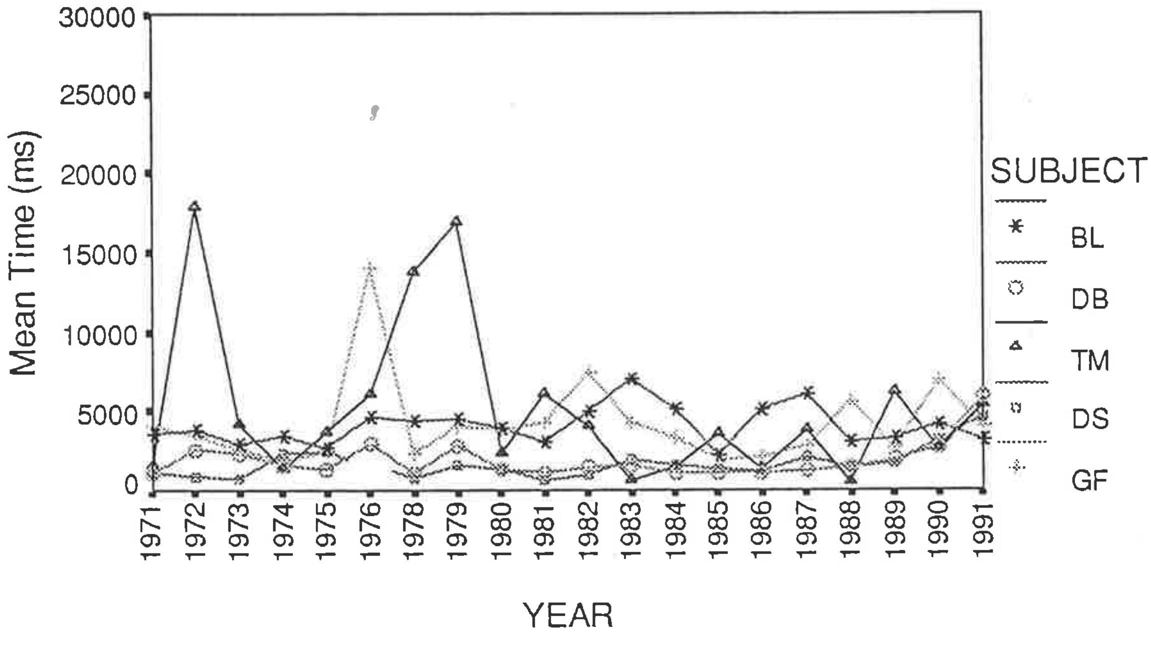


Figure 3.4

Response times (ms) to past dates presented in Experiment 4.



While the weekday on which a date falls, and with which a year begins were both reported by Hill (1975) to be significant variables, no commonality was found among these subjects, ruling out the possibility of generalisation. Because MR, in earlier experiments, had been heard to calculate dates by commencing with March 1, the years that had identical configuration beyond that date were compared, rather than the years that commenced on the same date. However, no significant differences between response dates to years with identical configuration beyond March 1 were found.

3.8. General Discussion

3.8.1. Practice and Perpetual Calendars

Behavioural observations, together with reports from the families of all ten subjects, suggested that all have had a long-standing, strong interest in calendars and have devoted considerable time to the study of calendars and dates, although it was not possible to determine how much. Certainly, however, each savant has had access to a perpetual calendar and was found to be familiar with the rules associated with its structural regularities. Subsequent to their involvement in the experiments all, 10 subjects were asked to identify the number associated with a particular year on the perpetual calendar. A selection of five or six years was presented from the 20th century. All subjects were familiar with the internal consistencies of year configurations within the calendar, with nine of the subjects being able to verbalise the number associated with that configuration. Only one subject was unable to provide the correct numbers, identifying the different configurations, although he was able to nominate all years with identical configurations within the 20th century. Overall the results from Experiment 3 showed that subjects were operating within a system consistent with such knowledge. One savant reported that he spent more than two days a week looking at the calendar, although family members thought that it was considerably less. According to family and subject reports, a feature common to all subjects was the sudden emergence of an interest in calendars at about

6 or 7 years of age, with no specific influence or trigger. These accounts support Jensen's (1990) idea of an innate capacity to perform the task upon which practice capitalises. (The nature of that capacity is discussed below.) From these reports, early skills among these savants were not as advanced as their current prodigious levels and it seems unlikely that this skill developed to such a level without extensive practice based on the study of the calendar and its configurations. Savant literature consistently supports the role of practice in the development and maintenance of calendrical calculations and other savant-type abilities (eg. Anastasi & Levee, 1960; Comer, 1985; Hoffman & Reeves, 1979; Tredgold, 1923). However, although biographies indicate that practice is necessary for the development of a skill, this does not account for its origins. Many autistic individuals have a tendency to engage in repetitive behaviour but few become savants, so that practice alone cannot account for the ability.

3.8.2. Calendar Calculation: How do they do it?

Consistent with previous findings (Hermelin & O'Connor, 1986a; Howe & Smith, 1988; Rosen, 1981), Experiments 2 and 3 found that all subjects had a knowledge of calendar regularities. All were aware of common day-date relationships across months and of common calendar configurations. Furthermore, some subjects were found to be more familiar with the structures of non-leap years. From Experiments 3 and 4 it was clear that the strategies followed by these savants were stable, rigid and not modified to incorporate calendar regularities emphasised by the experimental procedures, when to have done so would have facilitated and therefore reduced response times. Previous research finding evidence for knowledge of calender rules among savants (eg Rosen, 1981) has assumed that this knowledge would be incorporated in calendrical calculations. While the use of some calendrical knowledge may form part of the strategy, the analyses indicate that this is not always the case.

From Experiment 3 it was apparent that all subjects could associate a specific calendar's configuration with a particular year and that this formed part of their strategy for a solution.

Similarly, Hermelin and O'Connor (1986a) found evidence of this strategy, with future dates in a year with the same calendar configuration as the then current year (1984) being recalled faster than those closer in time to the current year but with different configurations. As a check on specific knowledge of this kind, each subject in the present study was presented briefly (approximately 5 seconds) with an unidentified calendar which all correctly identified as 1993. When asked if it could be any other year, all except one (MR) correctly identified the past years from within their perpetual calendars - 1982, 1971, 1965, 1954 back to 1909. MR was also able to extrapolate these years but he incorrectly included some leap years among his responses. This extension of calendrical ability has not, to the author's knowledge, previously been reported. Not surprisingly, the subjects could all respond to dates from the calendar when the presentation was limited to a brief exposure of less than a few seconds. However, as shown in Experiment 1, although these associations appeared to be spontaneously available within distinct ranges, for years beyond these all subjects experienced difficulties.

Specific knowledge in this sense would explain results from previous research with calendrical savants. Thus, while Hurst and Mulhall (1988) believed that eidetic imagery may have been involved, it seems plausible that their subject, having simply identified the calendar presented, could therefore respond rapidly and correctly. Recent research by Ho, Tsang and Ho (1991) is in agreement with the current findings. Their 19 year-old Chinese calendar savant had the ability of converting the Gregorian calendar to the Chinese calendar, as well as unusual memory abilities consistent with those found among these savants, such as knowledge of song titles and bus routes. These authors have discounted eidetic imagery, high-speed calculation, use of calendar regularities or monthly configurations to explain their subject's achievements, favouring instead a highly developed familiarity with the 14 calendar templates and a strategy of matching these templates to every year.

It is concluded that the savants in this study were not reliant on mathematical algorithms, since they demonstrated some use of rule-based strategies in a way not consistent with the use of any known algorithm. Moreover, evidence from Experiment 1 which indicated a limited range of dates for which they could calculate days is not in accord with the use of such an algorithm. Finally, a mathematical algorithm could not account for some aspects of their responses. For example, each savant could label a calendar configuration with several appropriate years, all could work from the day of the week to produce dates, and all could correctly respond to questions such as "on what date will the fourth Monday in February, 1993 fall" - all manipulations of calendrical configurations for which a mathematical algorithm cannot be applied.

3.8.3. Calendar Calculation, Concentration and Memory

Subjects' abilities to concentrate in the calendar experiments were in each case remarkable and consistent with other investigators' observations of exceptional concentration for long periods of time among their savant subjects (e.g. Hill, 1975). Certainly, the extensive concentration and motivation that savants direct toward their area of competence appear to be critical to any understanding of savant syndrome. However, while Hill (1975) believed that concentration was responsible for savants' achievements, he specifically excluded a special capacity to memorise as being involved. It is not clear, however, exactly what Hill meant by "special". Certainly, the results of the present study support Sack's (1985) view that memory is also important. Despite generally poor performances on WMS-R, all nine subjects demonstrated unusual and specific memory skills - in the sense that these were above levels predicted by other ability test results - in some areas of WMS-R, as well as in other areas not measured by this test. The most noticeable feature to arise from formal testing was reliable delayed recall of information that had been encoded through verbal and visual association. Because the score for delayed recall (see Table 3.1) also reflects information logically encoded, poorer performance in this aspect masked the contribution of good associative memory performance to the overall score. Besides this evidence from WMS-R, associations between calendars of identical configuration were understood and learned by all subjects. The ability to associate material with already learned and meaningful material has been noted among other savants with varying abilities (e.g, Hunt & Love 1982; Conners, 1992). Moreover, all savants demonstrated extraordinary recall of birthdates, visits, special events, record release dates, sporting results, work history, and the weather; all obviously memory-dependent. These observations are consistent with other studies finding good applied long-term memory, despite poor performance on memory tests (e.g., Goodman, 1972; Rosen, 1981). Thus, these findings have clearly indicated that a well-developed, associative long-term memory, as demonstrated by all subjects here, is critical to the development of savant skills associated with calendrical calculations.

3.8.4. Calendar Calculation and Cognitive Processing

The results of this study are consistent with Hermelin and O'Connor's (1986a), that while the extent to which rule-based strategies underpinning calendrical calculation can be manipulated may in principle be IQ-dependent, intelligence is not necessary for the straight-forward application of rules. Furthermore, while the relevant rules are complex, they are rigidly applied and application is heavily dependent on the retrieval of information stored through rote memory. From the foregoing four experiments it was apparent that the skills of these savants were markedly inflexible and not readily adapted, manipulated or modified, even when to do so would have made the task easier. Their approach was based on specific knowledge about calendars but appeared to require no modification or transformation of the input for subsequent recall. These abilities were therefore consistent with what Jensen (1969) described as Level 1 processing i.e., simple associative learning requiring little cognitive manipulation of cognitive stimuli, which becomes automatic because of extensive practice, making the correct answer immediately accessible for recall. Jensen (1990) described this automatisation in associations by analogy with calculations such as those involved in our times tables, or grammatical rules that we have long been able to use but, without necessarily being able to verbalise them. It is possible that long-term memory is enhanced under such circumstances, because reproduction is not influenced by elaborations or distorted by construction (Bartlett, 1932).

Shiffrin and Schneider's (1977) account of "automatic processing" also plausibly describes the ability demonstrated by the savants in the current experiments. Automatic processing is held to be well-learned and to involve abilities that are not hindered by short-term memory, do not require attention, involve considerable training and, once learned, are difficult to modify. Moreover, the speed of such processes will "usually keep their constituent elements hidden from conscious perception" (Shiffrin & Schneider, 1977, p160). The other fundamental processing mode in this model is "controlled processing", involving instruction and attentional capacity, and which is more flexible and can be modified.

While controlled processing may be involved initially in the acquisition of calendrical calculation ability, as the sequence is continually repeated it gradually becomes more automatic. For the three subjects whose performance was not automatic (i.e., MR, CT and TS) it is likely that their skills were still "controlled". Consistent with this, these subjects were able better to verbalise the strategies which they employed when making calculations, together with the structural rules and regularities of the calendar. When MR calculated dates he appeared to work from an "anchor date" of March 1st. If asked to calculate February 4th, 1959 for example, he was immediately aware that March 1st that year was a Thursday, and therefore February 29th was a Wednesday as was February 1st. He would then conclude that February 4th was a Saturday. Similarly, TS told the author that calendars 1 and 14 were similar, as were 2 and 8, 3 and 9, 4 and 10, 5 and 11, 6 and 12, and 7 and 13. He explained that "when the calendars were similar, usually the following month starts on a different day". Although the relevance of this comment was at the time lost on the author, it subsequently became apparent that the years TS perceived as being the same did not start on the same day, but instead March 1st was on the same day, consistent with the strategy and knowledge employed by MR.

Most perpetual calendars viewed by the author began in 1901. This might explain CT being unaware that 1900 was not a leap year. He assured me that it was a leap year because 1904 was a leap year. When it was explained to him that the four-year rule for leap years did not always extend to the turn of the century and, instead, such years had to be divisible by 400, he became quite distressed. His knowledge was consistent with having familiarity with the structures and regularities of the calendar as presented in perpetual calendars. The explanations offered by the other subjects provided no insights into the methods which they employed. Because the remaining subjects were significantly quicker when responding to dates, this is consistent with increased automatisation of processing.

The separation of processes in the manner outlined by Shiffrin and Schneider (1977) and by Jensen (1969) is consistent with the proposition that calendrical calculations are automatic responses that are to a limited extent rule-based, resulting from intense practice and rote learning of those rules. The controversy that savants have created for the unitary model of intelligence (Gardner, 1983; Howe, 1989a) assumes that their abilities involve "intelligent" cognitive processing but the four experiments reported in this chapter challenge this view. Nonetheless, how the complex rules required for calendrical calculation are acquired in the first place remains a critical issue. It is suggested here that the initial acquisition of relevant rules is dependent on an external source of knowledge which, with practice, becomes more automated.

Chapter 4

A comparison of savant skills and cognitive abilities.

4.1. Introduction

Generalisations about savants are difficult, due to the rarity of such cases and because of the unclear and anecdotal nature of early accounts which have mostly involved single-case studies. It was therefore desirable that the current study should involve a large number of savants, to enable more systematic comparisons to be made than have previously been achieved; and consideration of whether generalisations could be drawn. On the basis of literature reviewed in Chapter 1 the possible involvement of variables that might affect the development of specific savant skills was considered. These were (i) general and specific levels of cognitive functioning and whether there is a relationship between level of skill expertise and levels of cognitive abilities; (ii) to what extent the types of savant skills usually found depend on particular cognitive processes and / or environmental opportunities; (iii) the role of practice in the development of savant skills; (iv) whether creativity is involved particularly in artistic / expressive areas like music and graphic art; and (v) ability levels among family members.

4.1.1. Savant Syndrome and Cognitive Functioning

Research suggests that there are commonalities in the strengths and weaknesses found in cognitive abilities among savants. For example, Hill (1978) suggested that savants can be divided into three categories based on the constructs of Performance IQ and Verbal IQ as defined by the Wechsler Scales. The first category involves skills apparently based on rote memory (i.e., verbatim recall requiring little understanding of content), like calendar calculation; according to Hill such cases tend to produce similar scores on tests of Verbal (VIQ) and Performance (PIQ). The second category applies to individuals skilled in music, with such cases tending to have a higher VIQ than PIQ. For the third category, where graphic art (drawing, painting, sculpture) is the skill of expertise, PIQ is usually higher. However, later analyses of data presented in the literature (e.g., O'Connor, 1989) have not always supported this categorisation of savants based on differences between VIQ and PIQ. Moreover, even if Hill's observations were established as reliable, it is not clear how such categories might be interpreted. It has long been apparent that the factor structure of the Wechsler Scales is not best described in terms of the VIQ-PIQ dichotomy (Bannatyne, 1974; Kaufman, 1975, 1981) and that this distinction is almost certainly an oversimplification. VIQ and PIQ are each derived from several subtests, scores across which are not infrequently markedly different and therefore not consistent with a relatively homogenous construct, as implied by Hill's treatment of these quotients (see Szatmari, et al., 1990).

In the research presented here, factor analyses of the subtests used to estimate VIQ and PIQ from the Wechsler scales have been conducted, to determine if divisions based on performances on these subtests are appropriate. The objective has been to determine whether savants who demonstrate similar skills, albeit at different levels of ability, have commonalities in their intellectual profiles; and if these profiles are in some way different to those for savants with different types of skills. Alternatively, common cognitive abilities may be more indicative of level of ability rather than type of skill. Relationships between skill and cognitive performance, as indicated by speed of information processing and memory have also been investigated. Finally, the possible relevance to the development of savant skills of other common characteristics frequently reported among savants, such as language delay, obsessive pre-occupations and other behavioural abnormalities, has been investigated.

4.1.2. Types of cognitive processing.

Because differential diagnosis on the basis of the VIQ-PIQ dichotomy has been found to be inadequate among the autistic population (Lincoln, et al, 1988) other factors extracted from the Wechsler Scales of Intelligence were investigated, with the primary objective being to make inferences about the cognitive processes underlying such factors. Of particular interest were processes relating to dominance by either the right or left hemisphere of the brain.

Treffert (1989) has suggested that, when considering the possibility of dominance in hemispheric functioning, attention must be paid not only to the strategies involved (cognitive or symbolic) but also to the processes involved (sequential or simultaneous). Sequential processing is involved when the organisation of stimuli is sequential and the order of the stimuli is more important for processing than the relationship between them (Das, Kirby & Jarman, 1975). This type of processing is commonly associated with the left-hemisphere of the brain and is applied to verbal, logical and rational information (Restak, 1984). Simultaneous processing involves primarily spatial stimuli which may require multiple processing and is thought to be associated with information which is spatial, non-linear and holistic in nature. This distinction between sequential and simultaneous processing was initially derived from Luria's (1974) model of intellectual functioning which involves three basic functional units; attention, coding and planning. Das, et al., (1975) have extended this model, locating simultaneous and sequential processes in the second functional unit (coding). Following what has become known as the Luria-Das model, subtests from the Wechsler Scales of Intelligence have been factorised on the basis of research presented in this chapter, in an attempt to relate performances on these subtests to simultaneous and sequential modes of processing.

4.1.3. Speed of Information Processing

Hermelin and O'Connor (1983) found the reaction times (RTs) of savants to be consistent with their IQs except when measuring RT in response to calendrical tasks; on such tasks the speed of processing demonstrated by savants was much faster than typical RTs for individuals with higher IQs in conventional choice RT tasks. Despite small sample sizes, Hermelin and O'Connor (1983) suggested that the operational speed of savants, when processing information in their area of interest, is independent of their general speed of information processing.

It has long been suggested that mental speed is a fundamental aspect of all mental work (e.g., Jensen, 1979) and involves the same cognitive operations as tapped by other measures of intellectual functioning (Vernon, 1983), although many researchers are not convinced about the relationship between mental speed and IQ (e.g., Das, Kirby & Jarmen, 1979; Neisser, 1976). Nevertheless, recent correlational research between these measures has found correlations in the predicted direction (e.g, Jensen, 1979). The methods most commonly employed to predict mental speed have involved either Reaction Time (RT) or more recently Inspection Time (IT). Difficulties with RT tasks are that they are potentially confounded by processes other than those proposed as being related to individual differences in the fundamental rate of information processing (Vickers, Nettelbeck & Willson, 1972). One such process assumed to be involved in RT measures is movement time, that is the time taken for a subject to move his or her hand to a response key (Jensen, 1979). Furthermore, subjects vary in the level of caution with which they respond and a decrease in RT is usually associated with an increase in the number of errors made. This is known as the "speed-accuracy trade-off" (Pachella, 1974) and causes further difficulties when interpreting RT as a "fundamental " process. ITs, however, are held to be a better measure of mental speed given that the decision is based on only one inspection of limited exposure duration (Vickers, et al., 1972). As a result, nonprocessing variables such as caution, and movement time are thought to be removed within estimates of IT. The relationship between speed of information processing as indexed by IT, cognitive abilities and skill-level was therefore investigated further, not only among calendrical savants as tested by (Hermelin & O'Connor, 1983) but also for savants demonstrating other skills. Specifically, the objectives were to test Hermelin and O'Connor's observation that speed of information processing is unrelated to speed of calendrical response with a larger sample of calendrical calculators; and to test also whether skill level is related to speed of information processing.

4.1.4. Memory

The importance of the role of memory in the acquisition and maintenance of savant skills has often been questioned (Critchley, 1979; Duckett, 1974; Steel et al., 1985; Treffert, 1989). Nonetheless, results from the investigations of calendrical calculators presented in Chapter 3 have suggested that calendrical calculation is largely dependent upon memory - possibly a well-developed associative memory. The role of memory, particularly associative memory, in the development and performance of all savant-type skills has therefore been examined further in the research to follow, by assessing each savant's ability to recall associations immediately and after a delay. It was hypothesised that the ability to recall information encoded by associations underlies all savant skills.

4.1.5. Creativity

The musical and calendrical abilities displayed by the savants in Chapters 2 and 3 were rule-based, rigid and highly structured, and generally lacking in creativity; a quality often considered to reflect intelligent behaviour. Nevertheless, it has been observed that some savants are able to demonstrate a degree of creativity and flexibility (Viscott, 1970). The hypothesis to be tested by the research to follow was that the extent to which savant skills are creative is dependent on overall level of general functioning, rather than on the strength of specific cognitive processes responsible for the development of their skill. Creativity levels among savants and the relationship between creativity and other cognitive processes has been investigated in this chapter.

4.1.6. Familial Tendencies

Rimland (1978a) has noted that a large proportion of children with autism were the offspring of professional and scientific people. Similarly, investigations of savant family members suggests that many savants are the offspring or sibling of lawyers, mathematicians, accountants and doctors - professions which require considerable intelligence as well as an ability to narrow one's attention to a tight focus (Hurst & Mulhill, 1988). However, claims of high IQs among family members of savants have been inferred from the SES, occupation and education levels of parents and there have been no scientific evaluations of the IQ profile of parents or any other forms of psychometric assessment. In the research reported in this chapter, the IQs of parents and siblings were measured, where possible, to investigate the relationship between the IQ of family members and any inherited characteristics. Because autism is believed to be a congenital disorder and because there is no evidence to suggest that savants are coming from a background of familial retardation, it was assumed that had savants not suffered a neurological impairment consistent with autism they would have been bright individuals. It was hypothesised that savants are the offspring of people with above average level of intelligence.

Other studies have also reported abilities among some relatives similar to those displayed by a savant family member (Duckett, 1976; Rife & Snider, 1931; Rimland, 1978a). The IQ profiles of family members were analysed to determine the extent to which family members demonstrated strengths in cognitive processing similar to those demonstrated by their savant relative. Parents and siblings were also questioned regarding their interests and skills to determine if savant skills might develop due to other familial characteristics such as opportunity, modelling or encouragement.

4.1.7. Types of Abilities

As noted in Chapter 1, savant skills have generally been found to be limited to a discrete range of abilities. To test this observation further, savants were tested extensively across a broad range of areas, to determine if skills, other than those already reported in the literature, emerge among the disabled population. If savant skills are in fact limited, the reasons for this remain unclear. It may be due to environmental or structural limitations. Some support for the environmental view comes from the observations that skills in mathematics using an abacus have been reported in earlier studies but are not found in the more recent literature. However, it is also possible that the means of expression are environmentally determined, but the skill has a genetic basis. If environmental factors alone were responsible for the development of savant skills, one would expect the frequency of savants to be much greater than is the case - and possibly also that the range of skills would be wider.

In light of the above, the cognitive structures underlying the development of such skills were of interest and an attempt has been made to identify the relationship between such processes and savant skills. Furthermore, if similar cognitive processes underlie the development of particular savant skills, it was of interest to determine the level of ability (if any) demonstrated by savants in other savant-type skills. It was therefore considered necessary to test each savant's performance on all tasks that might reflect savant-type skills.

4.2. Method

4.2.1 Subjects

Letters requesting participation in the present study were sent to institutions for autistic and disabled persons throughout Australia and the United States (US). These letters suggested that the type of individuals required should demonstrate a level of skill considered by care-givers to be beyond that expected, given the individual's overall level of cognitive functioning. A brief descriptive overview of savant syndrome was included in these letters, together with examples of the type of skills typically demonstrated. It was emphasised, however, that these skills, while the most common, were only examples and any skill would be of interest. Eight savants, already documented in the savant literature, were contacted directly in the US.

In total, 56 subjects were recruited and visited by the author for assessment. Two of the subjects, considered by the author and other professionals (e.g., Treffert; personal communication October 13, 1993) to be prodigious musical savants, were unable to complete the pre-selected battery of tests because they were blind. One of these subjects did complete some of the verbal tasks in the battery but the other was largely nonverbal. A third subject with prodigious mathematical and calendrical calculating skills was pleased to complete the calendrical tasks but did not wish to participate in the remainder of the study. The author's assessment did not substantiate care-givers' claims of well-developed memory skills in a further two subjects and data from these two males have consequently not been included in the analyses. The remaining 51 subjects (43 males and 8 females) aged from 6 years to 53 years (M=21.8 years, SD=12.3) participated fully in the investigation.

The main area of expertise demonstrated by each subject was in the following areas; memory (26 subjects), music (8), calendrical calculation (7), artistic ability (6), mechanical skills (2) and mathematical skills (2). Eighteen subjects demonstrated more than one of the skills listed above and five subjects also demonstrated hyperlexia (i.e., limited comprehension, in comparison to recognition, of written material; Silberberg & Silberberg, 1967). This was not, however, considered to be their most developed ability or the reason for which they were recruited. Twelve subjects were considered by the author to be prodigious savants and a further 20 were rated as talented savants, following Treffert (1989). The level of skill of the remaining 19 subjects was best described as a splinter-skill. All subjects had either a formal diagnosis of autism (N=41) or another type of intellectual disability.

4.2.2. Procedures for Psychometric Assessment

All subjects completed the battery of psychological tests outlined in Chapter 3. These were the WAIS-R or WISC-R; Raven's Standard Progressive Matrices (PM) or Coloured Progressive Matrices (CPM) for young children (N=6); Wechsler Memory Scale-Revised (WMS-R); Schonell Graded Word Reading Test; Neale Analysis of Reading Ability-Revised (Form 2); Torrance Test of Creative Thinking (Thinking Creatively with Pictures: Figural Booklet A); the Bender Visual Motor Gestalt Test and Hooper Visual Organisation Test.

Inspection Time (IT) measures, assumed to index speed of information processing, were made from the Australian subjects only (N=23) because of difficulties transporting the equipment. These measures were made following the same method as outlined in Chapter 2; i.e. length-of-line two-choice discrimination presented on a computer screen, with an attentional cue displayed for 400 ms prior to the target figure and followed by a backward mask of 360ms duration. The response-stimulus interval was again 2000 ms. Subjects were familiarised with the requirements and received the same introductory trials and explanation as set out in Chapter 2. An estimate of IT required approximately 10 minutes.

Most subjects were involved in testing for approximately 5 hours - slightly longer for younger subjects. The number of sessions required to complete these tests ranged from one to 14 depending on the age of the subject and their ability to maintain concentration as well as their accessibility and availability. Where testing was completed within a single day, regular breaks were given. No more than two weeks elapsed between testing sessions.

4.3. Results and Discussion

4.3.1. Level of Skill

All raw scores are included in Appendices. In order to quantify skill level, subjects were ranked according to the precocity of their skill, independent of ability-type and level of general ability, as judged by the author. This was done on three occasions. The first ranking was done five months after the last subject was assessed, which was more than three years after the assessment of the first subject. One month after the first ranking the subjects were ranked again and they were ranked for a third time after a further five months. The correlations between the three ranks confirmed high reliability of opinion, all being 0.98. ($N=51$, $p<.01$). To test validity of rankings, Dr. Nettelbeck independently rank-ordered the subjects according to judged skill, working from videos of 31 subjects which demonstrated their skill. He was also provided beforehand with written information on the skill of each of the subjects and examples of the savant's work where applicable (e.g., drawings etc.). These 31 subjects covered the full range of skills involved and of precocity in the opinion of the author but selection was otherwise not knowingly guided by any other criteria. Dr Nettelbeck was also familiarised with Treffert's categorisation of savants, as outlined in Chapter 1. The correlation between the rankings given the subset of 31 by Dr. Nettelbeck and the mean ranks of the author for this group was 0.89 ($N=31$, $p<.01$). This outcome was taken to confirm the validity of the author's judgements and the mean of the three rankings by the author for each of the full sample of 51 subjects was consequently used in subsequent analyses as a measure of skill level for each savant; refer to Appendix 4.1 for details.

Regression analysis using these rankings as the dependent variable found that level of precocity was correlated with level of intelligence, as indexed by IQ. Correlation between IQ and ranking (controlling for age) were significant for IQ as indexed by the

WAIS-R (r=-.58, p<.01, N=30), WISC-R (r=-.37., p<.05, N=21), and by PM (r=-.60, p<.01, N=45), CPM (r=-.48, p=.70, N=6). Furthermore, six of the eleven subtests were also significantly-correlated with author's ranking (see Table 4.1). These results support earlier speculation by O'Connor and Hermelin (1988) that although savant skills may occur in the absence of normal intellectual ability, the extent to which they develop are to some extent IQ dependent. For those subjects with only splinter skills, however, ranking was not well correlated with measures with the Wechsler Scales of Intelligence. Instead, General Memory as indexed by the WMS-R was a better predictor of skill level (see Table 4.2). This finding might be expected, given that 18 of the 19 subjects with only splinter skills were recruited for their exceptional memory.

Author's ranking of skill level and age were significantly correlated (r= -.49, p<.01). This relationship is not apparent from Table 4.1 given that IQ scores are calculated as a function of age. When raw scores for the Wechsler Scales were used (standardised for each test i.e., WISC-R or WAIS-R) the correlations between raw scores and ranking remained even when age was controlled for, with all subtests except Picture Arrangement correlating significantly with author's ranking (rs -.23 to -.55, p<.05). These correlations were, however, reduced when age was not controlled for and in most cases the relationship was no longer significant. These results suggested that cognitive development and maturation may coincide with the development of savant skills. Alternatively, one may account for the relationship between ability and age due to the increased opportunity to practice simply by being older and having had more time (years) to practice.

4.3.2. Level of Intelligence

Although 15 subjects scored in the normal range for IQ (i.e., FSIQ ≥ 85; M=94.3, SD=10.3, range= 85-114) they were included in the analyses because all had a formal

Table 4.1

Correlations (controlled for age) between skill-level as indexed by author's ranking[a] and scaled scores of cognitive abilities from Wechsler Scales (WAIS-R; WISC-R) Raven's Matrices (PM; CPM), Inspection Time, and Music Discrimination (Bentley) for all subjects, savants and those with splinter skills.

	All subjects (N=51)		Savants (N=32)		Splinter skills (N=19)	
Test / Subtest		Controlled for age[b]		Controlled for age		Controlled for age
Information	-.03	-.18	-.00	-.08	-.24	-.21
Similarities	-.12	-.28*	-.44*	-.48**	-.11	-.04
Arithmetic	-.13	-.36**	-.25	-.35*	-.33	-.29
Vocabulary	-.28*	-.36**	-.19	-.24	-.33	-.30
Comprehension	-.20	-.21	-.15	-.14	-.33	-.31
Digit Span	-.31	-.42**	-.47**	-.49**	-.16	-.09
Picture Completion	-.11	-.19	-.49**	-.48**	-.19	-.14
Picture Arrangement	-.10	-.20	-.25	-.28	-.01	-.05
Block Design	-.27	-.50**	-.47**	-.64**	-.19	-.15
Object Assembly	-.11	-.34**	-.40*	-.52**	-.11	-.04
Coding	-.32*	-.51**	-.52**	-.63**	-.02	-.05
VIQ	-.29	-.38**	-.21	-.25	-.37	-.34
PIQ	-.31*	-.42**	-.66**	-.69**	-.07	-.02
FSIQ	-.35*	-.46**	-.44*	-.47**	-.28	-.24
PM /CPM (standard scores)[c]	-.34*	-.53**	-.51**	-.69**	-.03	.04
Inspection Time	.50* (N=23)	.55** (N=23)	.36 (N=13)	.36 (N=13)	.61 (N=10)	.52 (N=10)
Music	-.36**	-.24*	-.03	-.03	.26	.23

* denotes p<.05 ** denotes p<.01

[a] The most prodigious savant was ranked 1 through to the least able at 51 - hence the negative correlations.

[b] Correlations between these variables were calculated using the partial correlation coefficient which provides a single measure of linear association while adjusting for the linear effects of an intervening variable which in this case was age.

[c] Progressive Matrices scores (Standard and Coloured) were converted to standard scores due to the variability in the two tests used.

Table 4.2.

Correlations between rankings of skill level as indexed by the author and raw scores for subtests and memory quotients of the Wechsler Memory Scales - Revised, with the effect of age controlled.[a]

	All subjects (N=51)	Savants (N=32)	Splinter skills (N=19)
Subtests			
Mental Control	-.28*	-.15	.01
Figural Memory	-.32*	-.18	-.13
Logical Memory	-.42**	-.09	-.48*
Visual Paired Associates 1	-.33**	-.48**	-.16
Verbal Paired Associates 1	-.46**	-.48**	-.30
Visual Reproduction 1	-.51**	-.26	-.11
Digit Span	-.46**	-.42**	-.29
Visual Memory Span	-.47**	-.29	-.02
Logical Memory ll	-.39**	-.18	-.35
Visual Paired Associates ll	-.07	-.09	.13
Verbal Paired Associates ll	-.25*	-.26	-.22
Visual Reproduction ll	-.61**	-.36*	00
Scaled Scores / Quotients[b]			
Verbal Memory Quotient	-.35* (N=33)	-.28 (N=27)	NA[c]
Visual Memory Quotient	-.57**(N=33)	-.55**(N=27)	NA
General Memory Quotient	-.48**(N=33)	-.42* (N=27)	NA
Attention /Concentration Quotient	-.42**(N=33)	-.37* (N=27)	NA
Delayed Recall Quotient	-.58**(N=33)	-.47**(N=27)	NA

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

[a] Correlations between these variables were calculated using the partial correlation coefficient which provides a single measure of linear association while adjusting for the linear effects of an intervening variable which in this case was age.

[b] Quotients could only be tabulated for subjects over the age of 16

[c] Quotients could only be tabulated for 6 subjects so correlations for this group were misleading and therefore not included.

diagnosis of autism, all demonstrated idiosyncratic levels of ability and all had skills in a particular area. Six were categorised as prodigious, five as talented and four had splinter skills. IQ test results from all other subjects (N=36) were below 85 and suggested borderline to severe retardation (M=70.8, SD=9.5, range= 50-84).

In general, most tests of intellectual functioning were well intercorrelated among the normal population, supporting research in the field of intelligence which indicates that people operate with a degree of consistency (Jensen, 1981, Vernon, 1950;). Results of the various psychometric tests used in this study, however, indicated that, among this sample at least, there was not always consistency in performance. Although significant correlations were found between IQ estimates on the WAIS-R and PM ($r=.74$; $p<.01$, N=21); WISC-R and PM ($r=.74$, $p<.01$, N=24); WISC-R and CPM ($r=.63$; $p=.09$, N=6), the absolute values for the IQ scores measured by the two tests were vastly different for some subjects (see Appendix 4.2). For example, one subject scored 108 on the Wechsler Scales and 138 on the Progressive Matrices. Given such discrepancy, the validity of an overall IQ value as predicted by concurrent tests of IQ is questionable for individuals whose abilities are so diverse. Furthermore, significant variability within subtests of the Wechsler scales suggests that savants are not uniformly dull, and many of those participating here were found to function within normal limits for some areas of cognitive functioning. (see Table 4.3). If savant skills are, as suggested, independent of general levels of functioning and depend on other cognitive processes, the subtests that savants do well on should therefore be the poorest predictors of "g" and may in fact be measuring qualities or processes other than intelligence but which are nonetheless necessary for the development of savant skills.

4.3.3. Differences between savants with Prodigious, Talented and Splinter Skills.

Table 4.3 also presents mean scores of cognitive processing as indexed by the Wechsler Scales of Intelligence for the prodigious and talented savant group and participants with splinter skills. Oneway analysis of variance (ANOVA) showed that although ranking for skill was correlated with levels of intelligence as indexed by IQ (i.e., Wechsler Scales and Progressive Matrices), intelligence test scores were independent from the categorisation of subjects into ability groups (i.e., prodigious, talented or splinter). However, significant differences were evident between the PIQs of these three groups ($F(50)=3.27$, $p<.05$; see Table 4.3). Post hoc analysis by the Newman Keuls procedure revealed that this effect was due to the difference between the prodigious and talented (see Appendix 4.3). Although the PIQ of the prodigious group was noticeably higher, the difference between the PIQs of this group and the talented group combined, compared with those subjects with merely a "splinter skill" was not significant. These results suggested that higher PIQ is neither sufficient nor necessary for the emergence of savant skills because all savants would have higher PIQs than those of the splinter skills group. Higher PIQ may, however, facilitate subsequent development (i.e., skill level) although other variables such as abilities in more specific cognitive processes, interest in the skill area and practice are almost certainly involved.

This conclusion was further supported by dividing savants into two groups based on median FSIQ. The skill level of those with an IQ above the median (i.e. FSIQ ≥ 78) was best predicted by Performance IQ ($r=-.76$, $p<.01$) corrected for age (($r=-.82$, $p<.01$) but this did not hold for the lower IQ group ($r=-.45$, $p>.01$) corrected for age ($r=-.-41$ $p>.01$).

Factor analyses of the Wechsler Intelligence subtests based on the standardisation samples of the two tests reported in their manuals (i.e., WISC-R and WAIS-R), and other

Table 4.3.

Mean measures of cognitive processing as indexed by Wechsler Scales (WAIS-R; WISC-R)[a] Progressive Matrices (PM or CPM)[b], for prodigious and talented savants and participants with splinter skills. Standard deviations are in parentheses.

Subtest / Test	Prodigious (N=12)	Talented (N=20)	Splinter skills (N=19)
Information	6.8 (3.2)	7.2 (3.2)	7.2 (4.0)
Similarities	7.5 (3.5)	6.3 (2.0)	7.1 (3.1)
Arithmetic	6.6 (4.4)	5.6 (3.5)	6.1 (4.0)
Vocabulary	6.3 (3.8)	6.0 (3.5)	4.6 (3.7)
Comprehension	4.1 (2.7)	4.4 (3.7)	3.5 (2.9)
Digit Span	10.2 (4.2)	6.2 (3.1)	6.8 (3.2)
Picture Completion	7.4 (3.3)	5.5 (2.4)	6.9 (2.9)
Picture Arrangement	6.7 (4.9)	6.0 (2.6)	6.2 (4.0)
Block Design	10.2 (4.3)	8.2 (2.9)	8.3 (4.4)
Object Assembly	8.3 (2.8)	7.4 (3.1)	8.1 (4.0)
Coding	7.2 (4.5)	4.3 (1.9)	4.6 (2.5)
VIQ	81.3 (18.4)	78.8 (14.5)	73.1 (17.3)
PIQ	90.4 (16.7)	77.0 (9.8)	79.8 (17.4)
FSIQ	84.5 (17.8)	76.8 (11.0)	74.4 (14.8)
PM	86.0 (24.5)	74.7 (12.7)	78.0 (12.2)

[a] Scaled subtest scores on WAIS-R and WISC-R range from 1 to 19 (M=10; SD=3). A score of 8 or less places the adult in the lower 25% of adults and a score of 5 or below places the adult among the least able 5%. For WAIS-R scales, PM and CPM, scaled scores follow the conventions of mean=100, SD=15.

[b] Progressive Matrices scores (Standard and Coloured) were converted to standard scores (M=100, SD=15) due to the variability in the two tests used.

large samples of disabled and nondisabled individuals, have consistently resulted in the emergence of three factors commonly identified as Verbal Comprehension, Perceptual Organisation and Memory / Freedom from Distractability (e.g., Atkinson & Cyr, 1984; Bannatyne, 1974; Kaufman, 1975, Leckliter, Matarazzo & Silverstein, 1986; Naglieri, Kamphaus & Kaufman, 1983). Principal components analysis of the subtests of the Wechsler Scales of Intelligence followed by oblique rotation (oblimin) to a simple structure extracted three components which largely resembled those factors already identified. The result of factor analyses using varimax rotation (which is the mode of extraction consistently used) (Donder 1993; Hubble & Groff, 1981; Ryan & Schneider, 1986), was consistent with this result However, because intercorrelations between factors were evident (rs .16, .21 and .37), orthogonality could not be assumed, making oblimin rotation more appropriate. Consistent with earlier research, the Verbal Comprehension component consisted of the subtests Information, Vocabulary and Comprehension. The subtest Picture Completion, Block Design, Picture Arrangement and Object Assembly formed the Perceptual Organisation component, while Digit Span, Coding and Arithmetic formed the Freedom from Distractability component (see Table 4.4).

Given that the purpose of this study was to identify processes underlying savant skills, these components were interpreted in terms of the processes they reflected. In terms of the Luria-Das Model, the subtests loading on the Perceptual Organisation factor were held to reflect simultaneous processing while the Freedom from Distractability component reflected sequential processing. Similarities also loaded on Perceptual Organisation (simultaneous processing) which, although an outcome not found among the normal population, was consistent with factor analyses of the WISC-R among learning disabled groups (e.g., Mishra, Lord & Sabers, 1989). Furthermore, differences in processing modes adopted by various subgroups (divided on the basis of general level of functioning), to perform tasks of the same type, were found by Naglieri (et al., 1983). He suggested that the processing mode adopted by individuals may depend not only on the type of stimuli involved but also on other factors such as ability level. It is likely, therefore, that the subjects in this study approached the Similarities subtest using a different mode of information processing than would be expected among the normal population. This explanation could also account for Arithmetic loading on Freedom from Distractability rather than on the Verbal Comprehension component.

Table 4.4

Components produced following a Principal Components Analysis followed by an oblimin rotation.

Subtest	FACTOR 1	FACTOR 2	FACTOR 3
	Perceptual Organisation	Verbal Comprehension	Freedom from Distractability
Information	.20391	**.80670** [a]	.42531
Similarities	**.98553**	.34186	.37755
Arithmetic	.44486	**.51651**	**.83871**
Vocabulary	.43719	**.91103**	.37986
Comprehension	.31087	**.87775**	.08918
Digit Span	.28450	.29365	**.81019**
Picture Completion	**.83013**	.37023	.29479
Picture Arrangement	**.84354**	.43214	.18881
Block Design	**.69133**	.04574	**.67519**
Object Assembly	**.82480**	.06223	.48409
Coding	.38822	.22290	**.87981**
VIQ	.40265	**.94330**	**.51159**
PIQ	**.93103**	.29491	**.64127**
FSIQ	**.74712**	**.75119**	**.64852**
PM	**.54904**	.44227	**.77010**

[a] Loadings above .5 are in bold

It is also noteworthy that the Progressive Matrices loaded on the Freedom from Distractability (sequential processing) component rather than Perceptual Organisation (simultaneous) processing, reinforcing the idea (e.g., Naglieri et al., 1983) that the stimuli involved are not always indicative of the processes that individuals may use or the strategies they may depend on to perform a task. Furthermore principal components analysis of only the savant data (i.e., excluding those with splinter skills) suggested that the process underlying their performance on Block Design was sequential not simultaneous.

The prodigious group performed better on subtests held to reflect sequential processing (i.e., Picture Completion, Block Design, Picture Arrangement and Object Assembly) than the talented group ($t(30)=2.3$; $p<.05$). There was no significant difference in sequential processing (i.e., Digit Span, Coding and Arithmetic) between the talented and splinter skills groups suggesting that although skills in sequential processing may be responsible for the level of development of savant-type skills, they are not sufficient for the acquisition of such skills. No significant differences were found between the simultaneous processing ability of any of the groups. It was hypothesised at the outset that a preserved ability in this type of processing may account for the underlying ability once it is well-developed. Significant correlations between ranking and simultaneous processing when controlled for age ($r=-.37$, $p<.01$) supported this hypothesis.

No significant differences were found between subjects' ability to process information (i.e., either simultaneous or sequential) depending on the type of skill that the subject demonstrated -i.e., music, art, mathematics etc. (see Table 4.5). This result suggests that although strengths in modes of processing may underlie the development of a skill they do not appear to influence the type of skill that a subject may develop.

Table 4.5

Mean measures of cognitive processing as indexed by Wechsler Scales (WAIS-R; WISC-R)[a] and Raven's Matrices (PM; CPM), for prodigious and talented savants divided into groups dependent on skill-type.

		Primary Type of Savant Skill					
		Music (N=8)	Art (N=6)	CC (N=7)	Mechanical. (N=1)	Memory (N=8)	Maths (N=2)
Test / Subtest							
Information	M	7.0	7.0	6.1	3	9.4	3.5
	SD	2.7	2.8	2.1		3.5	3.5
Similarities	M	6.8	7.9	5.9	4	7.0	6.0
	SD	3.1	3.7	1.4		2.0	4.2
Arithmetic	M	6.5	5.7	4.9	2	7.1	5.5
	SD	4.4	3.0	3.2		4.6	5.0
Vocabulary	M	5.9	6.3	5.0	5	7.8	3.5
	SD	3.9	3.0	2.3		4.7	3.5
Comprehension	M	4.1	4.5	3.9	2	4.9	4.0
	SD	2.8	2.3	3.3		4.9	4.2
Digit Span	M	10.1	5.7	6.7	2	7.8	10.5
	SD	4.7	2.9	4.4		2.9	0.7
Picture Completion	M	7.0	7.8	5.4	1	5.9	5.0
	SD	3.3	2.7	1.0		2.5	5.7
Picture Arrangement	M	6.4	7.2	5.0	4	7.1	4.5
	SD	4.5	5.3	1.8		2.3	5.0
Block Design	M	9.0	11.5	7.1	6	8.5	10.0
	SD	5.0	2.7	3.2		2.4	1.4
Object Assembly	M	7.1	8.7	7.3	6	8.0	8.5
	SD	3.1	3.5	3.0		3.2	2.1
Coding	M	6.3	4.8	5.1	1	5.3	7.0
	SD	5.6	1.7	3.4		1.8	1.4
VIQ	M	82.4	78.8	75.4	61	87.1	67.0
	SD	15.6	14.6	9.9		17.5	31.1
PIQ	M	85.6	89.5	77.7	62	80.0	78.5
	SD	19.7	17.8	6.0		9.3	10.6
FSIQ	M	82.9	82.5	75.3	63	82.8	70.5
	SD	16.9	17.0	6.8		12.8	22.6
	Range	61-107	64-104	65-86		67-105	54-86
PM / CPM	M	86.8	81.3	71.9	59	78.1	78.0
	SD	28.6	15.4	13.9		13.5	4.2

[a] Scaled subtest scores on WAIS-R and WISC-R range from 1 to 19 (M=10; SD=3). A score of 8 or less places the adult in the lower 25% of adults and a score of 5 or below places the adult among the least able 5%. For WAIS-R scales, PM and CPM, scaled scores follow the conventions of mean=100, SD=15.

Because of the standardisation sample used in the WMS-R, memory quotients from the WMS-R could only be interpreted for subjects 16 years or older; (i.e., 10 prodigious savants, 17 talented savants and three with splinter-skills). The raw scores from the WMS-R for the younger subjects were, however, useful for within-subject analyses and for

statistical analyses where the effects of age were controlled for. Table 4.6 presents a detailed account of the means and standard deviations of each group on the WMS-R and the differences between each ability. The prodigious group demonstrated a superior performance for Visual Memory compared to the talented group (t(25)=2.00, p=.056). The same difference was found for Attention and Concentration (t(25)=2.09, p<.05) and making visual paired associations (t(25)=3.45, p<.01).

In order to identify processes that may result in the acquisition of savant skills, not just the level of development, raw data from the WMS-R was used and the savants' performance on these subtests was compared with the splinter group, partialling out the effect of age. The savants outperformed the splinter group on most memory subtests as well as on all Memory Quotients (i.e., Verbal, Visual, General, Attention and Concentration, and Delayed Memory Quotients; see Table 4.6). These results suggest that preserved abilities in memory are essential to the development of savant type skills. These memory differences may reflect the cognitions necessary for acquisition of savant skills. Superior performances by the prodigious savants compared with the talented on Visual Paired Associates (t(30)=2.5; p<05), Digit Span (t(30=2.3; p<.05) and Visual Memory Quotients (t(25)=2.0; p=.056), suggested that processes involved in these skills, (e.g., the ability to process information simultaneously and a well-developed declarative or rote-memory) may also underlie subsequent development of such skills.

Table 4.6

Mean measures of cognitive processing as indexed by Wechsler Memory Scales - Revised (WMS-R)[a] for prodigious and talented savants and participants with splinter skills. Standard deviations are in parentheses.

Subtest	Maximum Score	Prodigious (N=12)	Talented (N=20)	Splinter skill (N=19)
Mental Control	6	4.6 (1.7)	4.4 (1.9)	4.0 (2.1)
Figural Memory	10	6.3 (3.0)*S	5.7 (2.2)*S	4.5 (1.4)
Logical Memory	50	13.6 (10.8)*S	16.5 (11.9)**S	6.1 (6.7)
Visual Paired Associates l	18	14.6 (4.9)*S	10.6 (4.2)	10.4 (4.5)
Verbal Paired Associates l	24	18.4 (4.4)*S	15.2 (5.5)	13.4 (5.5)
Visual Reproduction l	41	26.8 (12.5)*T*S	28.1 (8.7)**S	15.8 (9.1)
Digit Span	24	14.6 (5.6)*T**S	10.6 (4.4)	9.2 (3.6)
Visual Memory Span	26	14.6 (6.1)**S	12.8 (3.7)	8.9 (3.5)
Logical Memory ll	50	10.1 (9.8)	12.0 (11.1)*S	4.2 (6.9)
Visual Paired Associates ll	6	5.2 (2.0)**S	5.1 (1.4)**S	5.1 (1.3)
Verbal Paired Associates ll	8	7.5 (0.9)	6.9 (1.5)	6.7 (1.8)
Visual Reproduction ll	41	22.6 (15.3)	22.9 (10.6)	8.5 (6.0)
Scaled Scores / Quotients		(N= 10)	(N=17)	(N=6)
Verbal Memory Quotient		77.5 (20.8)	75.3 (24.1)	64.0 (15.1)
Visual Memory Quotient		95.4 (28.6) *T*S	75.4 (22.8)	63.5 (12.1)
General Memory Quotient		81.4 (26.2) *S	71.1 (24.2)	56.8 (14.0)
Attention /Concentration Quotient		88.8 (28.7) *T*S	70.8 (16.5)	61.8 (14.5)
Delayed Recall Quotient		86.6 (23.1) *S	78.5 (23.2) *S	57.0 (14.4)

*T denotes significantly different from talented savants; p<.05
**T denotes significantly different from talented savants; p<.01
*S denotes significantly different from participants with splinter skills; p<.05
**S denotes significantly different from participants with splinter skills; p<.01
[a] For WMS-R, scaled scores follow the conventions of mean=100, SD=15.

4.3.4. Types of Skills Observed

Results from the Wechsler Scales of Intelligence did not support Hill's (1978) suggestion that the type of skill developed was related to superior performances in either PIQ or VIQ or any other division based on cognitive strengths. Although performances on some tasks were superior for some skill-type groups this was not consistent for all participants.

Overall measures of intelligence as indexed by the Wechsler subtests and Scales were more indicative of the level of skill developed rather than the type. Significant correlations between subtests of either the WAIS-R or WISC-R and rankings by the author of level of ability within groups of similar types of ability supported this conclusion. For example, PIQ and FSIQ correlated with level of ability within the musical savants ($rs=-.81$ and -74; $p<.05$), Object Assembly and Similarities were highly correlated with ranking for the artists ($rs=-.88$ and $-.82$; $p<.05$) and the skill level of those with exceptional memory was significantly correlated with Vocabulary ($r=-.48$, $p<.05$), VIQ ($r= -.50$, $p<.01$) and FSIQ ($r=-.41$, $p<.05$).

The types of skills observed will now be addressed in more detail:

4.3.4. (i) Music

Eight subjects were recruited for this study on the basis of anecdotal reports of their musical skills. The musical skills of six of the subjects were considered by the author to be "prodigious" while the skills of another two were considered "talented", following Treffert (1989). In addition, another savant demonstrated "prodigious" musical ability, although he was recruited because of his abilities in calendrical calculation, as well as his encyclopedic knowledge. Further, two prodigious artistic savants demonstrated musical skills - one with "prodigious" musical skills and the other "talented". Therefore, although musical ability was considered to be the primary skill demonstrated by eight savants, because these three additional subjects also demonstrated musical ability they were placed in this group for the following analysis.

While demonstrable musical ability was of interest, so too was the potential to develop such ability. Inherent or apparently unlearned skills such as a good sense of pitch and the ability to make basic elementary musical judgements were held to reflect such potential. Therefore all subjects were tested on the "Pitch Discrimination" subtest of the Measures of Musical Abilities (Bentley, 1985). This test required subjects to discriminate between two sounds and indicate whether the second sound was "up" or "down" from the first. There were difficulties, however, when testing trained musicians on this test (as has already been noted in Chapter 2). Such individuals can have difficulties with this test because, even though they recognise that the notes are slightly different, they may interpret two sounds as the same note. Thus the two sounds may be identified as A, but with one (e.g., 3 hz) out of tune. On the basis of earlier experience with TR, as outlined in Chapter 2, this difficulty was explained to all subjects with formal musical training. Nevertheless, some subjects were clearly unable to understand these verbal instructions, and two subjects still persisted in naming both sounds. However, when testing pitch on the piano, both were able to demonstrate perfect pitch by re-playing notes that had been played to them unseen.

Another difficulty with the test was that some savants, including those with musical skills, found the verbal instructions too difficult to understand. Subjects with musical knowledge were able to overcome this difficulty by naming the notes. The responses by such individuals were accepted as correct if they correctly identified the notes (or the relative direction between the named notes was correct) even though they could not state whether the second note was "up" or "down" from the first. Those who could neither name the notes nor understand the requirements of the test were therefore disadvantaged by the use of this test. For example, one musical savant with minimal formal musical training only scored 13/20 on this test. However, when subjected to further testing on the piano in the same manner as outlined above, he demonstrated perfect pitch. These observations were consistent with anecdotal reports of perfect pitch among all prodigious musical-savants and good relative pitch for the talented savants. Overall, the high incidence of outstanding pitch discrimination among the musical savants suggested that an important relationship exists between this ability and the acquisition of savant musical skills.

Difficulties with the pitch discrimination test notwithstanding, musical savants in general, performed well on this test ($\underline{M}$=17.5/20, SD=2.9, range 12-20, $\underline{N}$=11) compared with savants skilled in other areas ($\underline{M}$= 13.7, SD=3.8, range =5-18, $\underline{N}$=21). Despite excellent performances on this test by some savants skilled in other areas (e.g., 18/20 see Appendix 4.4) the difference in performance on the Bentley pitch discrimination test between musical savants and other savants was significant ($t(30)=2.87$, $p<.01$). Nevertheless, because some other subjects (with no known musical ability) also had good pitch discrimination as measured by the Bentley it was of interest to investigate reasons why these subjects had not also developed musical ability. The scores on the Bentley pitch discrimination test for these subjects, (i.e., those registering pitch discrimination above the median of 14; $\underline{N}$=23) were compared with that of the musical savants, the purpose being to attempt to isolate cognitive strengths among the musical savants required for the emergence of musical skills, in addition to good pitch discrimination. Although musical savants outperformed those nonmusical savants with good pitch on tests of visual and verbal memory, these differences were not significant. In fact, the only significant difference found between the two groups was age ($t(21)=2.61$; $p<.05$). These results therefore fail to isolate specific cognitive processes that may underlie the development of precocious musical skills, thereby suggesting that external factors (e.g., environmental stimuli, practice, interest, opportunity or musical training) are the critical variables involved in the development of such skills. Furthermore, because some of the nonmusical subjects were still quite young (one subject was only 6 years of age) it is possible that some subjects, given the right opportunities, could yet develop musical skills.

Significant correlations between the pitch discrimination subtest and some subtests of the Wechsler Scales of Intelligence and Memory (see Table 4.7) suggested that the Bentley may not provide a pure index of pitch discrimination but may in fact reflect other cognitive processes. By its nature the test obviously requires memory and sequential processing. For example, subjects who scored well on this test (i.e., scores >14) had significantly higher VIQ ($t(49)=2.05$; $p<.05$), PIQ ($t(49)=2.63$; $p<.05$) and FSIQ ($t(49)=2.82$; $p<.01$), and better performances on many of the subtests of the Wechsler Memory Scales including superior Attention and Concentration Memory Quotients ($t(31)=2.12$; $p<.05$) than those who scored below the median. Although some subtests on the WMS-R correlated with pitch discrimination, these correlations did not reach significance for the musical savants alone. These results suggested that musical savants may be able to overcome the difficulties with the Bentley because of their musical knowledge, while the nonmusical subjects rely on other cognitive processes such as IQ and memory. This interpretation was supported by a significant correlation between FSIQ and pitch discrimination among the non-musical subjects ($r=.30$, $p<.05$) when controlling for the effect of age using partial correlation, but this relationship was not significant for the musical savants.

Cognitive profiles of intelligence and memory scores for the 11 musical savants provided no evidence to suggest that any of the processes which underlie these scores favour the development of musical skill instead of any other type of skill. Although tests generally accepted as measuring short-term memory suggested an enhanced ability in this area compared with other savants (e.g., Digit Span - $t(30)=2.06$, $p<.05$; learning easy items on the verbal paired associates subtest of the WMS-R - t(30)=2.48, p<.05), this superiority was not uniform for all musical savants. Overall, results suggest that although some unaffected cognitive processes may underlie the development of precocious musical skills,

Table 4.7.

Significant correlation between Pitch Discrimination as indexed by Measures of Musical Abilities (Bentley 1966; 1985) and scaled scores of cognitive abilities from Wechsler Scales (WAIS-R; WISC-R; WMS-R), Neale Analysis of Reading Ability-Revised and Sequential Processing.

Correlate		Pitch Discrimination (N=51)
WISC-R/ WAIS-R		
Subtest	Similarities	.20*
	Arithmetic	.28*
	Digit Span	.38*
	Coding	.38**
WISC-R/ WAIS-R		
Intelligence Quotient	VIQ	.30*
	PIQ	.41**
	FSIQ	.41**
WMS-R (Subtest)	Figural Memory	.49**
	Verbal Paired Associates	.30*
	Visual Memory Span	.47**
NEALE	Reading Accuracy	.37**
	Author's Ranking for skill	-.33*[a]
	Sequential Processing	.40**

* denotes p<.05 ** denotes p<.01

[a] Negative correlations for ranking are because the subject with the highest skill level is ranked number one through to the subject with the least skill ranked at 51.

more important is an excellent sense of pitch combined with appropriate environmental opportunities.

Because of the difficulty that most savants had completing the Pitch Discrimination subtest of the Measures of Music Abilities (Bentley, 1985) only the musical savants with the ability to understand the verbal requirements of the test were assessed on the other subtests - Chord Analysis, Tonal Memory and Rhythmic Memory. The blind male subject who did not complete the other psychometric tests was also involved. The total number of subjects who completed the entire test was therefore nine.

The Chord Analysis subtest only requires subjects to identify the number of notes played in a chord but, seven of the eight subjects were also able to identify the chord; or if the chord was unconventional, they were able to identify the individual notes played. All subjects showed excellent memory for tones but some had difficulty with rhythmic memory (see Appendix 4.5). Overall scores for the four tests combined ranged from 52 to 60 out of 60 (M=54.5; SD=2.9, N=8). Although norms are not available for adults, these scores were above what one would expect from the top 10 percent of normal 14 year-olds.

4.3.4. (ii) Calendrical Calculation

Eight subjects were recruited for the study based on their skills in calendrical calculation. Furthermore, one musical savant and one artistic savant also had calendar skills. One of the calendar calculators died in a house fire before his speed of responses to dates could be measured and another was involved in one of the calendar experiments but would not participate in any of the standardised psychometric tests. One mathematical savant also demonstrated calendrical skills but the extent of his ability could not be measured due to erratic and often uncontrollable behaviour and he was therefore not involved in the calendar experiments. He was the youngest savant with this skill (aged 10 years); with all others being 18 years of age or older. The total number of savants for which speed of response to dates and IQ scores were available was eight.

The average speed of response from these calendrical calculators (N=9; obtained from Experiment 2 of Chapter 3) was calculated for each subject and correlated with IQ and other indices of cognitive functioning. No significant correlations were found between speed of response to dates and IQ. Although conclusions cannot be drawn because the sample size is too small, these results suggest that response times to dates and IQ are unrelated. No significant correlations were found between response times and any other measure of cognitive functioning, so that no further insight was gained about the mental processes that underlie the speed of the calendar ability.

4.3.4. (iii) Artistic Ability

Overall FSIQ was significantly correlated among the savant group (controlled for age) with creative fluency ($r=.44$, $p<.01$), flexibility ($r=.34$, $p<.05$), originality ($r=.56$, $p<.01$) and elaboration ($r=.32$, $p<.05$). These correlation were not significant among those subjects with only splinter skills. These results suggested that such qualities although somewhat limited may be involved in the acquisition and development of these skills.

Three subjects were considered prodigious and another three talented on the basis of their artistic ability. The artwork of four of the savants involved in this study is well regarded among artists for its representational accuracy, perspective and attention to detail, with three having achieved financial restitution and recognition for their work at art shows throughout the US (Blavitt; personal communication September 9, 1993). All this considered, most of their artwork did not reflect "personal style" and, despite all savants having been actively encouraged to be creative in their artwork, most persisted in copying two-dimensional subjects presented on post-cards, pictures, or drawings done by other artists. One female artistic-savant who participated in the research presented here now produces original work after extensive formal training, but the quality of this work is not as sophisticated or accurate as her reproductions (Blavitt; personal communication September 9, 1993). Nevertheless, one might consider it to have greater artistic merit than her reproductions (see Figures 4.1 and 4.2).

Only one subject had a preference for drawing from three dimensional representations. The abilities of this subject differed from those of the other savants because he created his own subject materials using three-dimensional models in real space and transposing them using computer-graphics. In order to achieve the high quality which he demanded of himself, his artwork consumed much of his time, with many pieces requiring more than 24 hours to complete, on the basis of work sessions lasting about 4 hours at a time (see 4.3). The skills of this savant were ranked second by the author, behind the musical savant featured in Chapter 2. It is noteworthy that these two subjects also had the highest IQs on the Wechsler Scales and had skills, in addition to their art and music, that were clearly at a prodigious level. Furthermore, a musical-savant who also had an interest in three dimensional graphics had the third highest IQ. Given that these subjects had higher IQs than the other artistic savants, and were the only ones capable of three-dimensional representations, it is possible that a higher general level of intelligence may be required for this type of artistic representation, although due to the small sample size this suggestion could not be tested.

As noted for the musical savants, a particular interest and focus in the skill area appeared to be paramount to the development of artistic skill. This focus appeared, for artistic savants, to be not only limited to the manner in which the art was produced (e.g., painting, drawing, sculpting) but also to the specific subject matter, with all savants having a special focus of interest. For example one subject only drew boat races, trains or telegraph poles. His depiction of the finish of boat races, drawn from memory, were

Figure 4.1

Original Drawing by a savant artist.

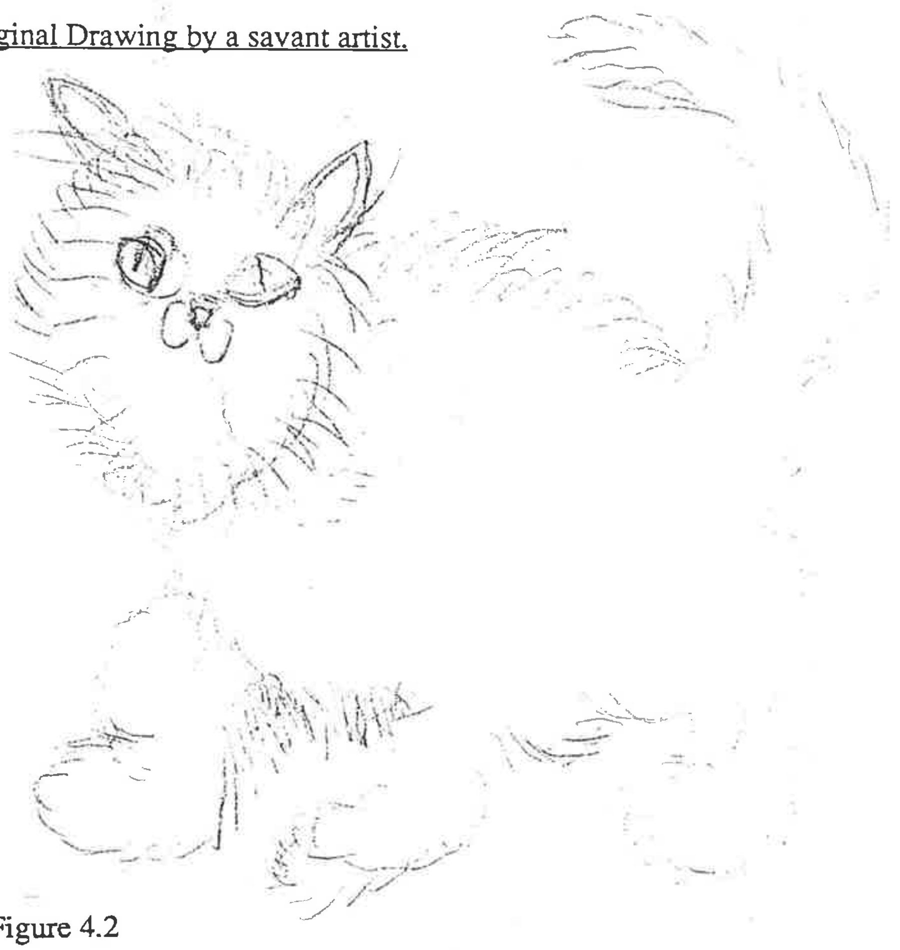


Figure 4.2

Replication by the same savant artist as shown in Figure 4.1.

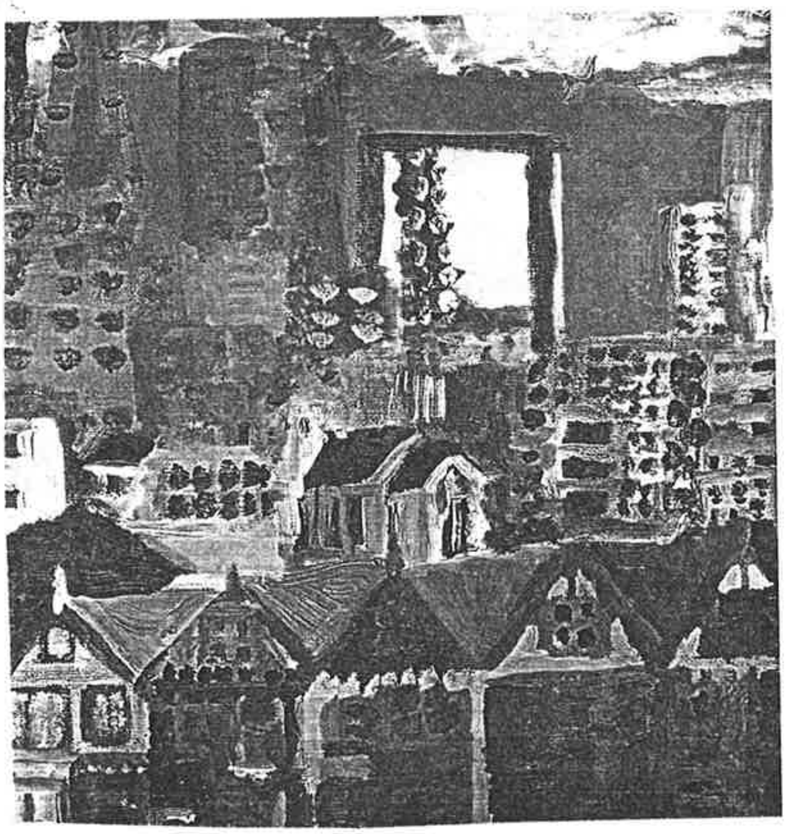
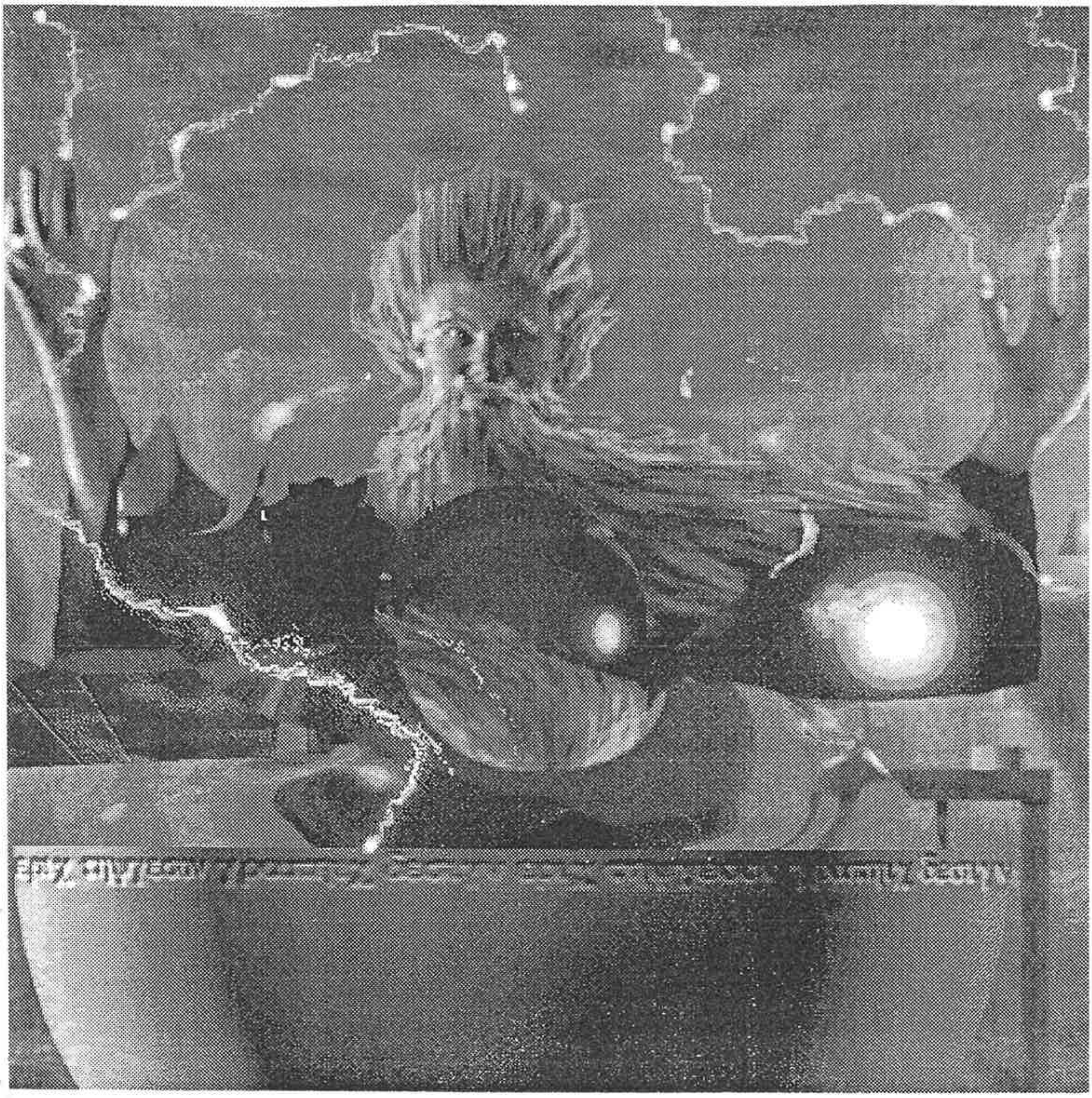


Figure 4.3

Artwork produced by one savant which required more than 24 hours to complete, on the basis of work sessions lasting about 4 hours at a time.



according to his mother, accurate representations of the order in which the boats finished (see Figure 4.4). This savant also had an excellent knowledge of types of telegraph poles which he would draw constantly (see Figure 4.5). Each other savant had a narrow preference for particular subject matter (e.g., animals, buildings, train-tracks, cats) and had to be actively encouraged to draw other subjects.

One artistic savant (aged 16) also demonstrated skills in engineering. His drawings of an "Oil/Air Bearing" (see Figure 4.6) were examined by a professional mechanical engineer (C. Snook, B.E. (Hons); examined November, 1991) for their accuracy, drawing skills and the extent to which they reflected a knowledge of oil bearings and engineering. According to the professional engineer, the drawings demonstrated technical skills far superior to those expected from normal school-aged children. Furthermore, the drawings were judged to show average to strong ability to visualise three-dimensional objects, attention to details, and knowledge of standard drawing conventions. Nonetheless, professional examination of the drawings also revealed that oil or air could not be supplied to the bearings, suggesting that the savant artist may have had no technical knowledge about what he drew. The extent of his knowledge was certainly questionable, given that the drawings resulted from his listening to a radio talk-back program which outlined the design. The design was a near-accurate representation of a standard design which did not reflect creativity because its "overall appearance is consistent with that of most common air bearing units" (Snook, November, 1991; see Appendix 4.6 for full report)

On the Torrance Test of Creative Ability all artistic savants showed concrete thoughts, with poor flexibility and elaboration. Many savants perseverated on a particular theme such as letters, numbers, geometric shapes or light bulbs. Although some subjects were able to produce original ideas, few were able to elaborate on these. There was no significant difference between the creative performance of the artistic savants (as indexed

Figure 4.4

Representation of the order in which boats finished - produced by an artistic savant.

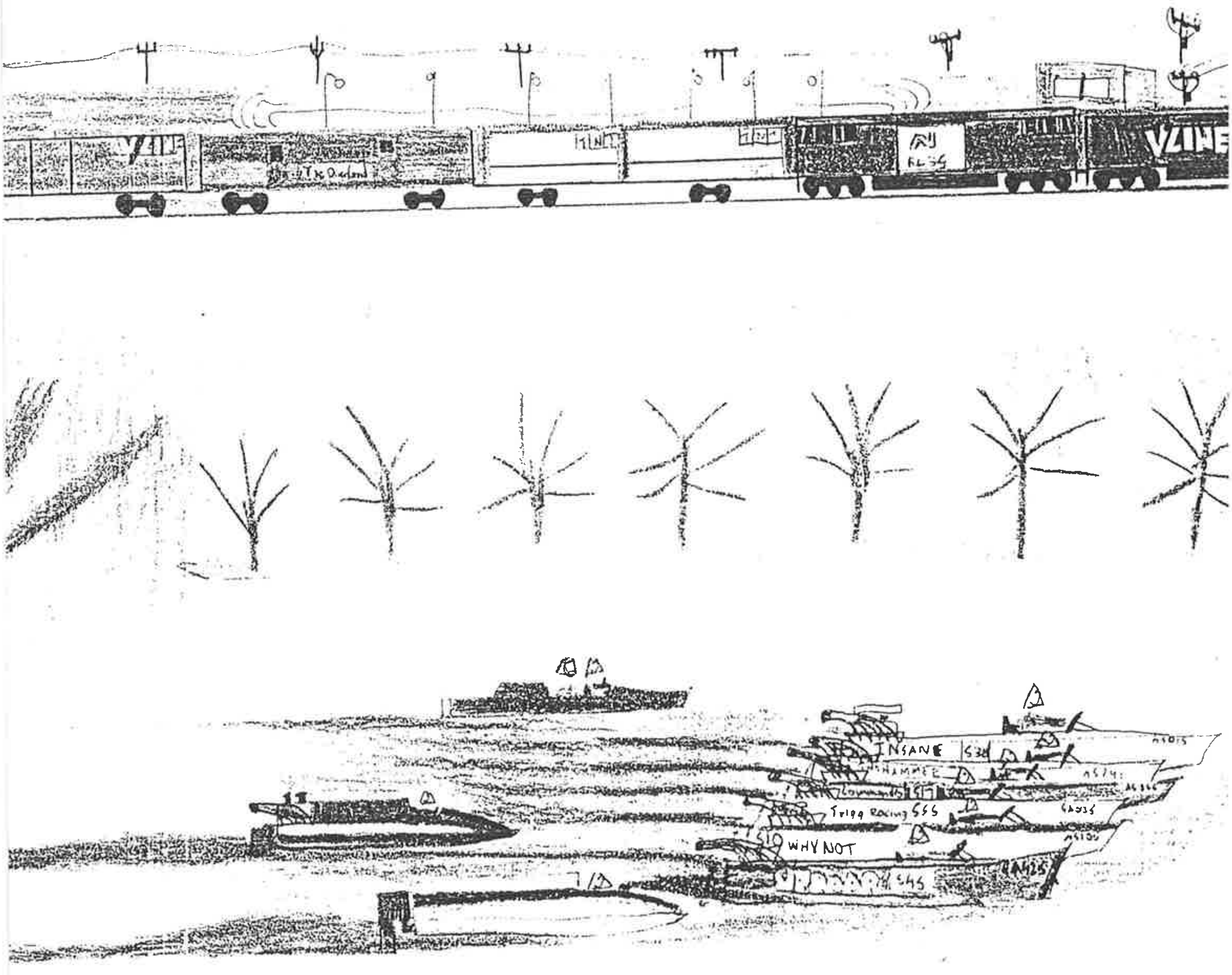


Figure 4.5.

Drawing of telegraph poles produced by the savant featured in Figure 4.4.

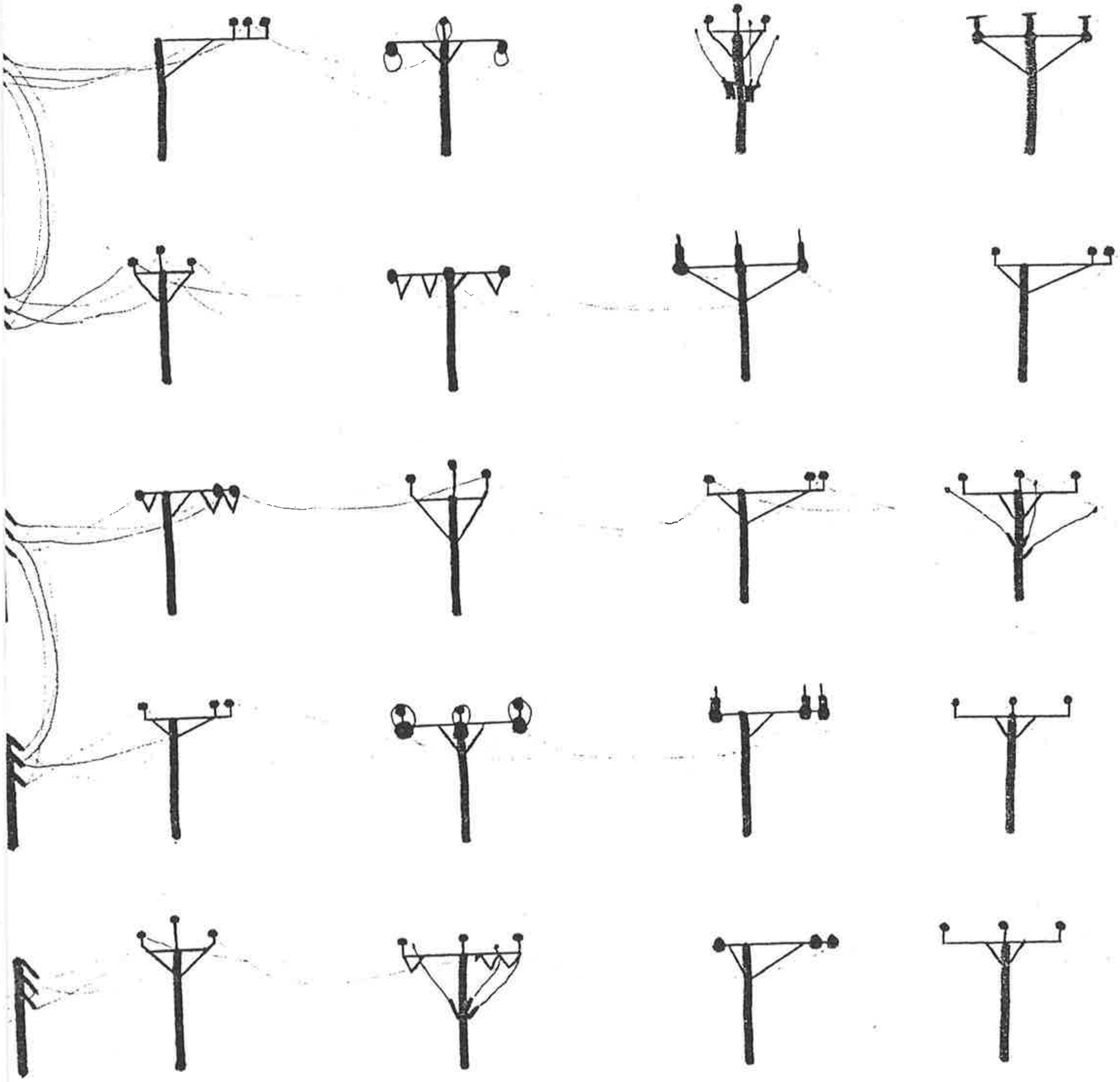
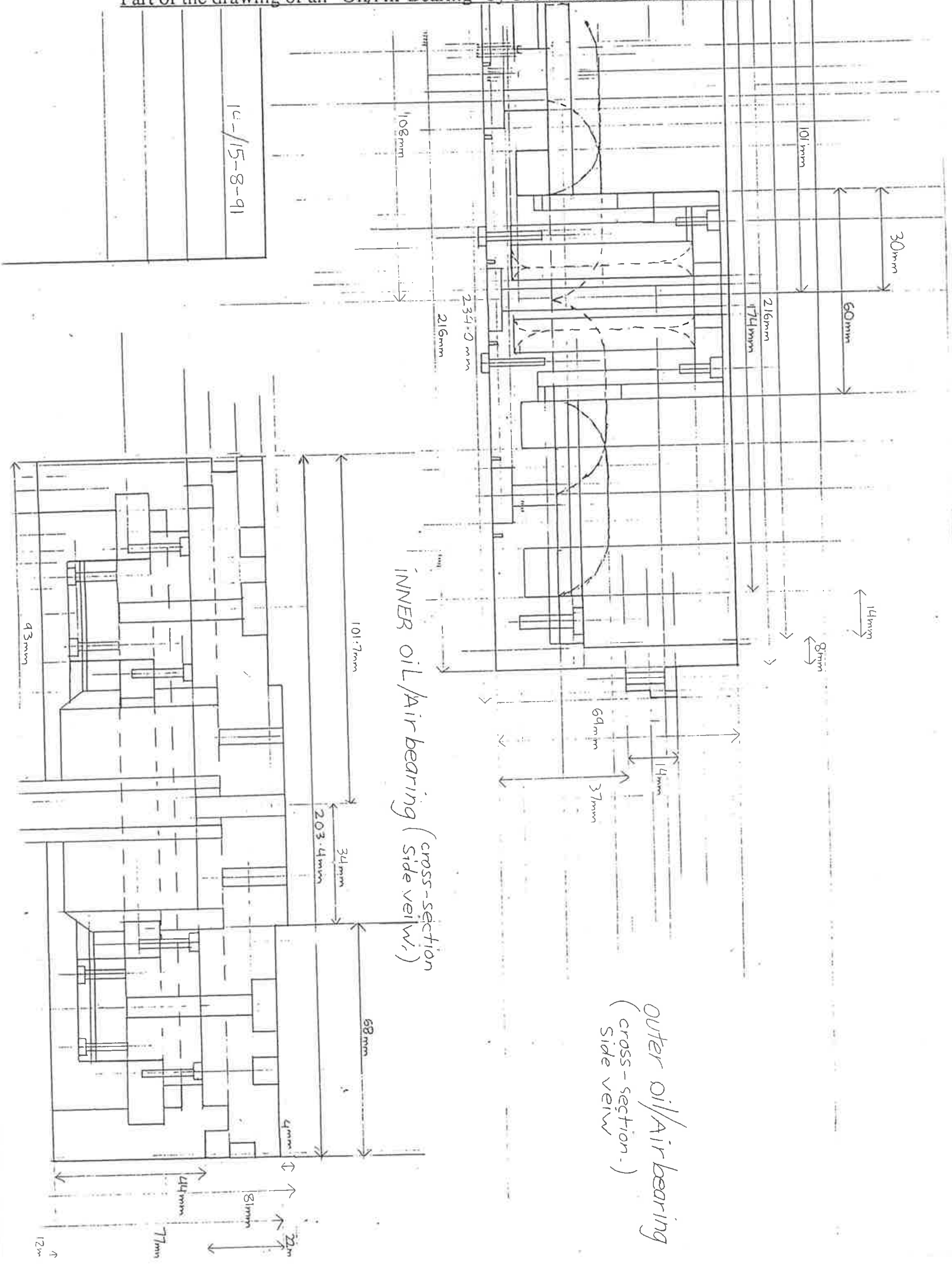


Figure 4.6

Part of the drawing of an "Oil/Air Bearing" by one artistic savant (aged 16).



by the Torrance) and any other group of savants, suggesting that their ability to draw did not depend upon a well-defined ability to create.

4.3.4. (iv) Verbal Skills: Representation without Comprehension.

No subject was recruited on the basis of precocious verbal skills alone. Overall, however, reading rate and accuracy was above what one would expect from subjects' overall level of functioning and measured levels of general intelligence. Fourteen older subjects reached the ceiling level for norms on the Neale Analysis of Reading Ability-Revised for rate and accuracy (i.e., equivalent to 12 years of age) with varying levels of comprehension. Four of the younger subjects (i.e., CA <12 years) demonstrated levels of reading accuracy or rate more than two years above their chronological age; their comprehension was, however, in all cases extremely poor (see Group A, Table 4.8). Another four younger subjects demonstrated a reading age (for rate and accuracy) consistent with their chronological age, rather than their mental age, with comprehension once again poor (see Group B, Table 4.8).

Although comprehension was in general extremely poor, 11 of the 51 subjects demonstrated good comprehension of the material read. Comprehension of written material was correlated with FSIQ as indexed by the Wechsler Scales after controlling for age (given that the comprehension scores were not normalised and were therefore a function of age; $r=.57$, $df=48$, $p<.01$). The mean scores for rate of reading and accuracy are only useful for comparison with the mean score for comprehension because many subjects reached the ceiling level which was above 12 years. These results show that the ability to comprehend material was poor, particularly when compared with reading skills for rate and accuracy, which were for many subjects within normal limits. Most subjects therefore could be considered hyperlexic, not because of extraordinary skills in word recognition, but because of word-recognition superiority in comparison to their general level of comprehension (Silberberg & Silberberg, 1967) and IQ. The use of a test such as the Schonell on this population was inappropriate given that it measured accuracy, not comprehension, which is the area within which these subjects demonstrated the most difficulty. The mean score on the Schonell (9 years 7 months, raw score M=51.1, SD=28.9, N=51), was, however, consistent with the accuracy level on the Neale(9 years 8 months, SD=2.4) .

Table 4.8.

Reading Age (years-months) for scores for Rate, Accuracy and Comprehension on the Neale Analysis of Reading Ability-Revised (Form 2) compared with CA, MA and FSIQ as indexed by the WISC-R.

	Neale Analysis of Reading Ability-Revised (Form 2);					
Subjects	Rate (years-months)	Accuracy (years-months)	Comprehension (years-months)	CA	FSIQ	MA*[a]
Subjects with reading rate and accuracy more than two years above CA						
.Group A (N=4)						
Subject 14	9-6	9-2	5-9	7-1	80	5-9
Subject 26	11.-3	8-9	5-9	6-2	108	6-7
Subject 30	> 12	8-7	7-4	9-10	89	8-9
Subject 54	11-7	7-5	6-2	7-3	84	6-1
Subjects with reading rate more consistent with CA						
.Group B (N=4)						
Subject 21	8-1	6-4	5-6	8-1	84	6-9
Subject 31	7-3	6-1	6-11	7-0	89	6-3
Subject 44	>12	6-1	<5-6	12-10	57	7-4
Subject 51	8.1	7-4	6-11	10-3	71	7-3

[a] Where MA = $\frac{IQ \times CA}{100}$

When divided into two groups split by the median comprehension score for the Neale, subjects with comprehension scores above the mean performed better on tests believed to measure sequential processing (as indexed by the Wechsler Scales). Well-developed sequential processing has previously been associated with enhanced written comprehension (e.g., Das & Mensink, 1989). Preserved abilities in simultaneous processing have, however, been associated with reading rate and accuracy. Because there was no difference in reading ability for rate and accuracy for the two groups who had previously been divided on the basis of comprehension (Das & Mensink, 1989). one would expect no difference between the simultaneous processing measures (as indexed by the Wechsler Scales) for these abilities, which there was not.

4.3.4. (v) Sensory Discrimination

Although no subject was classified as a savant on the basis of this ability alone, acute sensitivity to sensory stimuli was noted in many of the subjects. Such observations included an intense interest in the smell of the testing equipment, an ability to select audio and video-tapes from other seemingly identical tapes and acute hearing. These skills were not evaluated in any way.

4.3.4. (vi) Mathematics

Only one subject was considered a lightning mathematical calculator. His skills involved calculating equations of high complexity at exceptional speed, and were limited largely to multiplication. Although he could solve calculations presented visually or aurally, his technique did not reflect standard multiplication strategies. For example, if the equations were presented in writing (e.g.,) he answered by writing down the correct answer from left to right, apparently computing the number as a whole, rather than by the conventional method of multiplying units, tens, hundreds and thousands and subsequently making additions. His ability to add, divide or subtract was limited, as was his ability to apply his skills to mathematical problems requiring verbal comprehension (e.g. "At 15 cents each how much will 12 oranges cost?"); yet if asked simply to multiply these (i.e., 15x12) - and numbers up to four digits - responses were almost always instantaneous. He was presented with a set of equations in written format and he responded correctly to each of them. He would only respond to verbally presented problems when the answer was immediately apparent to him and always correct. If he did not know the correct answer he would wail and bite his hand. This reaction, together with his methodology, suggests that his ability was the result of over-learned associations between the questions and the responses, rather than an ability to multiply numbers using normal conventional methods taught in formal learning environments. The speed at which he was able to perform these calculations, and the obsessive pre-occupation he had with multiplying numbers on a calculator, supports this conclusion. This preoccupation was evident from his performance in the Torrance Test of Creative Thinking where subjects are required to create pictures from sets of parallel lines. His response was simply to place numbers between each line set demonstrating his obsession with numbers. In addition to his mathematical ability, this savant also demonstrated exceptional skills in reading (rate and accuracy more than two years above his chronological age), memory for dates and the ability to make some calender calculations. His obsession with numbers and written material often led to inappropriate behaviours, such as writing apparently random words and numbers on any available surface and constantly searching for material to read.

Another savant with mathematical skills was able to factorise numbers up to seven digits and the musical savant outlined in Chapter 2 also demonstrated precocious mathematical abilities. One savant selected because of good calendar skills had been documented in the past as having precocious mathematical skills, particularly in the production of prime numbers (Sacks, 1985). He was, however, unable to demonstrate this skill during the testing situation. As two of the mathematical savants had calendrical skills the link between these skills is worthy of further investigation, and the frequency of its occurrence has been investigated further in Chapter 5.

4.3.4. (vii) Mechanical Skills

Although two subjects were recruited for this study based on reports of their mechanical skills only one could be classified as a savant ("talented" - Treffert 1989). The skills of the other subject were best described as "splinter". Both subjects were interested in the assembly and disassembly of technical equipment (e.g., video and tape-recorders). The skills of the talent savant extended to creating electrical circuits and constructing novel mechanical apparatus, whereas the other subject's skills were limited to the disassembly and occasional reassembly of appliances.

On a standardised test of mechanical ability (the ACER Test of Mechanical Ability) both subjects performed poorly, with the savant scoring on the thirtieth percentile and the subject with splinter skills on the thirteenth. A good performance on this test would, however, require good comprehension of written material, which neither subject had. Moreover, both had an interest in electricity and general appliances, not cogs and pulleys and other mechanical systems as assessed on this test. A more practically orientated test with greater content validity, for example one which required assembling familiar mechanical objects, may have been more indicative of the skill level of these subjects. No such standardised test was available but the author did ask these two subjects to assemble a crystal radio, something that they could both do with ease. These results highlight the inadequacy of the available standardised tests when testing the specific skills of savant individuals. It is understandable that more savant skills were not found, given the specific tasks required to isolate such specific and unusual skills.

4.3.4. (viii) Memory

Twenty-six subjects were recruited for the study on the basis of reported superior abilities in declarative memory (i.e., memory for facts), eight of whom were subsequently judged by the author to be savants. The skills of the other 18 were best described as "splinter". Superior memory was commonly demonstrated by excellent recall of facts; but principally of a trivial kind and usually associated with numbers or chronology. For example, subjects could recall race results from racing-boat or Formula 1 competition, the dates of events such as for birthdays, or for the release of popular musical recordings, telephone numbers, post-codes, bus and train information and sporting scores. Other information memorised involved knowledge of capital cities, the human reproductive system, the solar system, addresses of family friends or institutions, types of cars, floor plans and legal codes. Excellent declarative memory was not unique to these subjects, however, with many of the savants recruited because of skills in other areas also demonstrating similar well-developed skills in memory.

Memory is not generally considered to be a unitary function but rather is held to involve distinct functions, such as recall for visual and verbal information, storage, recognition and whether the information is available for short or long terms. These multi-dimensional characteristics are particularly evident among the savant population. For example, Valentine and Wilding (1994) reported that two of their savant subjects scored on the hundredth percentile for memory of telephone numbers but only on the second and fourth percentile when recalling the details of a story. These authors accounted for these discrepancies in performances by suggesting that the savants used mnemonic techniques for the recall of telephone numbers which were inappropriate in the story recall. The present author therefore selected the WMS-R to test memory, because this test provides not only a general memory quotient, but it also assesses specific types of memory. The test manual acknowledges, however, that the test does not provide a measure of all memory functions, including the assessment of material held in long-term storage, one of the primary features of savant memory.

In general, performances by savants and subjects with splinter skills on most subtests of the WMS-R were consistent with IQ. Because norms were unavailable for the WMS-R scores for subjects less than 16 years of age, raw scores were used in subsequent analyses and the effect of age was partialled out because memory quotients, like IQ, are a function of age. Every subtest on the WMS-R was significantly correlated with FSIQ for the group of 32 savant subjects, with the exception of Mental Control (rs .34 to .71 $p<.05$). Significant correlations were not found consistently among the splinter-skills group (N=19), however. Subtests such as Digit Span, Mental Control and Visual Reproduction were on the whole not well correlated with FSIQ for the splinter skills group and nor were tests that measured memory after a time delay (see Table 4.9).

Although results from the present study revealed diversity in memory functioning, they were not indicative of precocious or well-developed general memory for either the savant group or the group with splinter skills. Despite specific areas of expertise, most subjects experienced difficulties with some subtests. For example, most subjects had poor recall of a story when this ability was tested by the "Logical Memory" subtest of the WMS-R. Results from Logical Memory indicated that most subjects, with a few exceptions, scored below the second percentile when compared with age-matched peers (M=14.2, SD=11.3, N=30). This finding might be expected, given that such tasks are generally performed poorly by those with difficulties in comprehension and poor semantic encoding. The near-perfect verbatim recall of one subject after just one hearing might be explained in terms of a well-developed rote-memory because he was unable to respond to informal questions about the content of the story. It has been suggested that laterality of verbal

Table 4.9.

Correlation between FSIQ as indexed by from the WMS-R with the effects of age controlled for.

Correlations with FSIQ	Savants (N=32)	Splinter skills (N=19)
Test / Subtest / Quotient		
Mental Control	.24	.04
Figural Memory	.69**	.32 *
Logical Memory	.69**	..49*
Visual Paired Associates l	.66**	.52*
Verbal Paired Associates l	.67**	.56**
Visual Reproduction l	.52**	.02
Digit Span	.47**	.00
Visual Memory Span	.48*	.49*
Logical Memory ll	.65**	.33
Visual Paired Associates ll	.55**	-.01
Verbal Paired Associates ll	.44*	.32
Visual Reproduction ll	.61**	-.04
	(N=27)	
Verbal Memory Quotient	.74**	NA[a]
Visual Memory Quotient	.67*	NA
General Memory Quotient	.61**	NA
Attention / Concentration Quotient	.30	NA
Delayed Recall Quotient	.70**	NA

* denotes p<.05 ** denotes p<.01

[a] Quotients could only be tabulated for 6 subjects so correlations for this group were misleading and therefore not included.

memory may be conditional on the task demands (Saling, et al., 1993) and, although for most subjects difficulties in Logical Memory are consistent with left hemisphere damage (e.g., Sass, et al. 1992), the performance of this subject suggests other processes, perhaps those utilising right-hemisphere processes, were involved.

Overall, there was no significant difference between the memory scores on the WMS-R for the eight savants recruited for precocious memory, compared with the remaining savants. This might be expected given that most subjects demonstrated skills in memory in addition to the skill for which they were recruited. The variability in performance for savants on Logical Memory was extreme, with some subjects scoring very well although most scored poorly (M=21.5, SD=15.3, N=8). Poor performances were also found among the savants not skilled in memory (M=13.3, SD=9.4, N=24). The wide range for subjects within both groups, however, suggested that, although some subjects may make use of mnemonics or other strategies such as semantic encoding, not all did. The reasons for few differences being found between the two groups were at least twofold. First, the WMS-R was not sensitive to the precocious, yet narrow range of skills demonstrated by these eight subjects, but second, most savants in any case demonstrated highly developed memory in some areas, in addition to their primary skill.

The results of the subtests of the WMS-R were analysed to determine if particular aspects of memory were associated with the development of savant ability. Although the test was designed for adolescents and adults, it was administered to all subjects. Despite normative data being unavailable for subjects less than 16 years of age, data for the younger subjects were used for comparisons within subjects and for other analyses that controlled for the effects of age. Norms were available for 27 of the 32 savant subjects but only six of the 19 with splinter skills.

Due to the language difficulties experienced by most savants, researchers have commonly suggested that savant syndrome is associated with left-hemisphere damage. Although most savants examined here scored poorly on verbal tests such as Logical Memory, their memory for spoken paired associates (i.e., learning associations between word-pairs) was not significantly different from associations made through visual presentations (i.e., learning associations between a colour and a figure). Furthermore, the number of trials required to recall successfully items encoded on Visual Paired Associates was significantly correlated with Verbal Paired Associates ($r=.54$, $p<.01$), suggesting similar processes underlie both abilities. These results therefore suggested that the difficulties these subjects experienced with Logical Memory, which were most likely due to poor comprehension of the stories presented, did not affect their performance when recalling verbal paired associations. Furthermore, it is likely that most savant subjects were unable to benefit from the semantic associations of the Verbal Paired Associations, suggesting that both tasks were dependent on processes other than those typically associated with verbal learning and hence left-hemisphere processes.

Although performance was overall not extraordinary, some savants did demonstrate a talent for learning by association. Seven savants correctly matched all six colours and figures on Visual Paired Associates after just one showing, and two of these subjects made a perfect repetition on the first trial of the Verbal Paired Associates task.

From the eight word-pairs presented in the Verbal Paired Associates subtest, four are considered to be easy associations (e.g., metal-iron) and four to be difficult associations (e.g., cabbage-pen). There was evidence to suggest that items were encóded semantically (i.e., in terms of organised knowledge about word meanings), because there was a significant difference between easy and difficult items in favour of easy items ($t(50)=6.9$, $p<.01$). The role of semantics in the ability to learn and recall associations was of interest.

Therefore subjects' ability to learn and recall associations using words from their skill area was tested. This was done by the introduction of post-hoc verbal association tasks, administered to the last 12 subjects tested (two calendar calculators, six memory, one artistic and three musical savants). Three word-association tests each consisting of eight pairs (four easy and four hard), were presented using words connected with either the calendar, music or art (see Appendix 4.7). It was expected that performance would be facilitated by the subject's knowledge in a particular area. This was not the case, however. Four subjects were unable to achieve a perfect repetition after six trials on at least one of the tests. The number of trials required to reach a perfect repetition for the other eight subjects was consistent within subjects, irrespective of the content of the associations. Although significant correlations were found between all word-association tests (rs .73 to .90; $p<.05$), the word associations relating to art and the calendar were significantly harder than the standardised Verbal Association test of the Wechsler Memory scales ($t(7)=2.55$; $p<.05$ and $t(7)=3.4$ $p<.05$), although no other significant differences were found. The degree of difficulty of such tasks should therefore be addressed in future research.

Savants with precocious skills in memory attract attention because of their ability to recall information stored in long-term memory. One may therefore expect their Delayed Memory Quotient as measured by WMS-R to be superior. Again, however, this was not the case. The reason for this may be because the Delayed Memory Quotient reflects the amount of material learned and, although additional repetitions of the association items are permitted to enable non-impaired subjects to reach the criterion of one perfect repetition, 11 subjects did not achieve a perfect repetition for Verbal Paired Associates and 14 did not reach criterion for Visual Paired Associates. Although savant abilities have been linked to an inability to forget rather than an ability to learn, this was not always apparent. For example, there was a significant difference between the amount of information encoded and that recalled after some delay for Verbal Associations(t(25)=2.7, p<.05). Surprisingly, this difference was not significant for the subjects with splinter skills. Furthermore, there was also a significant difference for savant subjects between Logical Memory 1 and 2 (i.e., recall of a story after a delay; (t(31)=5.58, p<.01). Nevertheless, for Visual-Paired Associates, the amount of information recalled after delay was not significantly less than that encoded initially for either the savant subjects or for the group with splinter skills. This supports the idea that savant skills may depend on an ability to recall information that has been rehearsed and stored but the manner in which it has been encoded and the meaning of the information may have some effect. Because all subjects demonstrated good recall after delay, these cognitive processes alone are not sufficient for the acquisition of savant skills.

Visual Memory Span, a subtest of the WMS-R is a visual-spatial analog of Digit Span requiring subjects to touch coloured squares in the same order as demonstrated by the examiner. The mean length of the number of squares recalled for the savants (M=5.0, SD=1.1, N=32) was significantly less than the Digit Span subtest (M=5.9, SD=1.6, N=32) and less than expected among the normal population (Wechsler, 1984, p135). Although the performance of savant subjects was better than one might expect given their level of disability and functioning in other areas, it was not extraordinary when compared with the general population. It is unlikely, therefore, that the processes that underlie this ability are responsible for the development of savant skills.

4.3.5. Results of other Psychometric Testing

4.3.5. (i) Visual Organisation and Integration (Hooper, Bender).

Subjects correctly identified between 13 and 29 objects out of a possible 30 on the Hooper Test of Visual Organisation (M=22.2, SD=43, N=51), with most subjects scoring within the normal range (i.e., >23). The mean overall score for the Visual Motor Gestalt

Test (Bender) showed no gross peculiarities overall, although there were more errors than would be expected in the normal population (M=3.1, SD=3.2, N=51). Furthermore savants in general performed more poorly on this test than did those with only "splinter skills", suggesting that unimpaired ability in this area is not necessary for savant skills to develop.

4.3.5. (ii). Adaptive Functioning

Subjects were tested for Adaptive Functioning using questions relating to money handling and time (see Appendix 4.8). Positive correlations between the two sets of questions ($r=.94$, $p<.01$) indicated that they were measuring similar processes and knowledge. Despite claims that development of savant skills interferes with social and academic performance (e.g., Tsatsumi, 1969), there was no difference in performance on either set of questions between the savants and those subjects who had splinter skills. In fact, adaptive functioning as indexed by time and money questions was significantly correlated with IQ ($rs=.36$ and $.41$, $p<.01$) and ranking ($rs=-.36$ and $-.41$, $p<.01$) when controlled for age, which suggested the opposite and supported Miller's (1990) hypothesis that savant skills may increase social interaction and cognitive performance. This was consistent with the prediction that the development of savant skills is conducive to one's overall development, because it enhances confidence and self esteem as well as providing an alternative mode of communication (Treffert, verbal communication, October 13, 1993).

4.3.5. (iii) Inspection Time

Inspection Time (IT) measures were calculated for 23 Australian subjects (M=132.8 ms, SD=46.9); 13 savants and 10 with splinter skills. IT measures for some subjects were similar to those typically obtained in studies following the same procedure by Dr Nettelbeck for normal adults (e.g., M=83.8 ms, SD= 21.3, N=87; Personal communication, T. Nettelbeck, June, 1994). These results suggested that speed of information processing, as indexed by IT, is not necessarily affected by the nature of their disability. Significant correlations between IT and level of skill as indexed by ranking (r=.50, p<.05; controlled for age r=.55, p<.01) suggested that IT measures processes common to those involved in savant-type skills. Despite significant correlations between IT and subtests on the WISC-R or WAIS-R with normal populations (e.g., Nettelbeck, 1987; Nettelbeck and Young, 1988; 1989), IT was not well correlated with any of these measures among this sample. Significant correlations were found, however, between IT and some of the subtests of the WMS-R (i.e., Logical Memory l and ll, Verbal Paired Associates l and II, Visual Reproduction l and ll Digit Span and Visual Memory Span), which were also the subtests that were well correlated with the author's ranking of savant skills. These results suggested that the cognitive processes underlying IT may also be those which underlie savant's ability to develop their skill.

4.3.6. Sex Differences.

Of the total of 51 subjects only eight were female; four of whom were savants. Two of the female savants were skilled in art and the other two were musicians. The other four females had splinter skills in memory. The ratio of females to males for savants was 1:7 and consistent with that reported in Hill (1977; 1:6). The ratio of males to females found among the subjects with only splinter skills was consistent with the normal ratio of females to males among the autistic population (i.e., 1:4).

One reason suggested for the predominance of male-savants, offered by Treffert (1989), is linked to the prenatal influences of sexual hormones in the developing foetus. He suggests that cortical growth is slowed by circulating testosterone which also promotes neuronal migration to the right hemisphere. This explanation would also account for the predominance of skills among savants being associated with the right hemisphere.

4.3.7. Family members with high levels of intelligence and similar abilities.

Because many subjects were recruited in institutions, access to family members was not always possible. Nevertheless, IQ estimates were obtained from members within the family nucleus wherever possible. Where more than one sibling of the same sex was tested (in some case some savants had three brothers), the mean of each variable tested was used to provide a more stable estimate of sibling IQ.

Family members of eight savant subjects and eight with splinter skills were tested with either the WISC-R or WAIS-R. Overall, the mean IQ of immediate family members was more than one standard deviation (SD=15) above the population mean (M=100). This outcome supported the hypothesis that had these subjects not suffered a neurological impairment they would have had high levels of intelligence. There was no support, however, in the profiles of the siblings of these subjects for the argument of significant familial clusterings of cognitive abilities, as has been suggested (e.g., August, Stewart & Tsai, 1981). Furthermore, although VIQ has been found to be lower among siblings of autistic individuals, this was not found to be the case in this study. In fact, higher levels of VIQ than PIQ were more common and consistent with high academic attainment, which has been postulated among the families of such subjects (e.g., Rimland, 1978). No significant differences were found between the IQ profiles of savant relatives compared to the relatives of those with splinter skills. This suggested that high IQ among family members is associated with the development of skill but it is not indicative of the level to which the skill will develop. Other factors, such as familial encouragement and interest and the level of functioning of the preserved abilities, may determine skill level.

4.4. General Discussion and Conclusions

Significant correlations between the author's rankings of savants' skills and measures of cognitive abilities and processes suggested that, although savant skills develop in the absence of normal intellect, there is a relationship between level of expertise and level of cognitive functioning. Furthermore, results from psychometric assessments suggested that, although savant skills develop within individuals with low IQs, no subject met the obsolete diagnostic criteria of "idiot", (i.e., an IQ level of less than 25), with the lowest FSIQ for a savant, as indexed by the Wechsler Scales, being 54. These results suggested that there may be a threshold or minimum level of cognitive functioning necessary for these skills to develop and this may vary depending on skill type. Despite idiosyncrasies in abilities within the performances of all savants, there was no consistent profile which emerged that might predict the type of skill that may develop, although consistently high performance by most musical and mathematic savants in tasks such as Digit Span suggested that the processes underlying this task might be necessary for the development of such skills. Similarly, the processes underlying performance on tasks such as Object Assembly may be more indicative of artistic potential. However, while such underlying processes may facilitate the development of such skills, they are not essential, given that not all subjects within these groups performed well on these subtests, with some even performing poorly.

Because most savant skills involve simple reproduction or, the use of rules to solve problems that have predictable or standard solutions, they do not require manipulations of cognitive input, insight or an ability to originate - factors generally considered to reflect intelligent behaviour (MacKinnon, 1962). In fact, savant skills appeared to be concrete not abstract, creative or flexible. Significant correlations between skill level and IQ suggested that the extent to which the ability is developed, appreciated and reflects more sophisticated cognitive processes, is IQ dependent.

Dividing "intelligence" into simultaneous and successive processing was an attempt to define intelligence in terms of processes rather than content (e.g., Wechsler Scales) or general ability (e.g., Jensen, 1986). Results suggested that it is unlikely savants have cognitive processes superior to the normal population. In fact, the cognitive strengths demonstrated by the savants in this study were consistent with those of other autistic subjects, irrespective of IQ or savant capàbilities(e.g., Lincoln, et al. 1988). What was apparent is that some of the processes which underlie savant abilities have been preserved and this, together with adequate reinforcement, a specific interest, practice and opportunity, can result in the emergence of a skill and subsequent development to savant level. Although savant-type abilities will not help individuals adapt, understand and function appropriately in society (Lincoln et al., 1988) results from this study have suggested that fears of such skills being detrimental to one's adaptive functioning are unfounded. Furthermore, evidence for the successful integration of these skills with other adaptive functions has suggested a better prognosis for savants than has been predicted in the past. In fact, recent projects have proved successful in utilising of splinter skills in the employment of autistic individuals (e.g., Shields-Wolfe & Gallagher, 1992). Although savants do not have extraordinary or over-developed cognitive processes, they may utilise different processes and strategies than the normal population when confronted with tasks involving similar stimuli and this is worthy of consideration when presenting savants or any other individuals tasks held to reflect a particular mode of processing. These findings support those of Bainbridge (1993), who proposed that the processes used by individuals are adaptable as a function of esoteric individual factors, including situation and context.

Despite claims of the sudden emergence of skills among savants, observations of savant's behaviour showed that considerable practice was involved, if not in the early acquisition of such skills, certainly the development, maintenance and probably the increased automatisation. The significant correlation between age and the author's ranking of skill-level was consistent with superior abilities developing with experience, pre-occupation and practice.

It was hoped that the tests selected for this study would enable savants to demonstrate the extent to which they demonstrated multiple skills, additional to the one for which they were selected. Results suggested that some skills tended to cluster in groups, with some calendrical calculators also demonstrating music and artistic skills. A young autistic male interviewed by the author because of his ability to multiply three digit numbers spontaneously was also found to be proficient at calendar calculations and he also had detailed knowledge of suburbs in Australian cities in alphabetical order. This ability only became evident, however, when he was left alone to play with the computer and he proceeded to type in cities beginning with "T" in alphabetical order. Another savant tested for his musical abilities also had mathematical and chess skills. Because of the specificity and often peculiarity of most savant skills, it was not clear whether all savants were given the opportunity to demonstrate their range of skills. Nevertheless, the frequency with which savants demonstrated more than one skill was considered worthy of further investigation and a questionnaire was designed to investigate this. The results of this are presented in Chapter 5.

Results from analyses of family data supported the hypothesis that savants emerge from families with above average levels of intelligence (see Table 4.10). High IQs among family members were consistent with the hypothesis outlined earlier that, had savants not suffered a neurological impairment, they would have been bright individuals. As well as a genetic disposition toward higher intelligence and hence special skills, environmental influences were considered worthy of further investigation. Because few parents and family members were available for questioning during the testing sessions a questionnaire was sent to all families of those participating. The results of this are presented in Chapter 5.

Table 4.10.

Mean measures of cognitive processing as indexed by Wechsler Scales (WAIS-R; WISC-R) [a] for relatives of savant subjects and those savants whose families were tested.. Standard deviations are in parentheses.

Subtest / Test	Subject (N=16)	Mothers (N=13)	Fathers (N=9)	Brothers (N=6)	Sisters (N=7)
Information	8.3 (4.0)	13.0 (2.8)	13.7 (3.2)	12.8 (2.8)	13.4 (2.6)
Similarities	8.2 (3.2)	11.5 (3.4)	13.4 (3.3)	13.8 (2.2)	14.1 (2.9)
Arithmetic	6.9 (4.4)	13.4 (3.3)	11.7 (3.5)	14.3 (2.6)	13.3 (3.4)
Vocabulary	6.7 (3.9)	14.1 (3.2)	13.9 (3.3)	13.8 (4.1)	13.6 (4.0)
Comprehension	4.6 (3.7)	14.2 (3.4)	15.0 (2.7)	11.7 (4.5)	12.4 (3.6)
Digit Span	7.6 (4.3)	11.5 (3.1)	10.6 (1.6)	10.8 (5.0)	12.3 (1.8)
Picture Completion	6.6 (2.7)	12.2 (2.4)	11.4 (3.0)	11.0 (1.5)	10.6 (2.0)
Picture Arrangement	6.2 (3.7)	10.8 (3.2)	11.7 (3.6)	12.8 (2.6)	11.0 (3.4)
Block Design	8.6 (4.5)	13.1 (4.5)	11.6 (2.5)	15.7 (2.3)	13.3 (2.3)
Object Assembly	8.3 (3.2)	11.5 (3.5)	10.1 (2.8)	12.8 (4.1)	12.6 (4.5)
Coding	5.5 (4.2)	10.5 (3.0)	9.4 (2.2)	12.3 (3.7)	12.9 (3.5)
VIQ	82.6 (17.6)	121.6 (17.7)	122.5 (19.2)	123.8 (19.7)	123.1 (20.5)
PIQ	81.9 (15.3)	121.7 (16.6)	114.4 (15.0)	123.5 (13.2)	114.7 (21.5)
FSIQ	80.1 (14.3)	123.7 (17.3)	120.4(17.6)	126.2 (18.0)	122.1 (21.9)

[a] Scaled subtest scores on WAIS-R and WISC-R range from 1 to 19 (M=10; SD=3). A score of 8 or less places the adult in the lower 25% of adults and a score of 5 or below places the adult among the least able 5%. For WAIS-R scales, PM and CPM, scaled scores follow the conventions of mean=100, SD=15.

The results of this study have left a number of questions unanswered which were considered worthy of further investigation. Firstly, because most savant displayed autistic tendencies, the prevalence of such behaviours were considered useful in addressing the association between autism and Savant Syndrome. Secondly, the extent to which savants demonstrated skills in other areas that were not detected by formal assessments was addressed as was the skill and skill-level among family members to determine environmental influences on the development of these skills. These issues are addressed in Chapter 5.

Chapter 5

General Overview of Savants

5.1. Introduction

The results of the research presented in the first four chapters of this thesis have provided valuable information relating to the cognitive processes underlying savant type skills, the role of memory and creativity, familial tendencies, and the level and type of skills demonstrated by savants. At the same time, however, this research has given rise to a number of questions relating to the behavioural characteristics of savant, levels of abilities among family members, and practice and commonalities between skills, thereby highlighting the need for further investigation. A questionnaire was designed to address these questions and administered to the parents of the 51 subjects who had been involved in the earlier study presented in Chapter 4. Responses to this questionnaire are discussed in the sections to follow.

5.1.1. What are the behavioural characteristics common to autism and savant syndrome?

Although O'Connor & Hermelin (1991b) found that savants were almost evenly divided between those with a clear diagnosis of autism and those with other diagnoses for their disabilities, the frequency of autism among the savants who participated in the research presented in Chapter 4 was conspicuous. Furthermore, even though not all of the savants investigated in Chapter 4 were autistic in Kanner's (1943) terms, autistic tendencies such as preoccupation in an area of interest, and difficulties in communication, were present in all subjects. The investigation of characteristics common to both autism and savant syndrome was therefore considered worthwhile because the isolation of such characteristics might enable the early identification of individuals who are predisposed to develop savant skills. For example, it has been suggested that savant syndrome is common among the autistic population because such individuals have a pathological inability to broaden their focus and they therefore devote intense amounts of mental energy to internal preoccupation (Rimland, 1978a). The questionnaire, which is included in Appendix 5.1, was therefore designed to investigate the frequency with which autistic characteristics were demonstrated by each subject during their development. (See Section A of the questionnaire, Appendix, 5.1).

5.1.2. Are "similar" skills present in family members?

The higher IQ levels of family members of subjects participating in the work presented in Chapter 4 suggested a possibility that many subjects had a predisposition toward higher intelligence. Nevertheless, it was concluded that because there was no significant difference between the IQ of parents of the savant subjects and the parents of those subjects with only splinter skills, any such predisposition was not sufficient to generate the development of a skill to a prodigious or talented level. Because it is generally accepted that natural talents are developed by familial tendencies, encouragement and practice (Howe, 1989), it was hypothesised that such characteristics were involved in the development of savant-type skills. Although Tredgold (1923) found that similar abilities rarely existed in the ancestors of savants and LaFontaine (1976) found only one family member with similar abilities among the 23 relatives of her savant subjects, such studies have invariably sought precisely the same skill in family members as that displayed by the savant. Instead, it is suggested here that the demonstration of any skill(s) among family members, albeit different in kind, requires the same environmental stimulation and personal characteristics such as dedication and desire to achieve a high level of success that the development of savant skills require. It has therefore been argued that development of any skill among family members to a level of precocity, irrespective of skill type, would increase the likelihood that other members of the family including the disabled member will also develop skills. Accordingly, it was hypothesised that the frequency with which skills were present among family members would be related to the level of precocity achieved by subjects. Information relating to the type and level of skills demonstrated by family members was therefore requested. (See Section C, Appendix 5.1).

5.1.3. Are multiple skills common among savants and do certain skills tend to occur together?

Multiple skills have been reported among savants in the literature (Rimland, 1978a; 1978b), with this being more common among savants with a diagnosis of autism (Rimland, 1978b). The prevalence of multiple skills within individuals was therefore further evaluated, as was the frequency with which groups of skills tended to cluster within individuals (See Section B, Appendix 5.1). .

5.1.4. How much time is involved in the acquisition, development and maintenance of precocious skill?

The importance of practice to the development of savant skills has been frequently reported among the literature (Anastasi & Levee, 1960; Ericsson & Faivre, 1988; Shiffrin & Schneider, 1977). Morishima and Brown (1977), for example, demonstrated that a savant artist could be "created" from a mentally retarded individual whose only skill prior to instruction and training was his ability to draw a perfectly straight line. After 15 years of formal, structured and consistent artistic tuition and considerable practice, his artistic skills developed to a level considered worthy of savant classification. As a result of findings such as these, the present author was sceptical of accounts that suggested the sudden emergence of a skill with full-blown competency. Instead, it was hypothesised that, although individuals may have shown an early interest in a skill area, besides a capacity or talent which may have facilitated subsequent development of that ability(e.g., absolute pitch where music is involved, Charness, 1988; or the ability to draw a straight line for artistic talent, Morishima & Brown, 1977), intensive training and rehearsal was still necessary for the development of an ability to a talented or prodigious level.

The amount of time that subjects had spent engaged in their area of interest was investigated, together with the amount of training that subjects had received (See Section B in the questionnaire, Appendix, 5.1). It was hypothesised that the time spent practicing and the extent of formal instruction would be directly related to the level of expertise achieved by each subject.

5.1.5 Background of savants.

In order to identify any commonalities in the psychological, biological and social development of savant subjects, questions concerning abnormalities during their mother's pregnancy and the subject's early development were included in the questionnaire (See Section A: Personal Detail, Appendix 5.1).

5.2. Method

5.2.1 Subjects

All subjects involved in the study presented in Chapter 4 (N=51) were included in the following research.

5.2.2. Questionnaire and Procedure

A questionnaire which addressed all of the above issues (i.e., personal details, diagnosis, skills and family background) were designed by the author and sent to the parents of all subjects (see Appendix 5.1), either directly or via the institution from where subjects had been recruited. The content of the questions relating to the behavioural characteristics of autism and its diagnosis were based on the Autism Diagnostic Interview - Revised (ADI-R) and the Diagnostic and Statistical Manual of Mental Disorders lll-R (DSM-lll-R).

To increase the likelihood that parents would respond, each questionnaire was personalised by inserting the subject's name in the questions where applicable and a stamped addressed envelope was supplied for the return of the questionnaire. After two months only 23 questionnaires from the 51 sent had been returned, so a reminder letter accompanied by another copy of the questionnaire was sent out to those who had not replied. This follow-up netted a further 14 completed questionnaires. In a final attempt to encourage parents to respond, parents were either telephoned by the author or the centre, requesting an immediate return of the questionnaire.

5.3 Results

5.3.1. Validity of Responses.

In total 39 questionnaires were returned from the 51 sent. Twenty-three of the returned questionnaires involved savant subjects while the remaining 16 were from the parents of subjects who demonstrated splinter skills. Early developmental histories were unavailable for two subjects; one subject had been adopted shortly after birth and another questionnaire was completed by a care-giver, not a parent, who although aware of the parent's background was unfamiliar with the subject's early development. Although it was accepted that respondents answered the questions honestly, it was also noted that the accuracy of parent's observations and memories could on occasion be questioned, because of inconsistencies between the parent's responses and the author's observations. For example, the mother of the mechanical savant outlined in section 4.11.7, although noting his skills, responded that he had no special talent. In addition, the care-giver who responded on behalf of a musical savant enrolled in a special school for musically talented individuals responded that the subject involved had no formal training and only practiced two hours a week, yet the author was aware from direct observation that this person played the piano at school for more than 10 hours a week, under the instruction of a professional musician. Another mother responded "no" to questioning about her child having any interests unusual in intensity, yet the author was aware that her son, aged 8, prepared projects for school relating to his interest at that time which required more than three hours work every night. Moreover, this was accomplished with the help of his mother who laboriously collected reference material for him. These observations notwithstanding, however, most responses were consistent with the author's impressions of the subject's abilities.

5.3.2. What are the behavioural characteristics common to autism and savant syndrome?

Questions relating to behavioural characteristics associated with autism were divided into three sections in the questionnaire: Section A, Language and Communication; Section B, Social Development; and Section C, Interests, Rituals and Routines. (The number of responses to each question in the affirmative and the negative are tabulated in Appendix 5.2). The responses relating to each subject were tabulated within each of these sections to determine the number of autistic characteristics demonstrated by each subject. For quantitative analysis, responses were recoded where necessary so that an affirmative response was indicative of autistic tendencies.

The numbers of autistic characteristics demonstrated by each subject for each section and the combined total are presented in Appendix 5.3. Subjects were divided into two groups on the basis of those having had a formal diagnosis of autism by a health-care worker (N=27) and those who had not received such a diagnosis (N=12). Although the diagnosis for some subjects did indicate autism (e.g. Asperger's Syndrome (N=3); or language disorder with autistic tendencies (N=2)), such individuals were classified as not formally diagnosed as autistic for the purpose of this analysis. No significant difference was found between the number of autistic characteristics demonstrated by those with a formal diagnosis of autism and those with another diagnosis for their disability, for any of the above sections. The difference between the two groups for total number of autistic tendencies demonstrated throughout their development was however, significant ($t(37)=2.29$; $p\leq.05$). Differences were found between these two groups for a number of individual questions. For example, autistic subjects were more likely to confuse personal pronouns (Question A-12), invent their own words (Question A-13) and continually repeat what they had heard (Question A-18) (ts between 2.6 and 3.7, ps<.05). Socially, autistic subjects experienced more difficulties with showing appropriate facial expressions (Question B-20; $t(37)=2.4$, $p<.05$) and finally, autistic subjects were more likely to play with a part of a toy rather than the whole toy (Question C-3) and insist on doing things in a particular order (Question C-12; ts 2.1 and 2.8, $p<.05$). Despite these minor differences between the two groups, the subjects who had not been formally diagnosed as autistic showed equal likelihood of demonstrating other autistic-type behaviours, particularly those generally associated with the development of savant skills such as poor communication, and socialisation, together with a limited range of interests that were unusual in their intensity (see Table 5.1). This result suggested that, although autism may not be a suitable diagnosis for some of the subjects, all subjects demonstrated autistic characteristics. Furthermore, it is possible that a formal diagnosis of autism was overlooked for some of the lower IQ subjects, in favour of a more general diagnosis such as mental retardation.

It was not possible to isolate those autistic characteristics directly associated with the development of savant skills because there were no significant differences between the savant group and those subjects with splinter skills for any of the variables outlined above. Although significant differences were found between the two groups for responses to a few questions which indicated that savants were more skilled in nodding for yes (Question A-3), had more complicated body movements (Question A-10) and better facial expressions

(Question B-20), it was considered unlikely that such characteristics were associated with the development of subjects' skills.

5.3.3 The Occurrence of Multiple Skills and Groups of Skills.

The responses from the parents of all but one subject reported the presence of more than one skill. Moreover, the reliability of data for this subject was questionable because the mother responded in the negative to all questions relating to skill and skill level, although this subject had been identified by the author as a talented mechanical savant. Most parents reported that their child had more than one skill, with some suggesting their child had as

Table 5.1

Mean scores for subjects with a formal diagnosis of autism and those without such a diagnosis, for questions relating to the demonstration of autistic characteristics as seen in the questionnaire.

		Section A Language and Communication	Section B Social Development	Section C Interests, Rituals and Routines	Total Number of Autistic Characteristics
Total Score possible		17	21	13	51
Diagnosis					
Autistic	M	8.0	11.4	9.5	28.9
(N=27)	SD	2.0	4.0	2.4	5.6
	Range	5-13	3-18	5-13	15-38
Non-autistic	M	7.2	9.2	8.2	24.5
(N=12)	SD	2.2	4.4	1.8	5.4
	Range	5-13	4-19	5-11	19-37
Overall	M	7.8	10.7	9.1	27.5
(N=39)	SD	2.1	4.2	2.3	5.8
	Range	5-13	3-19	5-13	15-38

many as nine skills (M=4.4, SD=2.2; see Appendix 5.4). The number of skills demonstrated by savants was significantly correlated with the skill level of each subject, as indexed by the author's ranking (as described in Chapter 4) (r= -.34, p<.05). Correlations between the number of skills and any other variable, including IQ, did not reach significance. This finding confirms the author's speculation that the more prodigious subjects' skills were, the more likely subjects were to demonstrate a wider array of skills. Moreover, although one might have suspected that IQ would also correlate with the number of skills demonstrated, given that it was well-correlated with subject's rank of skill, these results indicated that a subject who develops a skill to levels of precocity is more likely to demonstrate a wider range of skills, irrespective of IQ or any other variable. This suggested that the same underlying processes are involved in the development of subsequent skills, and these processes are not IQ dependent.

The most frequently reported skill was a precocious memory (N=37) mainly for a discrete range of interest areas such as birth-dates and the dates of record releases (see Appendix 5.5). The second most frequently reported skill was spatial skills (N=20) being demonstrated through media like jig-saw puzzles and playing with blocks. The next most reported ability was associated with marked sensitivity, mostly to sound (N=17), followed by calendrical calculation (N=15), musical (N=15) and artistic (N=15) skills. Although precocious athletic skills were not sought and therefore not observed by the author, parents of nine subjects reported athletic prowess. The range of skills in this area included, basketball shooting, volley-ball serving, bicycle riding, cross-country skiing, running, swimming, tenpin bowling and other unspecified ball skills. It is noteworthy that all of these athletic skills can be developed through practice, independently from interactions with others; that is, they are not skills that involve teamwork or an understanding of game rules, objectives or strategies. In that manner, therefore, they are similar to other savant-type skills. Other skills reported by parents to be evident in their child were computing skills, excellent hand-eye co-ordination, attention to detail and writing long, although incoherent, stories (see Table 5.2).

Table 5.2

The number of subjects (out of 39) reported by parents as having special skills in particular areas and the level[a] parents perceived their skill to be.

Skill	Number with special skill	Level 1	Level 2	Level 3
Memory	37	5	6	26
Spatial skills	20	9	4	7
Sensory sensitivity	17	8	2	7
Drawing/art	15	6	4	5
Musical ability	15	6	1	8
Calendar calculation	15	6	4	5
Hyperlexia	14	7	2	5
Mathematics	13	4	3	6
Good pitch	12	5	1	6
Athletic performance	9	2	4	3
Other skills	4	2	1	1

[a] Level 1 implies the skill is only special in relation to overall ability; Level 2 is special in comparison to other individuals of a similar age and Level 3 would be considered exceptional in the normal population.

The frequency with which skills tended to occur together is illustrated in Table 5.3. Of interest was the frequent grouping of specific skills which might suggest common cognitive processes underpinning the development of those skill. Principal components analysis followed by varimax rotation identified three main components or groups of skills (see Table 5.4). The first component incorporated the skills of music, pitch, hyper-sensitivity to stimuli, maths, memory and art and although largely consistent with Rimland's (1978b) music/memory category, the fact that art also loads on this factor is unexpected. The second component extracted grouped the skills of calendrical calculation, maths, athletic skills and spatial ability. Hyperlexia loaded highly on the third factor with no other skills loading significantly on this factor. appeared to be an independent ability (see Table 5.4) Overall, this analysis suggests that different skills may involve the same neurological substrates or underlying cognitive processes, which would account for the co-existence of more than one skill in individuals.

Table 5.3.

A frequency count of the number of individuals who demonstrated both of the skills indicated.

Skill	Memory	Music	Maths	Art	Pitch	Spatial	Calendar	Sensory	Athletics	Hyperlexia
Music	15									
Maths	13	8								
Art	15	8	6							
Pitch	12	12	8	8						
Spatial	19	8	7	7	5					
Calendar	14	6	7	3	4	7				
Sensory	17	11	7	10	7	9	6			
Athletics	10	6	8	5	4	7	5	4		
Hyperlexia	13	5	5	4	4	8	6	8	4	
Other	4	2	1	1	1	1	1	2	1	1

Table 5.4

Components produced following a Principal Components Analysis followed by a varimax rotation.

	Factor 1	Factor 2	Factor 3
Memory	.46265	.39797	.14489
Hyperlexia	.15524	.13446	.80807
Maths	.59174	.48173	.27205
Art	.46017	.34991	-.57798
Music	.90027	.02835	-.14717
Pitch	.81554	-.25683	-.39858
Spatial	-.03746	.76498	-.24790
Calendar Calculation	-.13503	.51140	.24015
Sensory	.74806	.08894	.22714
Athletic Prowess	.33045	.75648	.04777

5.3.4 Skills among Family Members

There was substantial support for the existence of high levels of skills among family members, although not always within the domain of the skill exhibited by the savant. From the responses documenting the abilities of close relatives of the subject (i.e., parents, siblings, grandparents, cousins, aunts and uncles) 49 relatives were documented as demonstrating skills mostly within the discrete range of abilities associated with savants. Skills also reported included prodigious writing ability, skills in physics that had been well-recognised and computer skills that had resulted in one relative achieving 16 patents with IBM (see Appendix 5.6). Interestingly, only 10 of the subjects had a relative or several relatives (N=15) with the same skill as theirs, despite 23 of the subjects having relatives with a skill of some precocity. It was interesting to note that all subjects skilled in art had relatives with similar skills and three of the four musical savants whose parents had responded also had relatives who were musically inclined (see Table 5.5). These results conflict with earlier reports that have suggested no history of similar skills existing among family members (LaFontaine, 1974; Tredgold, 1923).

As predicted, the frequency with which skills were reported in families was related to the skill level of savants as indexed by their ranking ($r = -.47$, $p < .01$). This result supported the suggestion that the existence of skills among family members increased the likelihood that a skill would develop, albeit different in kind. Thus the finding, among the disabled population is as one would expect in the normal population (Howe, 1989). Furthermore, there was considerable evidence to suggest that, not only did many of these subjects come from talented families with higher levels of intelligence, the parents were also well educated, with more than half of the parents having tertiary education. A relatively common field of study for the fathers was engineering (N=7 out of 38), with mathematics being the most frequent vocational preference for the mothers (N=4 out of 38) (see Appendix 5.7).

Table 5.5

The number of family members that demonstrated well-developed skills either in the same area, or different areas from the skills of the disabled relative

	Skill							
	Memory	Calendar Calculation	Music	Art	Mech-anical	Maths	Spatial	Total
Number of subjects from whom questionnaires were returned	21	4	4	5	2	1	1	38
Number of subjects with a skills in this area that also have relatives with a skill in another area	10	3	4	5	1	0	0	23
Number of relatives of subjects skilled in the same area	3	0	5	7	0	0	0	15
Number of subjects with a relative skilled in the same area	2	0	3	5	0	0	0	10
Skill of family member								
Memory	3	1	0	2	0	0	0	6
Music	2	3	5	0	0	0	0	10
Maths	3	2	4	0	0	0	0	9
Art	8	0	1	7	3	0	0	19
Spatial Skills	2	0	1	0	0	0	0	3
Writing / Reading	0	0	3	0	0	0	0	3
Physics	0	0	3	0	0	0	0	3
Hyperlexia	0	0	0	1	0	0	0	1
IQ	1	1	0	0	0	0	0	2
Computing	0	0	1	0	0	0	0	1

5.3.5 Practice and Training

The responses relating to the time subjects spent practicing their special skill, ranged from no time at all to 84 hours. Although the question requested a quantitative response, only nine parents estimated the time their child spent practicing. Many parents gave qualitative statements to describe their child's involvement in their skill, such as "every waking hour", "whenever possible" and "as much time as we'll allow". Such responses were indicative of the preoccupation that most subjects had demonstrated to the author. Furthermore, because the development of savant-type skills appears to involve "mental rehearsal", in addition to overt behavioural displays, the author believes that the time that savants engaged in their skill exceeded the time estimated by parents. Nevertheless, and bearing in mind these difficulties, no relationship was found between the time that parents reported their child practiced and other factors like the author's ranking of skill level or IQ. Although interpretations based on these data should be treated with caution due to the difficulties outlined above, what was apparent was that, irrespective of skill level, many subjects have spent considerable time practicing their skill but not all have reached savant levels. This finding suggests that although practice may be an integral part of the development of a skill, other factors determine the level to which a skill can be developed. Such factors might include an innate pre-disposition (Jensen, 1990) and environmental reinforcement. For similar reasons it was impossible to measure the amount of training that subjects had received and whether this occurred before or after the demonstration of ability. All subjects skilled in "trainable" areas such as music and art had received formal training at some point.

5.3.6 Background Information

No single variable relating to a subject's developmental history emerged which could account for either the development of a skill or reasons for the subject's disability. The gestation period of most of the subjects was within normal limits(i.e., 40 ± 2 weeks) with only four being outside this range (i.e., 33 weeks, N=1 and 37 weeks, N=3; M=38.7 weeks, SD=1.7, N=40). Although some subjects had experienced a difficult birth, with one having had a brain haemorrhage and eight receiving oxygen, the birth of twelve subjects was reportedly "trauma" free.

When questioned about the possible causes for their child's disabilities, most parents blamed environmental factors during pregnancy such as rubella and lifting heavy objects. Other explanations included reference to inherited characteristics akin to autistic tendencies and schizophrenia among family members, particularly relations on the father's side (see Appendix 5.8).

Concerns that their child was disabled began as early as birth for some parents while others did not become concerned until as late as when the child had turned 4 years. The mean age for initial concern was around 16 months (M=16.16 months, SD=13.03, N=37). Most parents became concerned about their child due to delayed or unusual language development (N=21) while others noted that lack of responsiveness (N=7), excessive crying (N=3), and seizures initiated their concern. Only two of the subjects had received main-stream schooling throughout their education, with seven having a mixture of both special and main-stream education and 31 subjects experiencing only special schools.

Twenty-eight of the parents completing the forms had suspected above average levels of intelligence early on in their child's development. The reasons for this suspicion ranged from demonstrable mechanical abilities to precocious reading skills (see Appendix 5.9). The age at which parents noted their child's skill ranged from 2 months to 20 years of age (M=7 years, SD=5.0, N=25). Unfortunately, these responses related to the skill that the parent considered to be the most precocious and do not reflect the age at which parents first observed a talent of any kind.

The prevalence of subjects who did not demonstrate a preference for their right hand was more common among these subjects (N=18, i.e., 46 %) than is found among the normal population (e.g., 13.8%; Spiegler & Yeni-komshian, 1983), although higher incidence of left handedness is more common among autistic populations, with Gillberg (1990) estimating its occurrence at 62%. Nevertheless, only six subjects (i.e., 15%), were reported to show a definite preference for the left hand. Ambiguous handedness, that is having no particular preference for one hand, while rare in the normal population (Sooper & Satz, 1989) was reported in twelve subjects (i.e., 31%). Furthermore, some parents stated that their child had been encouraged to use one hand, despite having no indication from the child as to which hand was dominant. It has been suggested that hand preference phenotypes are associated with different levels of cognitive functioning and may provide biological markers of different aetiological subgroups (Satz, Soper & Orsini,1988). Significant differences between these groups (i.e, right handed versus non-right-handed) for some subtests of the Wechsler Intelligence Scales (i.e., Similarities, Picture Completion, Digit Span and Block Design) supported this finding and further investigation in this area is recommended. It is hypothesised that delays in the development of hand-preference are also associated with delays in hemispheric lateralisation which may facilitate the development of savant skills.

Chapter 6

General Discussion and Conclusions

6.1. Terminology

At the outset of this thesis the author rejected the term autistic-savant to describe all savants and despite the prevalence of autistic behaviours among the subjects involved in this study, a diagnosis of autism was not suitable for all subjects, making the use of this terminology inappropriate. Furthermore the minimum IQ level found among these subjects was 52 (as indexed by he Wechsler Scales), supporting Hoffman's (1971) suggestion that savants are rarely of the lowest grade of mental deficiency implied by the term "idiot" and confirming that the term "idiot" is not appropriate.

6.2. Adaptive functioning

Concerns that the obsessional preoccupation demonstrated by savants in their area of interest is detrimental to their adaptive functioning (Tsatsumi, 1969) were not confirmed by the research presented in this thesis. In fact, the results from the questions relating to time and money reported in Chapter 4 (considered to reflect adaptive functioning), showed a significant correlation between these responses and skill level. If with a skill was detrimental to adaptive functioning, it would be expected that the most skilled subjects would demonstrate the lowest level of adaptive functioning but this was not the case. Furthermore, the responses from the questionnaire presented in Chapter 5 (see Appendix 5.1 Section A) showed that savants with higher level skills did not demonstrate more difficulties in socialising or communicating than subjects with splinter skills. It is therefore concluded that the involvement in a skill to levels shown by savants is not detrimental to their overall development. In fact, the development of a skill may even be beneficial to a savant's social development, by providing a means of communication and the opportunity to receive admiration from observers; something that most children strive for.

6.3. Savant-syndrome and Autism

Although the diagnosis of autism does not extend to all savants, the results of observations during all of the experiments presented in this thesis, together with the information collected from the questionnaire in Chapter 5, demonstrated that all subjects showed some autistic characteristics, principally social withdrawal and indifference and an obsessive preoccupation with an area of interest. A plausible conclusion is therefore that the higher incidence of savants observed among the autistic population compared with other intellectually disabled groups (Hill, 1977), is not coincidental and that these autistic-type characteristics play an integral role in the development of the savant's skill. This conclusion is consistent with the suggestion that difficulties experienced by individuals with autism in areas such as communication, play and socialisation, may be compensated by behavioural tendencies arising from needs for repetition and familiarity. Nevertheless, these tendencies are not peculiar to the autistic population and, in fact, many of these characteristics may be necessary for the development of a skill, even among the normal population. For example, an obsessive preoccupation demonstrated by savants is similar in some ways with the dedicated behaviour of many who invest enormous effort in the development of their talent, be it music, art or science, although the quality of such accomplishments is generally lower than savants. Such talents are, moreover, highly valued by our society and therefore such single-minded application is usually not considered to be excessive. Indeed, within such areas this is regarded as necessary if one is to succeed.

The dedication displayed by savants is comparable to the behaviour of young children who spend hours engaged in repetitive behaviours, such as watching the same video repeatedly, singing the same song, or doing the same puzzle over and over. However, with cognitive and social maturation, children diversify their interests and become bored by simple repetitive acts. This higher level of mental maturation is not achieved by savants and consequently their focus does not change. Instead, savants continue with their obsession and need for repetition. Nevertheless, given that all subjects participating in the work reported here demonstrated similar obsessive behaviours, but many remained at a “splinter” level and did not develop their skill to a "prodigious" or "talented" level, motivational factors alone are not sufficient to explain development of a skill to precocious levels.

6.4. Savant Syndrome and Practice

Despite anecdotal claims that savant skills emerge suddenly, observations of savants' behaviour and reports from their parents, showed that considerable practice and preoccupation with their skill was necessary, if not for the initial acquisition of a skill, then certainly for the skill’s maintenance and increased automation. The savant presented in Chapter 2 (TR) practiced his music extensively and had received substantial formal training in order to develop his musical ability. Likewise, the performance of the calendar calculators presented in Chapter 3 implicated practice as a major contributor to the development of their skills, particularly the increased automation of their responses. Furthermore, the responses by parents to the questionnaire presented in Chapter 6 indicated that practice was involved in the development of a skill, although it was not a good predictor of the level to which the skill would develop.

Howe (1989) claimed that a lengthy period of preparation was involved in all cases of outstanding accomplishment and as a result discounted the prospect of innate abilities being involved in their development. Ericsson and Faivre (1988) supported this argument, suggesting that practice alone could account for all precocious abilities. Moreover, there is evidence that individuals can be trained to develop savant-type skills through persistent and repetitive practice (Morishima & Brown, 1977). Such arguments are supported by the savant literature, with several studies emphasising the importance of practice in the development of a skill (Anastasi & Levee, 1960; Comer, 1979; Hoffman & Reeves, 1979). However, although the results of the studies presented in this thesis have supported the role of practice in the development of a skill, that all subjects had not developed their skill to a "prodigious' or "talented" level suggests that practice alone cannot account for their development. This conclusion is supported by the fact that most individuals with autism typically engage in repetitious activities but few become savants. Furthermore, all of the musical savants tested in this study demonstrated perfect pitch, and there were histories of well developed talents among family members, making it likely that savants had a predisposition to develop a talent. The question as to whether this predisposition is due to environmental factors or heredity remains unanswered by this thesis.

6.5. Types of Skills

No subject recruited demonstrated skills outside the discrete range of abilities outlined in Section 1.4 of this thesis. Anderson (1992) argued that, because the skills demonstrated by savants cluster in discrete areas, they do not reflect bizarre “rewiring” of brain centres responsible for human cognition, but instead represent specific "modules" of ability. Thus because savants universally present with the same range of skills, and most savant skills are represented in ways consistent with representation in the "normal" population, the argument for bizarre rewiring fails.

Parental reports did suggest that some subjects did have demonstrated athletic skills, in addition to the skill for which they were recruited. Although athletic skills represent a distinct type of ability separate from the skills that are normally reported among the disabled population, the type of athletic skills these subjects were reported to demonstrate (e.g., bowling, running, shooting free-throws in basketball) were consistent with the general nature of savant-type skills; i.e. predictable, structured and generally lacking creativity or high-level processing.

6.5.1. Multiple Skills

The results of testing and observations presented in Chapter 4 suggested that multiple skills were common among these subject, an observation that was supported by the responses to the questionnaires presented in Chapter 5. Results from the principal components analysis presented in Chapter 5 suggested that although subjects were skilled in more than one area, the types of skills displayed within individuals tended to form clusters or categories. Anderson (1992) also noted this pairing or grouping of skills within category variants.. Typically skills such as maths and music occurred together, as did art and calendrical skills. The subjects in this study demonstrated a wider range of skills within individuals than has previously been reported. Furthermore, three of the subjects demonstrated skills in mathematics and art, which is not a common skill pairing and many of the subjects demonstrated skills in areas that have not generally been grouped before. It is possible that several discrete modules are preserved within individuals demonstrating multiple skills but it is also possible that or the same neurological substrates underlie many if not all of these skills and the type of skill developed by individuals is related to other factors (e.g., environmental triggers. familial tendencies, early exposure, practice, interest).

The number of skills demonstrated by individuals was not affected by IQ. Instead, the skill level of their most precocious skill was a better predictor of the number of skills that an individual displayed. This is consistent with the suggestion that the development of multiple skills can involve same neurological substrates, which are largely independent of general intelligence.

6.5.2. Music

TR's performance, reported in Chapter 2, demonstrated a well-developed ability to access a representational system of relevant rules. His ability to memorise musical composition, although superior to the normal musician (AS) documented by Sloboda et al. (1985), was consistent with his superior skills in memory for tasks that involved serial recall (e.g., digit span). It was therefore concluded that TR's performance was dependent upon a preserved ability in a specific area of memory. This preserved area of memory enabled access to stored information, accumulated through extensive training and practice. This suggestion was supported by TR's performance, which was notably rule-based, inflexible and rigid, lacking creativity and originality.

Memory alone does not appear to be sufficient, however. The importance of perfect pitch among musical-savants was noted in Chapter 2, and developed in Chapter 4, with all musical-savants demonstrating perfect pitch. Although most musical savants rely on their sense of pitch for their musical performance, most trained musicians among the normal population tend to play from written score. It is suggested, therefore, that when future comparisons are made between savants and "normal" musicians, the latter should be divided into two groups to differentiate those who play from written scores and those who play by ear. It seems likely that the abilities of those who play by ear would better reflect the skills of a savant, because most musicians who are taught from written scores are not as dependent upon good pitch recognition. Although inferences cannot be made from the results of this study as to whether absolute pitch is an innate or learned ability, it appears that, even if someone has a predisposition to develop perfect pitch (Lynch & Eilers, 1992), this skill will not develop or continue without stimulation from a young age. Musical-savants all showed perfect pitch and their skills appeared to be dependent upon their sense of pitch, this seemingly being essential for the development of their skill. A hypothesis worthy of further consideration is that for perfect pitch to emerge and continue one must practice pitch recognition.

6.5.3. Calendar Calculation

Calendrical calculation is probably the most intriguing skill developed by savants because it is not generally found among the normal population, yet it is a skill frequently reported among savants. The series of experiments presented in Chapter 3 addressed this skill specifically. The first experiment (Experiment 1, Chapter 3) assessed the span of each subject's knowledge by measuring the response times to dates presented from the past and future. The results showed that the accuracy with which subjects responded to dates was limited to specific epochs and responses were slower when incorrect. Each subject (except TS) responded with high accuracy to dates in the 20th century. Two of the subjects (BL and GF) responded correctly to most dates presented from 19th century but dates prior to the year 1800 and beyond 2100 posed difficulties for all subjects. It was noted that the range of dates for most subjects was consistent with the years usually included on perpetual calendars (i.e., between 1900 and 2100).

The results from Experiment 2 in Chapter 3 demonstrated each subject's familiarity with common day-date relationships across months, an internal consistency within the Gregorian calendar. Nevertheless, most subjects did not incorporate this knowledge when making their responses, when to do so would have facilitated their performance.

Responses to dates presented in Experiment 3 were quicker within identical calendar configurations, indicating that subjects were familiar with consistencies within and between identical calendar configurations and were operating within a system consistent with such knowledge. Questioning of subjects indicated that they were aware of identical configurations within the structure of perpetual calendars, with all except one subject being aware of the number between 1 and 14 corresponding to a particular year on a perpetual calendar. It was concluded that subjects' skills could be explained in terms of a well-developed familiarity with the 14 calendar templates and the ability to match these templates with the associated year.

Results from the five subjects presented in Experiment 4, Chapter 3, indicated that most subjects did not have an anchor date from within a particular year from which they worked, because their speed of response was too automatic for the use of such methodology. Nevertheless, the five subjects not included in Experiment 4, but otherwise involved in the study, were slower and therefore less automatic when responding and may have been using such a strategy. In fact, one of the slower subjects (MR) who was not involved in Experiment 4 clearly worked from an anchor date, which in his case was March 1st. There was, however, no commonality found between the response times to dates from the other subjects indicating that the use of this anchor date was not part of the strategies followed in the "calculations" of all subjects.

The use of a mathematical algorithm in "calculating" dates was discounted for four reasons. First, subjects' responses were generally quicker than the utilisation of such a strategy would suggest. Second, most subjects demonstrated generally poor mathematical skills. Third mathematical algorithms would not be limited to a discrete range of dates as was found to be the case for all subjects in Experiment 1. Finally, most subjects demonstrated the ability to answer questions such as "On what date would the second Saturday in July be?", therefore requiring a strategy other than a mathematical algorithm.

A feature common to all subjects was a sudden emergence of an interest in calendars around seven or eight years of age, although the level of their calendrical skills at that time remains undocumented. Despite a failure to explain why this interest emerged at that time, it seems unlikely that these skills developed without extensive training and study of the consistencies within and between calendars.

There was wide variability between the speed of responses to dates presented for the subjects in Chapter 3, which may reflect differences in the level of processing involved. For some subjects (i.e., BL, DB, TM, GF and DS) responses were mostly immediate, reflecting a more automatic level of processing. The responses of the others (e.g., CT, TS and MR)., however, were more "controlled" and may therefore have reflected a more conscious level of processing. Consistent with this suggestion the slower subjects were better able to verbalise the strategies they employed when making their "calculations". It is therefore suggested that although "controlled processing" (Shiffrin & Schneider, 1977) may be involved in the acquisition and development of calendrical skills, with practice these skills become more automatic.

Although Hermelin and O'Connor (1989) found a correlation between speed of response to the dates presented among calendar calculators and IQ, this relationship was not supported among the present sample. Instead, the speed of individual "calculations" correlated with the speed of processing as indexed by IT, which supported the idea of a basic processing mechanism underlying the proficiency with which skills develop. This finding is discussed further in Section 6.11 to follow.

Overall, the strategies employed by the calendar calculators were rigid and stable and not easily modified to exploit regularities in the calendar, when to do so would have facilitated performance thereby reducing response times. Extraordinary recall of information by these subjects about birth-dates and number plates and information learned through association supports Sack's (1985) view that a well-developed associative long-term memory is involved in the development of calendrical calculation. Interest in the calendar in all probability reflects common availability of these materials

6.5.4. Artistic Ability

The most notable skills of the artistic savants presented in Chapter 4 were those requiring representative and reproductive accuracy. Although some subjects were able to produce work which might be considered creative, the extent to which creative ability developed and was demonstrated among these subjects was dependent upon considerable training and encouragement, together with the level of general intelligence as indexed by FSIQ. In fact, however, most subjects were limited in the content they selected for their artistic work and had to be actively encouraged to draw new or different content. In this area, as for music, specific aptitude may well be of critical importance. Just as pitch was associated with the development of musical skills, most artistic subjects were reported as demonstrating an excellent sense of perspective and thus may be essential to the subsequent development of artistic abilities.

6.6. Memory

Results from the study of the musical savant presented in Chapter 2 (TR), most notably his ability to reproduce music he had heard, demonstrated that he was able to access familiar and relevant rules and that his errors in musical performance were structure preserving. This finding suggested that his skills were highly dependent on the retrieval of information stored in memory and that his recall of musical information was structurally based. The knowledge of the calendar configurations of the savants presented in Chapter 3 also demonstrated the importance of memory to this skill. Nevertheless, despite the involvement of memory in these two skills, results from the WMS-R presented to these, and all other subjects, failed to isolate generally precocious levels of memory functioning. Significant correlations between Memory Quotients on the WMS-R and skill level as indexed by the author's rankings in Chapter 4, however, suggested that preserved abilities in some aspects of memory, probably declarative memory (i.e., the storage and retrieval of distinct units of rote memory functioning, facilitated by an ability to make associations, were essential for the development of savant-type skills. This argument was supported by the responses of 37 of the 39 parents who completed the questionnaire, indicating precocious declarative memory in their child. The neuroanatomical substrate responsible for declarative memory is allegedly distinct from other memory structures (Goldberg, 1987), which would account for superior performances in this area despite difficulties in other memory processes. Furthermore, if this type of memory is responsible for mediating all savant-type skills, then this finding would account for the development of more than one skill within subjects.

Results from the experiments presented in this thesis have suggested that memory skills were enhanced when the information encoded and recalled related directly to one's field of expertise, but not simply associated with it. For example, all subjects were able to access familiar rules relevant to their field. Nevertheless, an ability to remember associations between words that were related to their field of expertise, but not involving the usual strategies involved, was not enhanced, with performance among word-association tasks in the area of interest being consistent with performance on association items unrelated to this field.

6.7. Creativity

The results from the Torrance test of Creative Thinking presented in Chapter 4 showed that most savants, even those skilled in art, demonstrated concrete thoughts with poor flexibility and elaboration. This lack of flexibility and adherence to rules and structure was evident in TR, for example, who although demonstrating an ability to improvise musical pieces within context, displayed generative processing which was limited by the structural representations of his knowledge from familiar musical rules. There was evidence that the abilities of some subjects extended to the generative process, but this did not appear to develop spontaneously. Instead, much training has been required for savants to develop some degree of creativity. Furthermore, the extent to which their skills were considered by the author and others to be creative, and their demonstrated creativity on the Torrance, was related to IQ.

6.8. Cognitive Functioning

The cognitive profiles of the savant subjects did not reveal any cognitive strengths that might either predispose them to develop a skill, or suggest what type of skill they might develop. In fact, savant IQ profiles and levels of intelligence were overall not significantly different from those subjects demonstrating only splinter skills and consistent with those of autistic individuals in general (Lincoln et al, 1988). Most subjects demonstrated preserved abilities in some areas and difficulties in tasks that involved semantic properties associated with the real world, which is typical of the pattern of abilities found among autistic individuals (Anderson, 1992).

6.9. Familial Tendencies

Evidence of high IQ levels among family members, (16 out of the 38 relatives tested had FSIQ greater than 130), indicated that many subjects had a predisposition toward higher levels of intelligence. Furthermore, the families of many of the subjects contained members who had well-developed skills in areas such as music and art. Although the skill demonstrated by a family member was not always the same as that developed by the savant, subjects with musical or artistic skills most often had family members with similar well-developed abilities. High educational attainment was also prevalent among many of the families. Thus, at the very least, some families may provide an environment which encourages exceptional achievement. However, it is also feasible that good declarative memory represents an inherited familial trait.

6.10. Why do these skills develop?

Although this thesis has attempted to explain how savant skills develop, it has not specifically addressed the question as to why these skills develop. A likely explanation is that these skills compensate for deficits in other areas. Because all subjects had language difficulties, it is possible that savant-type skills involve processes that activate their minds in a manner similar to the way in which language stimulates the minds of those without such difficulties in communication. It is therefore likely that these skills compensate for deficits in areas such as language, communication and socialisation but the question as to whether this compensation is physiological or psychological still needs to be addressed.

The results from the psychometric assessment of subjects presented in Chapters 2, 3 and 4, confirmed that the general cognitive processes of savants were well below those found in the normal population. Nevertheless, some processes appeared to be within normal limits - unimpaired by their disability - and this fact, together with reinforcement of specific interest, practice and opportunity, and together with a familial predisposition toward achievement, provides a plausible explanation for the emergence of a skill and its subsequent development to savant level.

Because most savant-type skills occur within the normal population (calendrical calculation is a notable exception), one might speculate that such skills develop due to a natural encounter involving a subject and the area of skill. The prevalence of calendrical skills among savants, however, makes such a theory unlikely. Instead, the high frequency of calendar calculators among the disabled population, compared with the rare occurrence of this skill among the normal population, suggests that there is something about the types of processes involved in this skill which makes it not only attractive or interesting to savants but well suited to be developed by those cognitive processes that remain unimpaired among such individuals. It is also likely that other savant-type skills are well-suited to be developed by the disabled population for similar reasons. It is suggested here that savant skills are suited to the individuals who develop them because (i) they are highly dependent on declarative memory, (ii) they require little higher order manipulation of cognitive stimuli, (iii) declarative memory can occur in the absence of a high general level of intellectual functioning and (iv) the processes involved can be developed further with practice.

6.11. Implications for a theory of Intelligence.

A goal of this thesis was to evaluate the implications that the existence of savants have for theories of intelligence, particularly those theories that propose a general controlling factor. In order to determine whether savants do, in fact, pose difficulties for these types of models, it is necessary, first, to establish the requirements of a theory of intelligence, and second, to determine whether savant skills are intelligent.

A theory of intelligence must account for (i) individual differences in abilities, (ii) the existence of specific cognitive abilities, but (iii) the finding that, despite investment of considerable effort, psychometricians have not found it possible to develop a test battery which does not result in the extraction of a general factor (Anderson, 1992). To date, models of intelligence range from the suggestion of a single general ability (e.g., Spearman, 1927) to those which propose the existence of a small number of independent abilities with no central controlling factor (Thurstone, 1938). Others have proposed a compromise between these two extremes. Vernon's (1950) theory, for example, although supporting the notion of general intelligence, recognised that specific factors might also account for some of the variance in individual abilities. Although the actuality of savants has caused some researchers to dismiss general intelligence as merely a statistical artefact (Gardner, 1983), Anderson (1992) has proposed that the data from batteries of psychological tests are best represented in terms of a hierarchical model with general intelligence at the apex.

Anderson (1992) has proposed that a basic processing mechanism which constrains knowledge and thought could account for individual variation in general intelligence. Abilities which appear to be isolated and unconstrained by the basic processing mechanism are explained by him in terms of separate "modules" which he divides into two levels; Mark I and Mark II modules. Mark I modules involve processes such as language, vision and "theory of mind" - the ability to understand the mental states of others. Mark II modules include information processing mechanisms which may underlie long-term memory-storage and retrieval and are not affected by individual differences in intelligence. Such modules may also include those processes that have become automatic as outlined by Shiffrin and Schneider (1977), due to successful practice and rehearsal.

This account provides one of the most plausible descriptions of intelligence offered to date which can account for general intelligence as well as savant skills. Nevertheless, two findings in the present study present problems for this model. First, significant correlations were found between IQ and skill level as indexed by the author; and second, speed of information processing as indexed by IT was also significantly correlated with skill level. The relationship between speed, IQ and performance suggests that, despite savant abilities developing in the absence of normal levels of general intellect, and in that sense requiring modular representation within Anderson's model, general functioning has nevertheless been found to affect the level to which these skills were developed, the number of skills developed and the extent to which these skills reflected processes generally considered to represent intelligent behaviour such as creativity, the ability to make abstractions and perform in a flexible manner. Therefore, although preserved abilities in a specific domain or module may be necessary for the acquisition of the skill, general processing may still be involved in the subsequent development of a skill. The implications which this finding has for Anderson's theory is that, although modules may be to an extent independent of each other and of general intelligence, there is still some systemic link between the modules and general functioning.

Anderson (1992) has argued that individuals with neurological impairments may have suffered damage to their basic processing mechanism, specific processing mechanisms or select modules. Correlations between IT and level of skill has here indicated that the extent to which speed of processing is affected by disability will determine the level to which savants can develop their skill. Furthermore, if the basic processing mechanism is unimpaired, as appeared to be the case for TR, individuals will be able to develop skills in modules which are not affected. This argument was supported by a significant correlation between IT and the number of skills developed by subjects.

Overall the findings presented here suggest that a systemic approach to describe intelligence is required. Such an approach must, however, account for the relationship between independent abilities and general functioning, as well as the link between seemingly independent abilities which allows savants to develop more than one skill. Furthermore, this model must isolate and define all of the processes considered to reflect intelligent behaviour. Detterman, Mayer, Caruso, Legree, Conners & Taylor (1992) has suggested that such processes include encoding, memory, and retrieval.

Detterman et al. (1992) have proposed a modal model of cognitive functioning which permits independent operations of abilities but avoided the weakness of Gardner's (1983) position which denies the relevance of "g". Detterman et al.'s model suggests that cognitive functioning are best represented in terms of memory. The value in his approach is that it may isolate different forms of memory, while operating within a systemic approach. Although his initial model had memory processes controlled by what he referred to as an "executive function". A revised model in the same study isolated long-term memory from this controlling mechanism. Even so, according to this model, if information is to be stored in long-term memory it must first be rehearsed in primary and secondary memory which are still controlled by the executive function. While the results of the present study support the division of memory into secondary stores, perhaps similar to those suggested by Detterman et al. (1992), they indicate that separate neurological substrates, such as declarative memory, including initial rehearsal, may be independent of a central controlling function. The continued demonstration of a well-developed declarative memory by most savants, together with neurological evidence which supports the isolation of this process, suggests that this ability is largely uninfluenced by individual differences in intelligence.

While acknowledging and isolating abilities considered to be independent of general functioning, a suitable model of intelligence needs only to account for those functions and processes considered to reflect intelligent behaviour. The demonstration of declarative memory within generally dull individuals suggests that this function is not one of them. To describe intelligence accurately these independent cognitive processes need to be isolated. Anderson (1992) has suggested that reading ability is independent of a general controlling factor, a claim supported by the factor analysis reported in Chapter 4. Another independent ability suggested by Anderson (1992) was "theory of mind" - a deficit mostly associated with autism. Because, for many autistic individuals, this is their primary disability, damage to this module which might affect their performance of tasks that require semantic associations and consequently result in a poor performance on many of the subtests of the Wechsler Scales, need not impair one's performance on tasks assumed to represent general functioning such as IT and / or Progressive Matrices. Preserved abilities in these areas were found among some of the more prodigious savants, with two of the three most prodigious savant only making one incorrect response on the matrices. These results support the claim that, although modules may be preserved among savants, the level to which these skill can be developed to reflect more intelligent behaviour is dependent upon a more basic processing mechanism. For other savants, however, who have damage to their general controlling mechanism, only single modules have been preserved and as a result their skills do not reflect intelligent behaviour.

In summary, this study has suggested that a savant is a neurologically impaired individual with idiosyncratic and divergent profiles of intellectual ability and language and intellectual impairments consistent with autism, who has an intense interest and preoccupation with a particular area of skill. These circumstance, together with the necessary preserved neurological capacity to process information in a manner relevant to their skill (probably sequential or Level 1, Jensen, 1990), a well-developed memory, probably declarative, a familial predisposition toward high achievement (possibly innate), and adequate support, encouragement and reinforcement, provide the necessary climate for savant skills to develop. Furthermore, the author does not believe that the existence of such individuals poses any difficulties for theories of general intelligence, given that these skills cannot be considered to reflect intelligent behaviour. They are not creative and do not involve insight. It is suggested that the extent to which such skills reflect intelligent behaviour and higher order processing (e.g., Level 2 Jensen, 1990) is dependent on more general levels of functioning.

LIST OF APPENDICES

Appendix 2.1

Pitch Discrimination test administered to TR, NT and their mother following the procedure outlined in Miller (1989, p49).

	Response		
Note played	TR	NT	Mother
D^{L}	D^{L}	D^{L}	D^{L}
B	B	B	B
E^{L}	E^{L}	E^{L}	G
G	G	G	G
E^{bL}	E^{bL}	E^{bL}	E^{bL}
B^{L}	B^{L}	B^{B}	A
E^{b}	E^{b}	E^{b}	E^{b}
A	A	A	A
$C^{\#L}$	$C^{\#L}$	$G^{\#}$	$C^{\#L}$
$F^{\#}$	$F^{\#}$	E^{b}	lower than F
B^{b}	B^{b}	B^{b}	near G
E	E	E	E^{b}
C	C	C	G
A^{L}	A^{L}	A^{L}	A^{L}
$F^{\#}$	$F^{\#}$	$F^{\#}$	E^{b}
$C^{\#}$	$C^{\#}$	$C^{\#}$	$C^{\#}$
A^{bL}	A^{bL}	A	G
F^{L}	F^{L}	F^{L}	E^{B}
D	D	D	D
A^{b}	A^{b}	B^{b}	G
C^{L}	C^{L}	C^{L}	G
G^{L}	G^{L}	G^{L}	between F and G
B^{bL}	B^{bL}	B^{bL}	G
F	F	F	F

^{L}denotes lower note

Appendix 2.2

Chord Discrimination test administered to TR following the procedure outlined in Miller (1989, p54).

Chord Played	TR's Response
Cm closed	Cm closed
B major closed	B major closed
Dm open	Dm open
C + open	C + open
D^bo closed	D^bo closed
Em closed	Em closed
AØ open	Am
B7 open	B7 open
$A^{b/}$A open	unsure
Fo open	Fo open
E+ closed	E+ closed
G^b9 open	G^b9 open
G^bm closed	G^bm closed
A^b open	A^b open
Do closed	Do closed
G+ closed	G+ closed
E^b6 open	E^b6 open
A closed	A closed
F open	F open
B^b7 open	B^b7 open
E^b closed	E^b closed
B^bm open	B^bm open
Gm open	Gm open
D^b (major) open	D^b (major) open

Appendix 2.3

TR's performance on i) Peabody Individual Achievement Test and ii) Neale Analysis of Reading Ability-Revised.

i) Peabody Individual Achievement Test

Subtest	Standard Score[a]
Mathematics	105
Reading Recognition	107
Reading Comprehension	101
Spelling	126
General Information	101
Overall Achievement	113

[a] Standardised M=100, SD=15.

ii) Neale Analysis of reading Ability - Revised

	Time	Accuracy	Comprehension
Raw Score	204 seconds for 491 words	99 / 100 words	34 / 44 questions
Reading Age	>12 year 6 months	>12 year 6 months	>12 year 6 months

Appendix 2.4.

Results from the Pitch Discrimination, Tunes, Chord and Rhythm subtests of the Measures of Musical Ability (Bentley, 1985).

a) Pitch

	1[a]	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
TR's Response	G#	Bb	Bb	G#	Bb	G#	G#	A	A	Bb	G#	Bb	G#	G#	A	A	G#	G#	G#	A	
	✓	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	✓	✓	18

a TR correctly identified the first tone as A each time.

b) Tunes

Tune [a]	1	2	3	4	5
TR's response [b]	A G F# D E [b]	D F# A G **E**	D F# **E** A F#	**D** A G E F#	A G F# **E** G
	A **G#** F# D E	D F# A G **F**	D F# **F** A F#	**D#** A G E F#	A G F# **D** G

Tune	6	7	8	9	10
TR's response [b]	E D G F# **A**	D **F#** A G F#	A D F# **G** A	**F#** A G F# A	D G **E** A E
	E D G F# **G**	D **E** A G F#	A D F# **G#** A	**E** A G F# A	D G **F#** A E

[a] Although the objective of this test was to indicate the number of the note which was different between presentations TR was able to correctly identify all notes played in addition to the number of the note which differed.
[b] Bold denotes the note which note was different in the second presentation.

c) Chords

Notes Played	A#C#	EF	GBD (G major)	BbF	ACE (A minor)	F#D#	BbFD Bb major	F# B	FBbDG (F ninth)	GBE E min
TR's response	✓	✓	✓	✓	✓	✓	✓	✓	F B D G	✓

Notes played	Gb Bb F	G# E	B C	F Ab D	Bb E	G# B D# F#	C D	F Eb	A C F F major	F# A#
TR's response	Gb Bb A	✓	✓	✓	✓	✓	✓	✓	✓	✓

d) Results of the Rhythm subtest for the Measures of Musical Ability (Bentley, 1985).

Beat which was different	2	4	3	Same	1	3	4	Same	1	2	Total /10
TR's response	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10

Appendix 2.5

TR's initial performance of each bar of Grieg after a single hearing.

Bar	Performance
1	Correct.
2	Omitted embellishment.
3	Correct.
4	Omitted embellishment.
5	Correct.
6	Omitted embellishment and incorrect note (harmonically consistent).
7-8	Correct.
9	Bottom D omitted from rolled bass chord; otherwise correct.
10-13	Correct.
14	Incorrect note (F for E) in first chord; harmonically consistent and otherwise correct.
15-16	Correct.
17	Incorrect harmony; the D^b that appears in score in right hand from bar 19 is played from bar 17 onward. The harmony is simplified to a B^b minor 6th.
18	Incorrect harmony; as for bar 17.
19-20	F is lowered to an E so that the written harmony for bars 17-18 v. 19-20 is reversed.
21	Incorrect note (A^b for G) in first chord; harmony changed but consistent; melody is not doubled in bass hand.
22	Harmony as for bar 21 - diminished not dominant 9th harmony.
23	Incorrect harmony - diminished not minor 6th harmony; D as bass note instead of D^b consistent with the change that occurs subsequently in bar 24.
24- 30	Colour simplified by omitting a note from each; 4-note voicings but harmonically correct. Bass accompaniment has been simplified by omitting one note an octave below the melody. In bar 28 the lead-in melody of five notes preceding the theme in bar 29 is missing but the essential melody is correct.
31-32	$C^\#$ doubling melody in bass is missing but otherwise correct.
33-34	Embellishment missing (bar 33) or displaced (bar 34). Bass note in left-hand chord not doubled at the octave.
35	Incorrect bass note (E for F). Harmonically changed from dominant to minor but structure is preserved and diatonically consistent.
36	Incorrect. The harmony is as for bar 35. Lead-in of three notes to bar 37 is not played.
37	Harmonically consistent but simplified (4-voice) and closed voicing for F chord in left hand for beats 3 and 4. Melody D played as quaver not semiquaver.
38-53	Correct.
54	Embellishment omitted.
55	Correct.
56	Introduces chromatic embellishment to melody which incorrectly introduces key of A major not A minor.

57-58	Continues in A major.
59-61	Omitted altogether
61-66.	Plays four A major chords in the correct register to close instead of three.

Appendix 2.6

TR's initial performance of each bar of Bartok after only one hearing.

Bars	Performance
1-6	Correct but middle C not sustained
7-12	Correct but A in left-hand not sustained.
13-14	Correct but G^b (r.h.) and E^b (l.h.) not sustained.
15-17	He omits $A^b$and the sustained quality of the bell note C is omitted. Harmonically consistent. At 16 he adds a bar to accommodate the A^b in the melody. He spontaneously repeats elements of bar 16 but beginning on G^b and E^b, instead of B^b and G. This is harmonically consistent, producing a correct lead-in to bar 17 which is played accurately.
18	Starts from F which is not consistent with the whole-tone harmony. Immediately corrects F to F^b, thereby adding a beat, and continues accurately.
19	Correct, but the sustained element is omitted.
20-23	An attempt lasting two bars is a minor third too high. His second attempt is rhythmically accurate across bars 20-23 but the treble is a minor third above the written score of the bass line and is melodically inaccurate although the relative intervals are consistent with the score. It is not consistently based on a whole-tone scale.
24-25	Bar 24 is correct but he stops and starts again. In bar 25 the rhythmic pattern is reversed, the two quavers following the crotchet; and harmony is not totally consistent with a whole-tone scale; including E in the bass for E^b.
26-27	His renditions at bar 26 and beyond are an extension of the whole-tone idea but not consistent with the score. There are three false starts, with reference to material back as far as bar 21. Rhythm is as for bar 25; preserved instead of changing. The pattern in bar 25 reoccurs but is still rhythmically reversed. Two bars of music that do not exist, although consistent with the pattern of the piece, are played before the performance peters out.

Appendix 3.1
Results of Psychometric tests for subjects with skills in calendrical calculation.

i) Raw Scores for the Wechsler Memory Scales - Revised

	Maximum	DB	FC	GF	BL	TM	MR	TS	DS	CT
Mental Control	6	3	2	6	6	6	5	5	6	6
Figural Memory	10	1	4	7	7	6	6	6	8	9
Logical Memory	50	6	23	7	12	6	25	21	5	24
Visual Paired Associates 1	18	5	12	18	11	12	18	12	18	18
Verbal Paired Associates 1	24	11	17	13	15	19	20	12	22	20
Visual Reproduction 1	41	19	5	8	35	24	32	17	33	41
Digit Span	24	13	11	12	10	11	12	20	25	15
Visual Memory Span	26	13	7	16	15	14	14	17	22	21
Logical Memory ll	50	4	17	6	9	7	28	14	0	14
Visual Paired Associates ll	6	6	6	6	6	6	6	6	6	6
Verbal Paired Associates ll	8	8	8	8	6	8	8	6	8	8
Visual Reproduction ll	41	20	5	6	34	24	25	5	33	40
Verbal Memory (Raw[a])	124	23	43	27	39	31	70	54	32	68
Verbal Memory Quotient		59	77	63	69	62	97	87	64	93
Visual Memory (Raw)	69	25	21	33	53	42	56	45	59	68
Visual Memory Quotient		51	50	70	71	72	100	89	106	138
General Memory (Raw)	193	48	64	60	92	73	126	99	91	136
General Memory Quotient		50	57	55	69	54	96	86	74	102
Attention / Concentration (Raw)	106	55	38	62	56	56	57	79	100	78
Attention / Concentration Quotient		83	57	95	74	74	86	116	138	105
Delayed Recall (Raw)	119	52	50	40	67	59	61	43	61	80
Delayed Recall Quotient		77	76	71	84	78	83	73	81	98

[a]Raw scores are weighted according to the WMS-R manual.
[b] Memory quotients follow the conventions of mean = 100, SD=15.

ii) Raw Scores for the Neale Analysis of Reading Ability - Revised and the Schonell.

NEALE		DB	FC	GF	BL	TM	MR	TS	DS	CT
Reading Rate	words/ minute	9	76	44	52	76	91	105	99	47
Accuracy	/100	5	57	44	37	66	79	54	85	26
Comprehension	/44	0	22	4	3	3	7	11	12	2
Reading Age (months)		72	22	88	95	22	39	44	44	91
Schonell										
Raw Score	/100	10	62	35	17	76	64	70	88	24
Reading age (months)		81	125	99	78	144	127	135	144	89

iii) Raw Scores for Visual Organisation (Hooper and Bender Gestalt).

	Maximum	DB	FC	GF	BL	TM	MR	TS	DS	CT
Hooper	30	24	23	25	22	24	24	13	26	22
Bender Gestalt										
Distortion		1[a]	2	0	0	0	2	4	0	0
Integration		0	1	0	0	2	0	1	0	0
Rotation		1	0	1	0	0	0	0	0	0
Perseveration		1	0	0	2	1	0	0	0	0

[a] values reflect number of errors made by each subject

iv) Raw Scores for Torrance Test of Creativity.

Torrance	DB	FC	GF	BL	TM	MR	TS	DS	CT
Fluency	11[a]	10	10	18	22	17	0	40	11
Flexibility	7	12	12	14	9	12	0	11	7
Originality	19	2	2	32	17	32	0	18	13
Elaboration	1	2	2	38	14	11	0	3	11

[a] Scores indicate the number of times subjects demonstrated any of the above characteristics (i.e. fluency. flexibility, originality or elaboration).

Appendix 3.2.1

Mean, standard deviation, minimum and maximum response times for correct and incorrect responses to Experiment 1 for all five subjects combined and each subject separately.

1) Mean correct response time for all subjects.

Variable	Mean	Std Dev	Minimum	Maximum	N
TIME	7401.70	6142.37	106.00	47820.00	204

ii) Mean correct response time for individual subjects.

SUBJECT BL

Variable	Mean	Std Dev	Minimum	Maximum	N
TIME	6920.59	3187.88	2782.00	17243.00	51

SUBJECT DB

Variable	Mean	Std Dev	Minimum	Maximum	N
TIME	4481.17	1188.42	2964.00	7263.00	29

SUBJECT TM

Variable	Mean	Std Dev	Minimum	Maximum	N
TIME	12605.21	10581.57	2761.00	47820.00	39

SUBJECT DS

Variable	Mean	Std Dev	Minimum	Maximum	N
TIME	3967.09	1926.27	818.00	10918.00	35

SUBJECT GF

Variable	Mean	Std Dev	Minimum	Maximum	N
TIME	7931.82	4490.76	106.00	24381.00	50

iii) Mean incorrect response time for all subjects.

Variable	Mean	Std Dev	Minimum	Maximum	N
TIME	8736.99	8875.72	.00	52953.00	156

iv) Mean incorrect response time for individual subjects.

SUBJECT BL

Variable	Mean	Std Dev	Minimum	Maximum	N
TIME	9588.71	5558.00	4371.00	25507.00	21

SUBJECT DB

Variable	Mean	Std Dev	Minimum	Maximum	N
TIME	7741.26	2815.72	2854.00	15877.00	43

SUBJECT TM

Variable	Mean	Std Dev	Minimum	Maximum	N
TIME	14115.82	13490.57	.00	52953.00	33

SUBJECT DS

Variable	Mean	Std Dev	Minimum	Maximum	N
TIME	2447.11	1757.15	776.00	7088.00	37

SUBJECT GF

Variable	Mean	Std Dev	Minimum	Maximum	N
TIME	12380.36	11033.18	3413.00	47090.00	2

Appendix 3.2.2

Overall differences between correct and incorrect responses for Experiment 1 for i) raw scores ii) standard scores and iii) each subject separately.

i) raw scores

	Number of Cases	Mean	SD	SE of Mean	Variances	t-value	df	2-Tail Sig
Correct	204	7401.69	6142.37	430.05	Equal	-1.69	358	p=.09
Incorrect	156	8736.98	8875.71	710.62				

ii) standard scores

	Number of Cases	Mean	SD	SE of Mean	Variances	t-value	df	2-Tail Sig
Correct	204	-.13	.81	.05	Equal	2.96	358	p<.01
Incorrect	156	.17	1.17	.09				

iii) individual subjects

SUBJECT BL

	Number of Cases	Mean	SD	SE of Mean	Variances	t-value	df	2-Tail Sig
Correct	51	6920.58	3187.88	446.39	Equal	-2.57	70	p<.01
Incorrect	21	9588.71	5557.99	1212.85				

SUBJECT DB

	Number of Cases	Mean	SD	SE of Mean	Variances	t-value	df	2-Tail Sig
Correct	29	4481.17	1188.42	220.684	Equal	-5.88	70	p<.01
Incorrect	43	7741.25	2815.72	429.393				

SUBJECT TM

	Number of Cases	Mean	SD	SE of Mean	Variances	t-value	df	2-Tail Sig
Correct	39	12605.20	10581.57	1694.41	Equal	-.53	70	p=.60
Incorrect	33	14115.81	13490.57	2348.41				

SUBJECT DS

	Number of Cases	Mean	SD	SE of Mean	Variances	t-value	df	2-Tail Sig
Correct	35	3967.08	1926.26	325.59	Equal	3.50	70	p<.01
Incorrect	37	2447.10	1757.14	288.87				

SUBJECT GF

	Number of Cases	Mean	SD	SE of Mean	Variances	t-value	df	2-Tail Sig
Correct	50	7931.82	4490.75	635.08	Equal	-2.44	70	P< .05
Incorrect	22	12380.36	11033.18	2352.28				

Appendix 3.3.1

Analyses of Variance (ANOVA) using i) the variables Showing (i.e., First Showing and second showing) and Leap (i.e., whether the year was leap or not) for Experiment 2 and investigating the variable showing in ii) non-leap and iii) leap years separately.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	20.57	2	10.28	11.10	p<.01
SHOWING	19.67	1	19.66	21.22	p<.01
LEAP	.78	1	.77	.83	.36
2-Way Interactions	.07	1	.07	.07	.79
SHOWING LEAP	.07	1	.07	.07	.79
Explained	20.62	3	6.88	7.42	p<.01
Residual	734.12	792	.93		
Total	754.75	795	.95		

11) Analysis of Variance (ANOVA) using the variables Showing (i.e., First Showing and second showing for non-leap years in Experiment 2.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	11.36	1	11.36	12.11	p<.01
SHOWING	11.36	1	11.36	12.11	p<.01
Explained	11.36	1	11.36	12.11	p<.01
Residual	380.78	406	.94		
Total	392.14	407	.96		

111) Analysis of Variance (ANOVA) using the variables Showing (i.e., First Showing and second showing for leap years in Experiment 2.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	8.46	1	8.46	9.25	p<.01
SHOWING	8.46	1	8.46	9.25	p<.01
Explained	8.46	1	8.46	9.25	p<.01
Residual	353.33	386	.92		
Total	361.80	387	.94		

Appendix 3.3.2

T-test for independent samples comparing the response times of the four slower subjects (CT, TS, MR and GF) and the five faster subjects (DS, DB, JS, TM and BL) for Experiment 2.

Variable	Cases	Mean	SD	SE	t-value	df	2-Tail Sig
TIME							
slower	323	13699.54	1830.04	658.241	18.17	794	p<.01
faster	473	3414.09	2821.04	129.712			

Appendix 3.3.3

Individual ANOVAs comparing response times between First and Second showings for i) non-leap years and ii) leap years.

i) non-leap years

SUBJECT: BL

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	11986692.95	11986692.95	2.22	.14
Within Groups	44	237530669.2	5398424.3		
Total	45	249517362.1			

SUBJECT: DB

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	7239882.021	7239882.02	6.6218	p<.01
Within Groups	46	50293745.23	1093342.29		
Total	47	57533627.25			

SUBJECT: TM

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	32683.3929	32683.3929	.0048	.94
Within Groups	46	311060007.9	6762174.084		
Total	47	311092691.2			

SUBJECT: CT

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	58028317.20	58028317.20	.3917	.53
Within Groups	46	6815516425	148163400.5		
Total	47	6873544742			

SUBJECT: DS

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	7499787.28	7499787.28	6.5945	p<.05
Within Groups	45	51177431.8	1137276.26		
Total	46	58677219.11			

SUBJECT: GF

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	49619191.66	49619191.66	3.5074	.07
Within Groups	45	636620126.6	14147113.92		
Total	46	686239318.2			

SUBJECT: TS

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	1404557160	1404557160	4.5155	p<.01
Within Groups	27	8398420586	311052614.3		
Total	28	9802977746			

SUBJECT: MR

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	46993777.30	46993777.30	.7979	.38
Within Groups	45	2650305436	58895676.36		
Total	46	2697299214			

SUBJECT: JS

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	19120853.83	19120853.83	1.95	.17
Within Groups	46	450563096.5	9794849.92		
Total	47	469683950.3			

ii) leap years.

SUBJECT: 1.00 BL

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	6282061.800	6282061.800	.9719	.3294
Within Groups	46	297316727.2	6463407.113		
Total	47	303598789.0			

SUBJECT: DB

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	3938820.448	3938820.448	4.1781	p<.05
Within Groups	45	42422493.47	942722.0770		
Total	46	46361313.91			

SUBJECT: TM

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	41763.6868	41763.6868	.0017	.9672
Within Groups	45	1096694037	24370978.59		
Total	46	1096735800			

SUBJECT: CT

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	1310737.831	1310737.831	.0076	.9311
Within Groups	38	6565652077	172780317.8		
Total	39	6566962815			

SUBJECT: DS

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	8979963.761	8979963.761	11.9757	p<.01
Within Groups	44	32993209.57	749845.6719		
Total	45	41973173.33			

SUBJECT: GF

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	45766469.30	45766469.30	5.3913	p<.05
Within Groups	42	356534382.4	8488913.867		
Total	43	402300851.7			

SUBJECT: TS

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	30602840.06	30602840.06	.2099	.6516
Within Groups	21	3062301486	145823880.3		
Total	22	3092904326			

SUBJECT: MR

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	25214181.78	25214181.78	.2916	.5920
Within Groups	43	3718568203	86478330.30		
Total	44	3743782385			

SUBJECT: JS

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	1250504.301	1250504.301	.1764	.6765
Within Groups	46	326170331.2	7090659.373		
Total	47	327420835.5			

Appendix 3.4.1

ANOVA of combined data for the five subjects involved in Experiment 3 using standard scores for response time for the dependent variable and configuration(same v different) and leap (leap v non-leap) as the independent variables.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	32.261	2	16.131	18.97	p<.05
CONFIG	30.322	1	30.322	35.65	p<.05
LEAP	2.274	1	2.274	2.67	.10
2-Way Interactions	2.508	1	2.508	2.95	.09
CONFIG LEAP	2.508	1	2.508	2.95	.09
Explained	50.780	3	16.927	19.91	p<.05
Residual	294.220	346	.850		
Total	345.000	349	.989		

Appendix 3.4.2

Individual ANOVAs for each subject analysing the effects of configuration and whether the year was leap or non-leap.

SUBJECT BL

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	66073621	2	33036810.656	2.706	.074
CONFIG	66017431	1	66017430.945	5.407	p<.05
LEAP	63292	1	63292.385	.005	.943
2-Way Interactions	2727339	1	2727339.113	.223	.638
CONFIG LEAP	2727339	1	2727339.113	.223	.638
Explained	119933317	3	39977772.435	3.274	p<.05
Residual	818100360	67	12210453.138		
Total	938033678	70	13400481.108		

SUBJECT DB

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	12033348	2	6016674.022	2.490	.091
CONFIG	11548884	1	11548883.555	4.779	p<.05
LEAP	492963	1	492962.782	.204	.653
2-Way Interactions	467827	1	467826.982	.194	.661
CONFIG LEAP	467827	1	467826.982	.194	.661
Explained	21502624	3	7167541.358	2.966	p<.05
Residual	161912366	67	2416602.471		
Total	183414990	70	2620214.138		

SUBJECT TM

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	173478704	2	86739352.189	4.431	p<.05
CONFIG	171903784	1	171903783.960	8.781	p<.01
LEAP	1574920	1	1574920.418	.080	.778
2-Way Interactions	42816847	1	42816846.960	2.187	.144
CONFIG LEAP	42816847	1	42816846.960	2.187	.144
Explained	207277976	3	69092658.686	3.529	p<.05
Residual	1331246520	68	19577154.700		
Total	1538524496	71	21669359.094		

SUBJECT CT

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	33897814	2	16948906.972	10.939	p<.01
CONFIG	21103335	1	21103334.854	13.620	p<.01
LEAP	16919484	1	16919483.687	10.920	p<.01
2-Way Interactions	7819757	1	7819757.177	5.047	p<.05
CONFIG LEAP	7819757	1	7819757.177	5.047	p<.05
Explained	36418721	3	12139573.775	7.835	p<.01
Residual	96063025	62	1549403.630		
Total	132481746	65	2038180.713		

SUBJECT GF

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	8211440	2	4105719.751	.677	.512
CONFIG	5645700	1	5645699.598	.930	.338
LEAP	2552133	1	2552132.722	.421	.519
2-Way Interactions	187612	1	187611.666	.031	.861
CONFIG LEAP	187612	1	187611.666	.031	.861
Explained	21193255	3	7064418.395	1.164	.330
Residual	406552967	67	6067954.732		
Total	427746222	70	6110660.317		

Appendix 3.5.1.

Individual ANOVAs to determine if there were differences in responses for each subject depending upon the day of the week on which the date occurred.

SUBJECT BL

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	23478924	6	3913154.068	4.299	p<.01
ANSWER	23478924	6	3913154.068	4.299	p<.01
Explained	23478924	6	3913154.068	4.299	p<.01
Residual	30040267	33	910311.112		
Total	53519191	39	1372286.951		

SUBJECT DB

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	11040681	6	1840113.447	1.482	.215
ANSWER	11040681	6	1840113.447	1.482	.215
Explained	11040681	6	1840113.447	1.482	.215
Residual	40975680	33	1241687.282		
Total	52016361	39	1333752.846		

SUBJECT TM

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	135733088	6	22622181.370	.619	.714
ANSWER	135733088	6	22622181.370	.619	.714
Explained	135733088	6	22622181.370	.619	.714
Residual	1206219110	33	36552094.248		
Total	1341952198	39	34409030.728		

SUBJECT DS

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	5920197	6	986699.528	1.822	.125
ANSWER	5920197	6	986699.528	1.822	.125
Explained	5920197	6	986699.528	1.822	.125
Residual	17874302	33	541645.513		
Total	23794499	39	610115.362		

SUBJECT GF

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	19890486	6	3315081.013	.596	.731
ANSWER	19890486	6	3315081.013	.596	.731
Explained	19890486	6	3315081.013	.596	.731
Residual	183599562	33	5563623.088		
Total	203490048	39	5217693.538		

Appendix 4.0

Skills which were observed during testing sessions.

Subject	Music	Art	Mechanical.	Maths	Memory	Calendar Calculation
1	✓					
2					✓	
5		✓			✓	
6						✓
7					✓	
8			✓			
9					✓	
10						✓
11	✓				✓	
12	✓				✓	
13					✓	✓
14					✓	
15					✓	
16					✓	
17	✓	✓			✓	
18		✓			✓	
19		✓			✓	
20					✓	
21					✓	
22	✓					
23					✓	
24					✓	✓
25					✓	✓
26					✓	
27					✓	
28					✓	
29					✓	
30					✓	
31					✓	
32					✓	
33					✓	
34				✓		
35					✓	
36		✓			✓	✓
37	✓					
38					✓	
39		✓				
40				✓	✓	✓
41					✓	✓
42	✓				✓	✓
43					✓	
44					✓	
45					✓	
46	✓				✓	
47					✓	
48					✓	✓

Skills which were observed during testing sessions (cont.)

Subject	Music	Art	Mechanical.	Maths	Memory	Calendar Calculation
49	✓	✓			✓	
50				✓	✓	✓
51					✓	
52		✓				
53	✓	✓				
54					✓	
55	✓					

Appendix 4.1
Skill level of subjects ranked on three occasions and the mean rank.

Subject	First Ranking	Second Ranking	Third Ranking	Mean Ranking
1	9	13	11	11.00
2	50	50	49	49.67
5	25	22	21	22.67
6	15	17	18	16.67
7	27	24	23	24.67
8	30	31	28	29.67
9	32	25	24	27.00
10	19	19	19	19.00
12	4	4	4	4.00
13	8	6	8	7.33
14	46	49	45	46.67
15	40	40	37	39.00
16	42	46	38	42.00
17	3	3	3	3.00
18	20	23	25	22.67
19	7	5	7	6.33
20	18	20	22	20.00
21	47	48	47	47.33
22	12	15	14	13.67
23	44	42	46	44.00
24	17	16	15	16.00
25	16	14	16	15.33
26	39	38	36	37.67
27	33	34	34	33.67
28	51	51	51	51.00
29	23	30	30	27.67
30	43	45	42	43.33
31	45	39	40	41.33
32	22	18	20	20.00
33	41	44	44	43.00
34	37	35	31	34.33
35	21	21	17	19.67
36	13	9	13	11.67
37	24	26	29	26.33
38	49	47	48	48.00
39	31	29	33	31.00
41	11	12	12	11.67
42	10	7	9	8.67
43	34	36	35	35.00
44	48	43	50	47.00
45	36	37	41	38.00
46	1	1	1	1.00
47	28	32	32	30.67
48	29	28	26	27.67
49	2	2	2	2.00
50	6	10	6	7.33
51	35	33	39	35.67
52	14	11	10	11.67
54	38	41	43	40.67
55	26	27	27	26.67

Appendix 4.2

Scores for each subject reported in Chapter 4 for the Wechsler Intelligence Scales (WAIS-R and WISC-R) and Progressive Matrices (PM) and Coloured Progressive Matrices (CPM)

Subject	Information	Sim.	Arithmetic	Voc.	Comp.	Digit Span	PC.	PA.	BD	OA	Cod / Digit Symbol	VIQ	PIQ	FSIQ	PM /CPM IQ
1	3	1	2	1	1	8	6	1	2	3	2	62	66	61	59
2	7	5	2	5	4	3	4	4	2	1	1	71	64	66	59
5	11	8	17	8	3	13	5	9	11	10	9	96	91	92	90
6	2	6	4	2	2	5	5	2	5	5	2	65	70	65	59
7	5	5	5	1	1	4	6	6	10	8	4	67	79	71	85
8	3	3	2	5	2	2	1	4	6	6	1	61	62	63	59
9	14	12	9	8	1	10	7	4	11	10	4	92	81	85	84
10	9	9	4	9	11	6	6	7	2	3	3	90	72	81	59
12	7	9	4	6	4	10	11	13	10	10	5	79	98	85	96
13	6	4	3	4	4	8	4	4	5	7	4	74	78	75	63
14	8	8	6	6	3	9	8	9	9	9	5	77	86	80	85
15	6	7	4	2	2	11	4	1	4	4	1	65	52	55	68
16	5	5	2	3	1	1	2	1	4	4	1	59	49	50	61
17	11	12	11	13	10	11	11	11	10	10	8	109	105	107	129
18	5	3	3	5	2	7	5	5	9	9	4	68	77	71	59
19	11	8	6	7	5	4	10	7	12	9	5	84	90	85	92
20	6	11	9	6	7	10	9	8	9	10	6	89	86	86	81
21	1	7	6	4	3	9	11	15	13	15	3	65	109	84	85
22	5	6	5	4	2	7	9	8	9	9	6	72	93	84	61
23	5	5	7	1	1	5	6	10	14	14	6	62	100	78	80
24	7	6	4	7	3	4	7	6	9	12	5	74	82	76	85
25	6	7	3	4	1	3	5	7	10	6	7	67	78	72	83
26	15	5	18	11	5	13	12	9	14	13	10	105	111	108	108
27	10	10	9	10	8	8	6	8	8	12	6	96	86	90	68
28	7	5	3	1	1	8	5	3	1	5	7	59	63	57	68
29	12	9	6	12	8	5	6	8	6	5	5	90	75	82	75
30	10	11	11	8	8	9	10	8	6	5	7	97	84	89	90
31	7	9	5	11	10	9	10	9	11	9	4	90	90	89	85
32	10	7	9	8	7	9	11	8	9	12	6	90	90	89	77
33	13	10	6	1	1	9	7	7	8	7	5	77	78	76	86
34	7	4	4	2	4	6	11	5	10	8	1	65	80	70	75
35	12	14	4	16	15	6	5	11	8	8	6	120	85	105	96
36	6	3	8	5	5	8	6	7	10	9	5	78	88	82	70
37	8	10	6	3	5	3	1	2	4	7	1	78	54	64	82
38	1	1	4	1	1	5	4	1	17	13	4	46	85	64	87
39	5	4	2	3	2	2	5	1	8	3	3	63	71	64	63
41	7	7	6	6	5	13	6	4	8	5	5	87	82	84	68
42	6	8	12	5	3	16	5	5	11	8	12	88	88	86	91
43	3	1	2	2	1	3	6	4	10	9	5	55	79	65	70
44	5	3	2	1	1	1	7	5	3	5	6	52	69	57	69
45	4	9	6	4	1	7	9	13	9	9	8	67	96	80	73
46	10	11	15	10	4	19	7	3	19	10	19	100	111	105	129
47	6	5	4	4	2	8	2	6	4	2	4	74	62	67	59
48	7	6	4	4	3	5	6	4	8	10	3	70	76	72	63
49	10	14	10	12	8	10	12	17	15	14	8	105	123	114	99

Scores for each subject reported in Chapter 4 for the Wechsler Intelligence Scales (WAIS-R and WISC-R) and Progressive Matrices (PM) and Coloured Progressive Matrices (CPM) (cont).

Subject	Information	Sim.	Arithmetic	Voc.	Comp.	Digit Span	PC.	PA.	BD	OA	Cod / Digit Symbol	VIQ	PIQ	FSIQ	PM /CPM IQ
50	1	1	2	1	1	11	1	1	11	7	8	45	71	54	75
51	7	10	8	6	6	6	5	3	7	3	3	82	63	71	77
52	5	6	5	5	5	4	7	5	14	9	4	72	85	76	94
54	15	10	10	9	5	8	5	3	7	9	5	98	72	84	108
55	5	6	3	4	2	10	5	9	10	3	4	72	76	73	70

a Scaled subtest scores on Wechsler tests can range from 1 to 19 (M=10; SD=3). A score of 8 or less places the subject in the lower 25%; 5 or below defines the least able 5%.

Appendix 4.3

ANOVA using the variables category (i.e. prodigious, talented or splinter) and i) FSIQ, ii) VIQ and iii) PIQ

i) FSIQ

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	888.2317	444.1158	2.1788	.12
Within Groups	47	9580.3483	203.8372		
Total	49	10468.5800			

ii) VIQ

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	659.4508	329.7254	1.1921	.31
Within Groups	47	13000.3292	276.6027		
Total	49	13659.7800			

iii) PIQ

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	1526.8767	763.4383	3.5069	p<.05
Within Groups	47	10231.7033	217.6958		
Total	49	11758.5800			

Results from Student Newman Keuls

Mean PIQ		Talented	Splinter
77.0	Talented		
79.9	Splinter		
91.4	Prodigious	*	*

(*) Indicates significant differences between groups; p<.05

Appendix 4.4

Results of the Measures of Musical Ability (Bentley, 1985- PITCH.

Subject	Music /20
1#	20
2	17
5	18
6	10
7	10
8	14
9	17
10	08
12#	13
13	12
14	12
15	11
16	10
17#	20
18	16
19	16
20	17
21	13
22#	20
23	16
24	17
25	17
26	17
27	11
28	14
29	17
30	06
31	10
32	16
33	14
34	09
35	13
36	05
37#	18
38	09
39	13
41#	20
42	18
43	10
44	09
45	15
46#	18
47	15
48	16
49	18
50	06
51	07
52	14
53	12
54	11
55	15

# denotes musical savants

Appendix 4.5

Results of the Measures of Musical Ability (Bentley, 1985)- Tunes, Chords and Rhythm for those subjects with formal music training who were able to identify the notes.

i) TUNES[1]

First Tune Second Tune	A G F# D E A G#F# D E [a]	D F# A G E D F# A G F	D F# E A F # D F# F A F #	D A G E F# D# A G E F#	A G F# E G A G F# D G
Subject					
11	✓b	✓b	✓	✓b	✓
12	✓	✓	✓	✓	✓
17	✓	✓	✓	✓	✓
37	✓c	✓	✓	✓	✓
41	✓	✓	✓	D A G E F# Eb A G E F#	✓
42	✓	D E A G E D E A G F	✓	✓	✓
46	✓	✓	✓	✓	✓

First Tune Second Tune	E D G F# A E D G F# G	D F# A G F# D E A G F#	A D F# G A A D F# G# A	F# A G F# A E A G F# A	D G E A E D G F# A E
Subject					
11	✓b	✓b	✓b	✓	✓
12	✓	✓	✓	✓	✓
17	✓	✓	✓	✓	✓
37	✓	✓	x	✓	✓
41	✓	✓	✓	✓	✓
42	✓	✓	✓	✓	✓
46	✓	✓	✓	✓	✓

[1] The objective of this test was to state which note was different. However, some subjects were able to name the notes in addition to this requirement, while others who were unable to understand the verbal instruction scored correctly by naming the notes.

[a] Bold denotes the note which is different in the second presentation.

[b] On these occasions the subject failed to mention that the F was in fact F#.

ii) CHORDS

Results of the Measures of Musical Ability (Bentley, 1985) Chords for those subjects with formal music training who were able to identify the notes in each chord presented.

Subject	Chord 1	2	3	4	5	6	7	8	9	10
	A# C#	E F	G B D (G major)	Bb F	A C E (A minor)	F# D#	Bb F D Bb major	F# B	F Bb D G (F ninth)	G B E E ninor
1										
11	BD Minor 3rd	✓	✓	✓	✓	F Eb Major 6th	✓	F B Perfect 4th	✓	✓
12	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
17	Bb Db	✓	✓	✓	✓	✓	✓	✓	✓	✓
37	✓	✓	✓	✓	✓	✓	x	✓	✓	x
41	Bb Db	✓	✓	✓	✓	Eb Gb	✓	Gb B	✓	✓
42	D G#	E G#	✓	A E	✓	D F	✓	✓	✓	✓
46	✓	✓	✓	✓	✓	✓	✓	✓	F B D G	✓
55	B D	Gb F	Ab C Eb	B F#	Bb Db F	G E	F# B D#	G C	F# B G#	Ab C F

ii) CHORDS (cont.).

	11	12	13	14	15	16	17	18	19	20
Subjectt	$G^b B^b F$	$G^\# E$	B C	$F A^b D$	$B^b E$	$G^\# B D^\#$ $F^\#$	C D	$F E^b$	ACF F major	$F^\# A^\# E$
1										
11	✓	A E Minor 6th	✓	✓	✓	$A^b B E F^\#$	✓	F E	✓	✓
12	✓	✓	✓	✓	✓	✓	C# D#	✓	✓	✓
17	✓	✓	✓	✓	✓	✓	C# D#	✓	✓	✓
37	x	✓	✓	✓	✓	✓	✓	✓	x	✓
41	✓	$A^b E$	✓	$F G^\# D$	✓	$A D^b G^b$ x	$D C^\#$	✓	✓	$D^b F G^b$
42	F# A# C#	✓	$B C^\#$	F B D	✓	✓	$C^\# A^\#$	$A E^b$	✓	$C^\# A^\# E$
46	$G^b B^b A$	✓	✓	✓	✓	✓	✓	✓	✓	✓
55	$G B F^\#$	A F	$C D^b$	$F^\# A D^\#$	$B E^\#$	A C E G	$D^b E^b$	$F^\# E$	$B^b D^b G^b$	G B D

iii) RHYTHM

	Item	1	2	3	4	5	6	7	8	9	10	
	Note which differred											
Subject		2	4	3	Same	1	3	4	Same	1	2	Total /10
11		✓	2	✓	3	3	✓	3	3	3	3	3[a]
12		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
17		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
37		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
41		✓	3	4	✓	✓	✓	✓	✓	✓	1	7
42		✓	Same	Same	✓	Same	✓	Same	✓	Same	2	4
46		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10

[a]This subject played the tunes by memory, but could not number the beat which differed.

Appendix 4.6.
Professional report of the Engineering skills and drawing ability of an artistic -savant.

Comments on drawings of Oil/Air Bearings

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General

The overall appearance of the inner and outer oil/air bearings, shown in the drawings, is consistent with that of most common air bearing units. On closer examination, however, the bearings as drawn could serve no real purpose due to the fact that there is no way to supply oil/air to the bearing surfaces. This indicates that the author may have had no real knowledge of what was being drawn.

Drawing Concepts

Overall, the drawings are a good representation of a three dimensional object, and leave little doubt as to what the author intended to convey. The author has had little trouble in getting the three dimensional idea down on paper in two dimensional form.

Drawing Skills

The drawings contain many sub-views of each bearing. These sub-views often repeat detail, although some differences between views does occur. In particular, most dimensions differ slightly from one view to the next (i.e- the bottom view of the outer bearing has an overall diameter 232mm on one view and 234mm on another). There are also minor differences in the shape of the object depicted in each of the sub-views, indicating that it is likely that the author completely finished one sub-view before going on to the next.

Within each sub-view, the attention to detail is more precise. Most simple drawing conventions have - been followed, such as using thick outlines and thin dimension leader and projection lines. The dimensions themselves are all well proportioned and make sense to within 5mm. Dimensions are all placed in the correct location on the drawing.

One major problem with the drawings is that the so called "sectioned views" do not follow any set standard and do not convey any useful information. There is no cross-hatching to indicate the material which has been sectioned. The line-styles used in the side views are not correct for hidden line detail. This problem is to be expected, given that the author has had no formal drafting training.

Summary

If the work is original, the author shows

- Average/strong ability to imagine and visualise three dimensional objects
- Attention to detail when working on one view of a drawing

* Some skills in determining and depicting size and shape of complex components

* Some knowledge of standard drawing conventions or at least of methods of unambiguously presenting graphical information

* Minimal engineering/technical knowledge

It is difficult to give an overall assessment of the standard of these drawings without going into considerable detail. In particular, tie events surrounding the generation of these drawings should be examined more closely.

The drawings seem to indicate potential or actual skills in technical drawing much more than that expected of school age children. By comparison, most first year engineering students have some difficulty in visualising three dimensional objects, especially so for those who have had no prior experience in drawing or in hands on work. They also have great difficulty in conveying this information on a sheet of paper in two dimensional form. Based on my experiences with these engineering students, I would say that 1/3 of them would struggle to reproduce or to understand these drawings of the oil/air bearing. This, I believe, gives an indication of the potential possible given support in developing drafting skills.

As a follow-up, it is suggested that the author be encouraged to look at engineering drawing text books, and perhaps to duplicate drawings out of these books. Books such as "Australian Engineering Drawing Handbook", and "Technical Drawing" by Giesecke are good places to start.

Appendix 4.7

Word association items used for comparisons for association task on WMS-R.

Music	Calendar	Art
octave - quaver	April - calendar	brush -easel
pitch-tune	January - Monday	colour - photo
flat-sharp	Easter - Friday	paint - canvass
guitar - organ	leap - week	original draw
musical - note	date - holiday	picture sculpture
piano - instrument	century - decade	paint - artist
allegro - chord	year - Tuesday	create - design
staccato - crotchet	lunar - month	oil painting

Appendix 4.8

Questions designed to measure adaptive functioning for i) time and ii) money handling.

i) Time.

1. What time do you get up in the morning?
2. What day comes after Tuesday?
3. What season comes after spring?
4. How long have we been working together today?
5. On what date does Christmas fall each year?
6. Arrange the hands of the clock to show three o'clock.
7. Arrange the hands of the clock to show half past two.
8. Arrange the hands of the clock to show quarter past four.
9. Arrange the hands of the clock to show ten past nine.
10. Have the subject show one o'clock on the clock.
11. Have the subject show quarter to one the clock.
12. Have the subject show twenty to ten on the clock.
13. How many minutes are there in an hour?
14. How many months are there in a year?
15. Show the calendar for 1993 and ask subject to indicate the date on which the second Saturday in July will be that year.
16. If you leave for work at ten past seven and it takes you twenty minutes to get there, what time will it be when you arrive?
17. If it is 11 o'clock now what time will it be in two and one half hours?

ii) Money

1. What do you call this coin? (subject shown either a one cent piece or a penny)[a]
2. What do you call this coin? (subject shown either a ten cent piece or a dime)
3. What do you call this coin? (subject shown either a five cent piece or a nickel)
4. What do you call this coin? (subject shown either a twenty cent piece or a quarter)
5. How many 10 cent pieces (dimes) are needed to make one dollar?
6. How many 1 cent pieces (pennies) are needed to make ten cents (dime)?
7. How many 5 cent pieces (nickels) are needed to make ten cents (dime)?
8. How many 10 cent pieces (dimes) are needed to make one dollar?
9. How much money would you have if I gave you 5 cents and two one cent pieces (pennies)?

Two dollars worth of change was presented on the table in front of the subject and each subject was asked to:

10. Give me six cents.
11. Give me 42 cents.
12. Give me $1:13.

[a] Subjects from Australia received the former while subjects from the USA received the latter.

Appendix 4.9

Descriptive data on the subjects involved in Chapter 4 including their age, hand used during testing, sex, skill recruited for and the level of the skill as determined by the author.

Subject	Age (years)	Sex	Hand[a]	Primary Skill	Level
1[b]	47	Male	Right	Music	Prodigious
2	47	Female	Right	Memory	Splinter
5	14	Male	Right	Memory	Talented
6	36	Male	Left	Calendar	Talented
7	19	Male	Right	Memory	Talented
8	21	Male	Left	Mechanics	Talented
9	9	Male	Right	Memory	Talented
10	42	Male	Left	Calendar	Talented
12	25	Male	Right	Music	Prodigious
13	53	Male	Right	Calendar	Prodigious
14	7	Male	Left	Memory	Splinter
15	14	Male	Right	Memory	Splinter
16	13	Male	Left	Memory	Splinter
17	35	Male	Right	Music	Prodigious
18	25	Male	Left	Memory	Talented
19	16	Male	Right	Art	Prodigious
20	24	Male	Right	Maths	Talented
21	8	Male	Left	Memory	Splinter
22	40	Male	Left	Music	Prodigious
23	12	Female	Right	Memory	Splinter
24	20	Male	Right	Calendar	Talented
25	22	Male	Left	Calendar	Talented
26	6	Male	Right	Memory	Splinter
27	14	Male	Right	Memory	Splinter
28	15	Female	Right	Memory	Splinter
29	25	Male	Right	Memory	Talented
30	9	Male	Right	Memory	Splinter
31	7	Male	Right	Memory	Splinter
32	20	Male	Left	Memory	Talented
33	9	Male	Right	Memory	Splinter
34	16	Male	Right	Mechanics	Splinter
35	17	Male	Right	Memory	Talented
36	34	Male	Right	Art	Talented
37	13	Female	Right	Music	Talented
38	15	Male	Right	Memory	Splinter
39	36	Male	Left	Art	Talented
41	48	Male	Left	Music	Prodigious
42	25	Male	Right	Calendar	Prodigious
43	28	Male	Right	Memory	Splinter
44	12	Female	Left	Memory	Splinter
45	11	Male	Right	Memory	Splinter
46	13	Male	Right	Music	Prodigious
47	19	Male	Right	Memory	Talented
48	30	Male	Right	Calendar	Talented
49	24	Male	Right	Art	Prodigious
50	10	Male	Left	Maths	Prodigious

Descriptive data on the subjects involved in Chapter 4 including their age, hand used during testing, sex, skill recruited for and the level of the skill as determined by the author (cont.).

Subject	Age (years)	Sex	Hand	Primary Skill	Level
51	10	Male	Right	Memory	Splinter
52	27	Female	Left	Art	Talented
54	7	Male	Right	Memory	Splinter
55	27	Female	Right	Music	Talented

[a] Although this was the hand used during testing it did not always correspond with the hand suggested by the responses to the questionnaire presented in Chapter 5.
[b] Subject numbering is not consecutive because some subjects were removed from the analysis due to inability to demonstrate sufficient skill levels.

Appendix 4.10

Results from subtests for the WMS- R for all subjects.

	Mental Control	Figural Memory	Logical Memory 1	Visual Paired Associates 1	Verbal Paired Associates 1	Visual Repro-duction 1	Digit Span	Visual Memory Span	Logical Memory 11	Visual Paired Associates 11	Verbal Paired Associates 11	Visual Reproductio 11
Maximum Score	6	10	50	18	24	41	24	26	50	6	8	41
Subject												
1	2	2	0	7	15	12	12	12	0	2	6	6
2	1	4	2	9	18	16	6	8	0	2	7	0
5	6	8	36	14	21	38	18	18	17	6	8	30
6	3	1	6	5	11	19	13	13	4	6	8	20
7	6	5	3	8	11	25	2	7	1	4	7	25
8	0	6	7	5	1	27	5	8	2	5	5	8
9	6	7	11	15	15	35	14	13	8	6	7	24
10	2	4	23	12	17	5	11	7	17	6	8	5
12	4	6	17	18	23	37	15	15	16	6	8	37
13	6	7	7	18	13	8	12	16	6	6	8	6
14	4	5	1	13	8	16	8	10	0	6	7	14
15	4	5	4	8	17	8	15	13	0	4	8	0
16	4	2	0	6	3	14	4	0	10	6	8	4
17	6	9	34	17	24	41	17	14	33	6	8	41
18	4	5	11	7	15	17	11	12	6	4	5	11
19	2	4	13	14	21	37	8	10	9	6	8	31
20	6	8	23	14	16	25	15	15	17	6	8	25
21	4	4	2	17	12	24	10	10	0	6	7	14
22	4	7	2	17	17	14	7	7	0	6	8	13
23	6	5	0	9	14	22	8	13	0	6	7	5
24	6	7	12	11	15	35	10	15	9	6	6	34
25	6	6	6	12	19	24	11	14	7	6	8	24
26	4	5	6	14	18	11	9	10	3	6	8	3
27	6	5	25	17	19	27	12	14	27	5	8	11
28	5	5	4	9	9	13	12	8	1	6	7	10
29	5	9	25	7	15	23	8	13	17	3	5	21
30	6	7	16	16	19	6	10	14	12	6	8	6
31	0	3	12	15	12	10	6	7	12	3	7	8
32	2	4	44	12	21	37	14	15	41	6	8	38
33	4	4	7	13	11	4	10	8	4	6	6	2
34	1	6	12	9	12	30	10	7	1	4	7	16
35	4	7	34	12	24	32	9	9	32	5	8	31
36	5	6	25	18	20	32	12	14	28	6	8	25
37	6	1	10	11	13	31	6	13	2	1	5	14
38	6	4	0	13	7	29	9	11	0	6	3	11
39	2	4	6	5	9	25	3	13	0	6	6	10
41	5	6	21	12	12	17	20	17	14	6	6	5
42	6	8	5	18	22	33	25	22	0	6	8	33
43	2	5	0	3	5	28	6	5	0	4	3	14
44	1	3	1	5	10	17	3	4	0	3	3	16
45	6	2	8	3	21	20	9	10	3	6	8	18
46	6	10	22	15	23	35	22	25	14	6	8	28
47	6	5	8	4	13	22	12	7	4	4	8	10
48	6	9	24	18	20	41	15	21	14	6	8	40
49	6	9	24	18	20	41	15	21	14	6	8	40
50	6	0	0	3	13	15	12	5	0	0	6	

Results from subtests for the WMS- R for all subjects (cont.).

	Mental Control	Figural Memory	Logical Memory 1	Visual Paired Associates 1	Verbal Paired Associates 1	Visual Repro-duction 1	Digit Span	Visual Memory Span	Logical Memory 11	Visual Paired Associates 11	Verbal Paired Associates 11	Visua Repro ductio 11
Maximum Score	6	10	50	18	24	41	24	26	50	6	8	41
51	6	4	5	12	18	0	18	8	1	6	8	
52	2	6	7	9	7	37	7	13	5	3	3	38
53	2	8	18	18	18	31	10	11	15	6	8	31
54	6	7	11	6	21	6	8	10	6	5	8	10
55	4	5	8	12	20	32	16	16	8	6	8	25

Appendix 4.11

Results from the weighted raw score sums and the tabulated indexes for the WMS- R for all subjects. [a]

	Verbal Memory		Visual Memory		General Memory		Attention/ Concentration		Delay	
Subject.	Raw	Index	Raw	Index	Raw	Index	Raw	Index	Raw	Index
1	15	53	21	50	36	50	51	78	20	57
2	32	68	29	62	61	56	29	50	18	56
5	93	NA	60	NA	153	NA	60	NA	75	NA
6	23	59	25	51	48	50	55	83	52	77
7	17	50	38	63	55	50	34	50	48	50
8	15	50	38	66	53	50	26	50	30	50
9	37	NA	57	NA	94	NA	60	NA	68	NA
10	43	77	21	50	64	57	38	57	50	76
12	57	85	61	112	138	108	64	92	81	100
13	27	63	33	70	60	55	62	95	40	71
14	10	NA	34	NA	44	NA	40	NA	45	NA
15	25	NA	21	NA	46	NA	60	NA	24	NA
16	37	NA	22	NA	25	NA	30	NA	32	NA
17	92	122	67	138	159	129	68	101	102	138
18	37	69	29	56	66	54	50	70	35	58
19	47	67	55	93	102	69	38	50	68	78
20	62	88	47	82	109	84	66	92	70	87
21	16	NA	45	NA	61	NA	44	NA	40	NA
22	21	58	38	73	59	53	22	50	41	70
23	14	NA	34	NA	48	NA	48	NA	31	NA
24	39	69	53	71	92	69	56	74	67	84
25	31	62	42	72	73	54	56	74	59	78
26	30	NA	30	NA	60	NA	42	NA	34	NA
27	69	89	49	80	118	85	58	82	75	86
28	17	50	27	50	44	50	45	62	37	50
29	65	91	39	70	104	83	47	67	75	93
30	51	71	29	50	80	50	54	77	46	50
31	3	NA	18	NA	54	NA	6	NA	40	NA
32	109	134	53	93	162	128	60	81	107	138
33	25	NA	21	NA	46	NA	48	NA	30	NA
34	36	56	45	73	81	50	35	50	39	50
35	92	112	51	83	143	104	40	54	89	105
36	70	97	56	100	126	96	57	86	61	83
37	33	NA	43	NA	76	NA	51	NA	28	NA
38	7	NA	46	NA	53	NA	46	NA	29	NA
39	21	50	34	53	55	50	34	50	34	50
41	54	87	45	89	99	86	79	116	43	73
42	32	64	59	106	91	74	100	138	61	81
43	14	50	36	66	60	50	32	50	28	50
44	12	NA	25	NA	37	NA	15	NA	28	NA
45	37	NA	25	NA	62	NA	44	NA	49	NA
46	67	NA	60	NA	127	NA	100	NA	70	NA
47	29	55	32	53	61	50	44	60	38	50

Results from the weighted raw score sums and the tabulated indexes for the WMS- R for all subjects (cont.).

	Verbal Memory		Visual Memory		General Memory		Attention/ Concentration		Delay	
Subject	Raw	Index	Raw	Index	Raw	Index	Raw	Index	Raw	Index
48	68	93	68	138	136	102	78	105	80	98
49	68	93	68	138	136	102	78	105	80	98
50	13	NA	18	NA	31	NA	40	NA	12	NA
51	28	NA	16	NA	44	NA	62	NA	36	NA
52	21	56	52	93	73	59	44	63	55	77
53	54	83	57	85	111	88	44	63	74	100
54	43	NA	25	NA	68	NA	42	NA	42	NA
55	36	68	49	88	85	69	68	87	61	81

[a] For WMS-R, scaled scores follow the conventions of mean=100, SD=15.

Appendix 4.12

Results from the Neale Analysis of Reading Ability-Revised (Form 2) and the Schonell Graded Word Reading Test.

	Neale Analysis of Reading Ability-Revised				Schonell Graded Word Reading Test	
Subject	Rate /min.	Accuracy	Comprehension	Reading Age (months)	Raw Score	Reading Age (months)
1	88	44	0	135	52	116
2	0	0	0	72	0	36
5	146	100	22	144	95	144
6	9	5	0	72	10	81
7	52	42	1	96	32	95
8	0	0	0	72	4	76
9	82	28	7	129	37	102
10	76	57	21	122	62	125
12	100	86	22	144	85	144
13	44	44	4	88	35	99
14	68	42	2	114	34	100
15	28	11	1	72	8	79
16	76	57	0	74	62	125
17	120	90	42	144	90	144
18	80	62	3	126	71	136
19	100	80	6	77	76	139
20	68	42	2	114	34	100
21	53	17	1	97	25	91
22	28	11	1	72	34	100
23	83	50	0	130	36	102
24	52	37	3	95	17	78
25	76	66	3	122	76	144
26	88	43	9	134	36	102
27	57	23	8	78	67	130
28	90	54	3	138	54	118
29	120	90	22	144	96	144
30	103	41	9	144	84	144
31	43	14	7	87	9	80
32	137	98	38	144	92	144
33	74	39	3	120	35	101
34	100	39	19	144	42	83
35	152	99	42	144	96	144
36	91	79	7	139	64	127
37	0	0	0	72	5	77
38	95	34	2	143	74	140
39	5	1	1	72	15	84
41	105	54	11	144	70	135
42	99	85	12	144	88	144
43	25	30	0	72	24	90
44	104	14	0	144	25	91
45	125	20	3	144	70	135
46	120	144	26	144	90	144
47	97	61	8	144	76	144
48	47	26	2	91	24	89
49	120	85	26	144	90	144
50	80	26	0	137	30	96
51	61	28	7	114	32	98
52	71	62	7	117	55	119
53	62	85	26	84	75	142
54	91	29	4	138	47	112
55	105	48	2	144	68	132

Appendix 4.13

Results from the Hooper Visual Organisation Test and the Bender Visual Motor Gestalt Test.

	Hooper	Bender Visual Motor Gestalt Test[a]			
Subject	/30	Distortion	Integration	Rotation	Perseveration
1	17	4	3	0	3
2	14	3	7	0	1
5	21	0	0	0	0
6	24	1	0	1	1
7	27	0	1	0	1
8	16	0	1	0	1
9	21	1	2	0	0
10	23	2	1	0	0
12	29	0	1	0	0
13	25	0	0	1	0
14	21	2	4	0	0
15	18	6	2	0	1
16	19	2	1	0	1
17	29	0	0	0	0
18	22	0	0	0	0
19	26	0	0	0	0
20	27	1	0	0	0
21	25	0	0	2	1
22	28	1	0	0	1
23	23	0	0	0	0
24	22	0	0	0	2
25	24	0	2	0	1
26	19	0	1	0	1
27	21	0	0	0	0
28	25	1	1	1	2
29	28	0	0	0	0
30	18	0	0	0	0
31	23	2	3	0	1
32	27	0	1	0	1
33	20	3	5	0	1
34	23	2	3	0	1
35	20	3	0	0	0
36	24	2	0	0	0
37	18	1	1	0	0
38	27	1	1	4	0
39	19	1	0	0	0
41	13	4	1	0	0
42	26	0	0	0	0
43	24	0	0	0	0
44	21	6	3	0	0
45	28	0	0	0	0
46	20	0	0	0	0
47	14	3	0	0	3
48	22	0	0	0	0
49	28	0	0	0	0

Results from the Hooper Visual Organisation Test and the Bender Visual Motor Gestalt Test (cont.)

	Hooper	Bender Visual Motor Gestalt Test[a]			
Subject	/30	Distortion	Integration	Rotation	Perseveration
50	18	1	2	0	2
51	13	5	3	1	1
52	27	0	0	0	0
53	26	1	0	0	2
54	17	2	5	2	0
55	21	0	0	1	2

[a] The score indicates the number of errors made in each of these areas.

Appendix 4.14

Results from the Time and Money questions outlined in Appendix 4.8.

Subject	Time (/17)	Money (/12)
1	0	4
2	12	6
5	17	10
6	9	4
7	17	9
8	1	2
9	17	10
10	14	8
12	15	12
13	15	10
14	7	6
15	17	12
16	7	7
17	17	12
18	17	10
19	16	11
20	13	6
21	6	3
22	13	6
23	15	5
24	17	12
25	17	12
26	9	9
27	16	10
28	13	11
29	16	12
30	15	10
31	9	4
32	16	11
33	15	9
34	16	10
35	17	12
36	17	12
37	16	12
38	10	9
39	13	4
41	17	12
42	15	10
43	8	5
44	9	7
45	0	1
46	17	12
47	12	10
48	14	10
49	17	12
50	10	6
51	16	10
52	16	12
53	10	5
54	10	7
55	10	7

Appendix 4.15

Results from the Torrance Test of Creative Thinking (Thinking Creatively with Pictures: Figural Booklet A).

Subject	Fluency	Flexibility	Originality	Elaboration
1	1	1	0	0
2	9	7	12	4
5	6	6	3	0
6	11	7	19	1
7	9	1	0	0
8	4	11	25	20
9	21	4	54	1
10	10	12	2	2
12	15	13	11	12
13	10	12	2	2
14	2	2	1	0
15	9	4	17	4
16	11	5	17	12
17	22	17	32	32
18	17	25	31	59
19	2	1	3	9
20	25	18	42	113
21	17	8	34	17
22	0	0	0	0
23	40	24	43	7
24	18	14	32	38
25	22	9	17	14
26	11	4	1	1
27	22	17	28	12
28	0	0	0	0
29	18	17	21	15
30	0	0	0	4
31	40	2	0	0
32	26	13	46	80
33	11	2	0	3
34	20	10	20	4
35	23	5	67	135
36	17	12	32	11
37	16	12	17	25
38	11	7	10	1
39	0	0	3	0
41	0	0	0	0
42	40	11	18	3
43	0	0	0	0
44	11	1	0	0
45	0	0	0	0
46	99	99	99	99
47	0	0	0	0
48	11	7	13	11
49	20	19	42	122
50	11	1	0	0
51	11	7	18	6
52	14	10	18	89
53	16	12	17	55
54	16	12	17	55
55	2	1	0	0

Appendix 5.1.
The questionnaire sent to the parents of all subjects.

SAVANT-SYNDROME QUESTIONNAIRE
(Research by Robyn Young)
Psychology Dept
University of Adelaide
GPO Box 498
Adelaide. South Aust.
5001

Name_Subject's name[a] ______________________________
Date of Birth ______________________________
Name of Person Completing this form. ______________________________
Your Relationship to Subject ______________________________

INSTRUCTIONS: I am asking you to complete this form and return it in the envelope provided. The information that you disclose will be used for research purposes only and therefore will be confidential. Please choose the response which best describes Subject. Place a / in the box next to the most applicable response. For example:
"Has your child ever had chicken-pox?" no[ ] yes[✓]. This indicates that yes your child has had chicken pox.
There is a place for additional comments at the end, if you wish to make some. Any additional comments are welcome.
I thankyou for your continued support and involvement.

A). PERSONAL DETAILS

1. Was pregnancy and delivery normal? no [ ] yes [ ]
If no provide details______________________________
____
____
____

2. What week gestation was baby delivered? ______________ weeks
3. Did Subject ever receive Oxygen? no [ ] yes [ ]
If yes: When? ______________________________
4. Over the years I have found that a number of parents have ideas about possible links between their child's abnormality and environmental or other factors. Do you have any suspicions as to the cause of Subject 's problems (eg agent orange, flying, falling while pregnant, genetics etc)?
no [ ] yes [ ]
If yes, please provide details;
____
____
____
____
____

5. At what age did you first suspect that there may be a problem with Subject ? __ years __months
6. What was the reason for your initial concern? ______________________________
7. Briefly describe Subject 's educational history. (eg always at home, regular school until age 3 etc)
____
____

Did you suspect Subject to have above average ability at any stage during his/her development ?
no [ ] yes [ ]
If yes Why? ______________________________
9 Which hand does Subject use most? left[ ] right [ ] both [ ]
uncertain [ ]
10. At what age did Subject show a definite preference for one hand? ______ months or never [ ].

[a] Subject's name was inserted where "Subject" appears in the questionnaire.

A). DIAGNOSIS

1. Has Subject had a formal diagnosis for his/her disorder? no [ ] yes [ ]
   If yes what was the diagnosis? ____________________

   At what age was this given? __________ years __________ months
   Have any other diagnoses been suggested? no [ ] yes [ ]
   If yes, what?? ____________________
2. Are there any physical abnormalities eg blindness? no [ ] yes [ ]
   provide details____________________

A1) Language and Communication

1) Does Subject spontaneously point to objects to express interest? no [ ] yes [ ]
2) Is Subject able to use gestures? no [ ] yes [ ]
3) Does Subject nod his head for yes? no [ ] yes [ ]
4) Does Subject shake his head for no? no [ ] yes [ ]
5) Is Subject able to imitate or copy spontaneously the actions of others? no [ ] yes [ ]
6) Does Subject or has he ever engaged in pretend play? no [ ] yes [ ]
7) As a young child was Subject able to enter into the spirit of social games? no [ ] yes [ ]
8) Does Subject engage in conversation just to chat ie "small talk". no [ ] yes [ ]
9) Can you have a conversation with Subject other than him simply responding to questions? no [ ] yes [ ]
10) Has Subject ever tended to use the same phrases over and over? no [ ] yes [ ]
11) Has Subject behaved frequently in a socially inappropriate manner? no [ ] yes [ ]
12) Has Subject ever got his personal pronouns wrong? (eg You want a drink instead of I) no [ ] yes [ ]
13) Did Subject ever have his own invented words? no [ ] yes [ ]
14) Does Subject 's speech show appropriate intonation (ie. volume, rate, etc)? no [ ] yes [ ]
15) Can you tell how he is feeling by the tone of his voice? no [ ] yes [ ]
16) Did Subject ever continually repeat things that he/she heard)? no [ ] yes [ ]
17) What is the average length of words or sentences (ie. one word etc)____________
18) Would you describe Subject 's non-verbal communication as abnormal? no [ ] yes [ ]

A2) Social Development

1) Does Subject have good or appropriate eye contact? no [ ] yes [ ]
2) Does Subject have a social smile ie smile when greeting people etc? no [ ] yes [ ]
3) Does Subject show a normal range of facial expressions? no [ ] yes [ ]
4) When Subject was young (ie less than 4) did he put his hands up to be picked up? no [ ] yes [ ]
5) Did Subject ever play imaginative games with someone else where they shared the same ideas about pretending? no [ ] yes [ ]
6) Does/Did Subject watch his peers and make efforts to approach them? no [ ] yes [ ]
7) Does/Did Subject respond appropriately to approaches by his friends? no [ ] yes [ ]
8) Does Subject have any of his own friends that he may either play with or want to go out with? no [ ] yes [ ]
9) Does Subject offer comfort to you or anyone if you are sad or hurt? no [ ] yes [ ]
10) Does Subject seek comfort when he is hurt? no [ ] yes [ ]
11) Does Subject have what you would consider to be a normal range of spontaneous affection? no [ ] yes [ ]
12) When Subject was 4 to 5 years old did he tend to check back to see where you were? no [ ] yes [ ]
13) When Subject was 4 to-5 years old did he go through a clingy-mummyish phase? no [ ] yes [ ]
14) Does Subject show you things that are of interest to him? no [ ] yes [ ]
15) Does Subject offer to share things ? no [ ] yes [ ]
16) Does Subject ever want you to share in his enjoyment? no [ ] yes [ ]
17) Does Subject share other people's excitement? no [ ] yes [ ]
18) Does Subject show appropriate greeting skills? no [ ] yes [ ]
19) Does Subject use appropriate gestures and vocalisations to indicate that they may need help? no [ ] yes [ ]
20) Are Subject 's facial expressions appropriate for the situation? no [ ] yes [ ]
21) Do Subject 's responses differ according to his familiarity with a person? no [ ] yes [ ]

A3) Interests, Rituals and Routines

1) Does Subject have any special interests that are unusual in their intensity, that is they appear almost compulsive? no [ ] yes [ ]

2) Has Subject ever had an interest that others would consider unusual (eg traffic lights)? no [ ] yes [ ]

3) Did Subject ever play with just parts of a toy such as the wheels of a car instead of playing with it in the manner in which it was intended? no [ ] yes [ ]

4) Did Subject ever seem particularly interested in the touch, smell, sound taste or sight of objects or people? no [ ] yes [ ]

5) Does or did Subject ever get particularly irritated by particular sounds such as people coughing or babies crying? no [ ] yes [ ]

6) Does or did Subject have a particular attachment to particular objects that he liked to carry around with him

If so what was it ______________________________

7) Does or did Subject ever get frustrated if minor changes were made to his routine eg changing from shorts to long pants; or salt in a different place on the table)? no [ ] yes [ ]

8) Does or did Subject ever get upset if minor changes were made about the house? no [ ] yes [ ]

9) Does Subject have any odd ways of moving his hands or fingers? no [ ] yes [ ]

10) Does or did Subject have any complicated whole body movements such as spinning? no [ ] yes [ ]

11) Does or did Subject ever say things in the same way and insist on you replying in a certain way? no [ ] yes [ ]

12) Are there things that Subject has to do in a particular order like a ritual? no [ ] yes [ ]

13) Would you describe Subject 's range of interests as limited?

B. SKILLS

Does Subject show an unusual degree of skill in any or all of the following areas?

If the answer is yes to any of the following skills please rate the skill level as either:

1 only special in relation to his overall ability
2 special in comparison to other individuals of similar age
3 would be considered EXCEPTIONAL in the normal population

(circle the appropriate number associated with that particular ability). Furthermore, you may like to provide examples of the ability.

a). memory (eg telephone numbers, songs, TV commercials, places, events, birth dates, Presidents, capital cities, etc) no special skill [ ] yes demonstrates skill [ ] 1 2 3

examples______________________________

____

b) Hyperlexia (unusual ability in reading) no special skill [ ] yes demonstrates skill [ ] 1 2 3

examples______________________________

____

c) mathematics / numbers no special skill [ ] yes demonstrates skill [ ] 1 2 3

examples______________________________

____

d) drawing/art no special skill [ ] yes demonstrates skill [ ] 1 2 3

examples______________________________

____

e) musical ability no special skill [ ] yes demonstrates skill [ ] 1 2 3

examples______________________________

____

f) good pitch no special skill [ ] yes demonstrates skill [ ] 1 2 3

examples______________________________

____

g) spatial skills (eg puzzles, mechanics) no special skill [ ] yes demonstrates skill [ ] 1 2 3

examples______________________________

____

h) calendar calculation no special skill [ ] yes demonstrates skill [ ] 1 2 3
(ie. the ability to tell you on what day of the week a day will fall).
examples____________________

i) sensory sensitivity (sound, touch etc) no special skill [ ] yes demonstrates skill [ ] 1 2 3
examples____________________

j) ball skills or other athletic performance no special skill [ ] yes demonstrates skill [ ] 1 2 3
examples____________________

k) other skills____________________ 1 2 3

It is probable that Subject demonstrates more than one ability please respond to the following questions relating to the ability you consider to be the most prodigious. If Subject does not demonstrate any particular skills please move on to Section C Family Background section.

1. What would you describe as the most prodigious skill that Subject demonstrates __________
2. At what age did you first notice this ability __________ years
3. Do you have any idea as to what generated the interest in this ability?

4. How much time would you say that Subject currently spends rehearsing his ability? ______ hours / week
5. At its peak how many hours per week would he spend on the ability? __________ hours / week
6. What training in his skill area has Subject received?

7. Has Subject , to your knowledge, ever been exposed to a perpetual calendar?
   If yes at what age? __________
   How long has he/she spent studying it?

8. Attached to this questionnaire is a calendar. If it is possible, please ask Subject to tell you what year it might be. What did he respond?

If he responded with a year please ask him what other years it may be.

9. When referring to events such as last Christmas will Subject often refer to the day of the week on which it occurred?
   no [ ] yes [ ]

C) FAMILY BACKGROUND

1). Is there any members of Subject 's immediate family who demonstrate any of the above skills or might be considered gifted or talented in any other way?
If so provide details below:
If family members demonstrate any skills please rate the skill level as either:
1 only special in relation to his overall ability
2 special in comparison to other individuals of similar age
3 would be considered EXCEPTIONAL in the normal population

Relationship to Subject	Talent/Ability	Rating
eg Grandfather	good drawer,	1 2 3
		1 2 3
		1 2 3
		1 2 3
		1 2 3
		1 2 3

__________ __________________________________ 1 2 3
__________ __________________________________ 1 2 3

2). Is there any members of Subject 's immediate family that were/are known to have a mental illness or other disorders such as Klinefelters, depression., Asperger's Syndrome, Autism, dyslexia etc. If so please provide details below:

Relationship to Subject	Talent/Ability
eg cousin (male	Asperger's Syndrome, also appeared to have an attention deficit
disorder	
grandfather (father's father)	depression
__________	__________________________________
__________	__________________________________
__________	__________________________________
__________	__________________________________
__________	__________________________________
__________	__________________________________
__________	__________________________________

A MOTHER

1. How many years of schooling did mother complete? ____________________
2. What was the highest education level of mother (eg 6th grade, high school, some college subjects?

____

If mother went to college/university what was the main area of study? ____________

3. What nationality is mother?____________________________
4. What is the first language of mother? ________________________
5. Does mother speak any other languages no[ ] yes [ ]

If yes what languages ____________________

6. Is mother left or right handed? left [ ] right [ ]
7. Please list any special interests mother may have

____
____
____

8. Has mother ever had an IQ test? no[ ] yes [ ]

Can you provide any details? __________________________________
____

B FATHER

1. How many years of schooling did father complete? ____________________
2. What was the highest education level of father (eg 6th grade, high school, some college subjects?

____

If father went to college/university what was the main area of study? ____________

3. What nationality is father?____________________________
4. What is the first language of father? ________________________
5. Does father speak any other languages no[ ] yes [ ]

If yes what languages ____________________

6. Is father left or right handed? left [ ] right [ ]
7. Please list any special interests father may have ____________________

____
____

8. Has father ever had an IQ test? no[ ] yes [ ]

Can you provide any details? __________________________________
____

C 1. SIBLING (PLEASE FILL OUT ONE FOR EACH SIBLING)
NAME ______________________________________
AGE ______________________________________
1. How many years of schooling did sibling complete? ______________________________________
2. What was the highest education level of sibling (eg 6th grade, high school, some college subjects? ____
____

    If sibling went to college/university what was the main area of study? ____________________
3. Please list any special interests sibling may have ______________________________________
____
____

4. Has sibling ever had an IQ test? no[ ] yes [ ]
    If so, can you provide any details?
____
____

C 2. SIBLING (PLEASE FILL OUT ONE FOR EACH SIBLING)
NAME ______________________________________
AGE ______________________________________
1. How many years of schooling did sibling complete? ______________________________________
2. What was the highest education level of sibling (eg 6th grade, high school, some college subjects? ____
____

    If sibling went to college/university what was the main area of study? ____________________
3. Please list any special interests sibling may have ______________________________________
____
____

4. Has sibling ever had an IQ test? no[ ] yes [ ]
    If so, can you provide any details?
____
____
____

I realise that this questionnaire has been time consuming and I appreciate your co-operation in the matter. The completed questionnaire can be sent to me in the stamped addressed envelope. If this has been lost please send it to

Robyn Young
Psychology Dept, University of Adelaide
GPO Box 498
South Australia 5001

Appendix 5.2

<u>The responses to the questions relating to autism from the total of 39 returned questionnaires.</u>

Question	Section A: Language and Communication	No	Yes	Unsure
1	Does S spontaneously point to objects to express interest?	14	25	
2	Is S able to use gestures?	17	22	
3	Does S nod his head for yes?	12	27	
4	Does S shake his head for no?	17	22	
5	Is S able to imitate or copy spontaneously the actions of others?	18	21	
6	Does S or has he ever engaged in pretend play?	18	21	
7	As a young child was S able to enter into the spirit of social games?	10	29	
8	Does S engage in conversation just to chat ie "small talk"?	19	20	
9	Can you have a conversation with S other than him simply responding to questions?	13	26	
10	Has S ever tended to use the same phrases over and over?	20	19	
11	Has S behaved frequently in a socially inappropriate manner?	14	25	
12	Has S ever got his personal pronouns wrong? (eg You want a drink instead of I	16	23	
13	Did S ever have his own invented words?	11	28	
14	Does S 's speech show appropriate intonation (ie. volume, rate, etc.)	14	25	
15	Can you tell how he is feeling by the tone of his voice?	15	24	
16	Did S ever continually repeat things that he/she heard?	12	27	
17	What is the average length of words or sentences (ie. one word)etc? Eight respondents thought their child was within the normal range while 31 suggested that the length of sentences was impaired (i.e., 4 words or less).			
18	Would you describe S 's non-verbal communication as abnormal?	7	31	1
	Section B: Social Development	**No**	**Yes**	**Unsure**
1	Does S have good or appropriate eye contact?	7	31	1
2	Does S have a social smile ie smile when greeting people etc?	14	25	
3	Does S show a normal range of facial expressions?	12	27	
4	When S was young (ie less than 4 did he put his hands up to be picked up?	14	23	1
5	Did S ever play imaginative games with someone else where they shared the same ideas about pretending?	18	20	1
6	Does/Did S watch his peers and make efforts to approach them?	11	28	
7	Does/Did S respond appropriately to approaches by his friends?	16	22	1
8	Does S have any of his own friends that he may either play with or want to go out with?	15	23	1
9	Does S offer comfort to you or anyone if you are sad or hurt?	14	25	
10	Does S seek comfort when he is hurt?	13	26	
11	Does S have what you would consider to be a normal range of spontaneous affection?	13	26	
12	When S was 4 to 5 years old did he tend to check back to see where you were?	16	23	
13	When S was 4 to-5 years old did he go through a clingy-mummyish phase?	16	23	
14	Does S show you things that are of interest to him?	15	24	
15	Does S offer to share things ?	17	22	
16	Does S ever want you to share in his enjoyment?	19	19	1
17	Does S share other people's excitement?	13	25	1
18	Does S show appropriate greeting skills?	19	20	
19	Does S use appropriate gestures and vocalisations to indicate that they may need help?	16	23	
20	Are S 's facial expressions appropriate for the situation?	12	27	
21	Do S 's responses differ according to his familiarity with a person?	11	28	

C	Section C: Interests Rituals and Routines	No	Yes	Unsure
1	Does S have any special interests that are unusual in their intensity, that is they appear almost compulsive?	13	26	
2	Has S ever had an interest that others would consider unusual (eg traffic lights)?	15	24	
3	Did S ever play with just parts of a toy such as the wheels of a car instead of playing with it in the manner in which it was intended?	18	21	
4	Did S ever seem particularly interested in the touch, smell, sound, taste or sight of objects or people?	14	24	1
5	Does or did S ever get particularly irritated by particular sounds such as people coughing or babies crying?	13	24	2
6	Does or did S have a particular attachment to particular objects that he liked to carry around with him	12	25	2
7	Does or did S ever get frustrated if minor changes were made to his routine eg changing from shorts to long pants; or salt in a different place on the table?	19	19	1
8	Does or did S ever get upset if minor changes were made about the house?	13	25	1
9	Does S have any odd ways of moving his hands or fingers?	19	20	
10	Does or did S have any complicated whole body movements such as spinning?	21	18	
11	Does or did S ever say things in the same way and insist on you replying in a certain way?	25	14	
12	Are there things that S has to do in a particular order like a ritual?	17	22	
13	Would you describe S 's range of interests as limited?	16	23	

Appendix 5.3

The number of responses (recoded) depicting autistic characteristic for each subject for Sections A, B and C and a total score for autistic tendencies.

	Section A Language and Communication	Section B Social Developmen t	Section C Interests, Rituals and Routines	Total number of autistic tendencies
Maximum Score	17	21	13	51
Subject				
1	8	8	7	23
2	7	7	6	20
6	5	13	5	23
7	9	15	6	30
8	7	16	7	30
9	6	7	10	23
10	6	8	10	24
12	5	10	8	23
14	10	12	9	31
15	11	14	13	38
16	13	15	9	37
17	5	4	6	15
18	5	6	11	22
19	9	9	8	26
20	8	10	13	31
21	6	9	8	23
25	9	4	9	22
26	11	12	10	33
27	8	19	7	34
28	6	6	7	19
29	7	3	11	21
31	7	9	11	27
32	8	15	8	31
33	7	12	11	30
34	7	6	9	22
35	9	6	12	27
36	8	10	13	31
38	11	18	6	35
43	9	16	11	36
45	5	11	9	25
46	8	13	12	33
47	6	11	8	25
48	9	17	10	36
49	7	10	5	22
50	7	7	11	25
51	8	12	12	32
52	6	9	10	25
53	13	18	7	38
54	7	10	9	26

Appendix 5.4

The level[a] of skill demonstrated by each savant in each of the skills.

	Skill											
	Memory	Hyperlexia	Maths	Art	Music	Pitch	Spatial	Cal Calc.	Sensory	Athletics	Other	Total
Subject												
1	3	1			3	3	1		1			6
2	1						1					2
6	3							3				2
7	3				1		3	1		1		5
8							1					
9	2			2	2	3			2			5
10	3							2				2
12	3			1	3	3			3			5
14	1	1				1						3
15	1											1
16	2						1	2				3
17	3		3	2	3	3	3		3	3		8
18	2						1				1	3
19	2			2			2					3
20	3		3	2	3	3				2		6
21	1			1							2	3
25	3	2	2	1	3		3	3	3	2		9
26	3	3	2				3			2		5
27	2		2									2
28	3	1						1	1			4
29	3	3		1	1	1			1			6
31		2						1				2
32	3			1					1			3
33	3						2					2
34	1	1					1		1			4
35	3	3		1								3
36	3	1	3	3			2	3	1	3		8
38	3	1	1				2	1				5
43	3				1		3		2		1	5
45	3							2	3			3
46	3	3	3		3			2	3	3	3	8
47	3	1	1		1	1	1	1		1		8
48	3		1	3	1	1	3	3	1			8
49	3		3	3	3	3			3			6
50	3							3				2
51	3		1		1	1		1				5
52	2			3			3			3		4
53	3			3	3	2	1		1			6
54	3	3	3				1		3			5
Total	37	14	13	15	15	11	20	15	17	9	4	170

[a] Level 1 implies the skill is only special in relation to overall ability; Level 2 is special in comparison to other individuals of a similar age and Level 3 would be considered exceptional in the normal population.

Appendix 5.5

The frequency with which subjects demonstrated memory in a discrete range of interest areas.

Interest Area	Number Reported
birth dates	11
songs	10
life events	8
telephone numbers	6
registration numbers	5
time tables	5
TV commercials	5
post-codes	4
roads/ locations	3
general knowledge	2
street names	2
politicians	2
weather	2
astronomy	1
animals	1
data on trucks	1
information on books	1

Appendix 5.6

The reported frequency and level[a] of skill among immediate family members of each subject

Subject	Memory	Hyper-lexia	Math	Art	Music	Spatial / Engineering	Writing	Physics	Compu-ting	High IQ
1							M-3 F-3			
2										
6			B-2							
7										
8										
9				A-2						
10										
12				M-3	M-3,GM-3					
14	F-2			F-2						
15										
16										
17			F-3		S-3, M-3	F-3		F-3, S-3	B-3	
18				M-2, F-2						
19				F-2,M-2						
20										
21			F-3	GF-1						
25	M-2		F-3		C-3, C-3					
26										
27										
28										
29										
31	F-3 GF-3				A-3		M-3			S-3
32	Adopted									
33										
34				M-2, C-2 F-2						
35				GF-3		S-3				
36	GF-2, F-2			GM-2						
38										
43				M-						
45										
46			B-3, M-3 B-3		B-2			M-3		
47				S-2	S-2					
48					M-2					F-3
49		S-3		U-2		B-3				
50										
51			F-3							
52				F-2, GF-3						
53				U-3						
54			GF-2							

[a] Level 1 only special in relation to overall ability; Level 2 is special in comparison to other individuals of a similar age and Level 3 would be considered exceptional in the normal population.

[b]B=Brother; S= Sister; M=Mother; F=Father; C=Cousin; U=Uncle; GF=Grandfather; GM=Grandmother

Appendix 5.7
The area of tertiary study undertaken by immediate family of savant.

	Mother	Father	Sister	Brother
N	38	38	26	23
Area of further study				
Economics		2		
Mathematics / Accountancy	4	1		2
Architecture		1		
Nursing	3		1	
Business	1		2	2
Physics	1	1		
Art	1	1	1	
Teaching	2	1	1	
Engineering / Electronics		7	1	1
Lawyer		1	1	
English /Editor /Writer	2			
Medicine	1	1		
College (Unspecified)	1	2	5	1
Science		1		
Psychology / Social Science	2	1		
Music	1		1	
PhD (unspecified)	1	1		
Languages	1		2	
Drama			1	
Still in school			2	10
No further education	17	17	2	5

Appendix 5.8

Reasons attributed by parents for the cause of their child's disability.

Reason attributed			Frequency
Pregnancy	a) Environmental	drugs (e.g. smoking, alcohol)	5
		virus / rubella	2
		fall during pregnancy	1
		paint fumes	1
		stress / lifting	6
		nuclear "fall out"	1
		rash	1
	b) Physiological	constant contractions	1
		thyroid problems	3
Genetics		autistic characteristics in relatives / schizophrenia	9
		other	1
Difficulties at birth		non-expanded lungs	1
		premature (appearance)	1
		brain haemorrhage	1

Appendix 5.9

<u>Reasons why the child was suspected to be of above average intelligence.</u>

Skill Observed	Frequency
Music	9
Hyperlexia	8
Mechanical Skill / Spatial Abilities	5
Art	1
Calendar Calculation	1
Memory	2
Hyperactivity	1
Acute sensory perception	1
Pronunciation of words	1
Child not considered at any stage to be above average	10

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