MEMORY IN THE CALENDAR CALCULATING SAVANT

By

Lisa Jane Heavey

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Goldsmiths College
University of London

ABSTRACT

The phenomenon of the *idiot-savant* represents an intriguing paradox. Such individuals function at a low level of general mental ability yet they show outstanding talents in a particular area. Comparatively little, however, is understood about the cognitive processes which underlie such talents. The present series of experiments investigated the unusual skill of calendar calculation. Savant calculators can provide with speed the day of the week of a given date. Many researchers have previously suggested that the skill depends on extensive practice and the rote memorisation of the calendar, although this has never been studied systematically. In the present series of studies, the memory ability underlying savant date calculation was investigated with a group of 10 calendrical calculators, most of whom have a diagnosis of autism. The following conclusions were reached. First, the savants exhibit a highly efficient, talent-specific memory ability. In comparison to age, verbal IQ and diagnosis matched controls, the savants recalled more calendar-related items. However, the groups did not differ in their short- or long-term recall of more general items, unrelated to the calendar. Second, although the savants' calendar-specific memory ability can operate independently of the calculation process, it is maximally effective when the calculation component is involved. Dates which were calculated were more memorable for the savants when compared to studied dates. Finally, several studies revealed that the domain-specific knowledge base, suggested to underlie calculation, is organized according to the principles of calendar regularity. To account for the present findings, a distinction is drawn between two sources of talent-related knowledge; implicitly activated, calendrically structured knowledge and consciously accessible, event-related information.

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CHAPTER ONE

INTRODUCTION: AN OVERVIEW OF SAVANT RESEARCH

Definition

We continue to be fascinated by the phenomenon of the idiot-savant. Since Langdon-Down's (1887) original description of the condition, savants remain an intriguing and, as yet, unexplained enigma. The term idiot-savant is taken to refer to a mentally handicapped individual who shows an outstanding area of talent and ability. The extent of this ability contrasts markedly with the individual's low level of general mental functioning. In actual fact, the term idiot-savant denotes the paradox between superiority and deficiency which coexists within the same individual. The word "idiot" represents a previously used clinical classification denoting an IQ of 25 or below. "Savant" derives from the French word *savoir*, meaning "to know". The term idiot-savant is now regarded as unsatisfactory for a number of reasons. The first relates to the rather negative connotations carried by the term "idiot". The second relates to the fact that most talented mentally handicapped individuals have an IQ of *above* 25, rendering the label "idiot" a misnomer. Alternative, more acceptable labels for the phenomenon include "savant", "Savant Syndrome" and "monosavant" (Charness, Clifton and MacDonald, 1988).

For over one hundred years such talented, mentally handicapped individuals have been the subject of theoretical speculation, but very rarely the subject of systematic experimental investigation. The majority of publications on savant syndrome are descriptive single case studies. These publications usually begin with a detailed case history of the subject and then proceed to merely *describe* the talent, rather than attempt to *explain* it. In addition, the literature on savants is replete with rather uninformative review articles. Most of these can be regarded as uninformative because they choose to review the same single case studies which contributed very little to our understanding of the phenomenon in the first place. Prior to the mid-1980's, savant research was most definitely in need of well-controlled experimental investigations which addressed specific questions in order to explore the cognitive processes underlying the abilities.

In the present chapter, the following aspects of savant research will be reviewed. First, general information relating to the prevalence of savant ability, the relationship between talent, diagnosis and gender, and the theoretical explanations of savant syndrome will be discussed. This will be followed by a summary of the relevant studies relating to the separate areas of savant ability. Importantly, an emphasis will be placed on those studies adopting a systematic experimental approach. Finally, an attempt will be made to explore the relevance of more general areas of research to our understanding of savants. These include theories of intelligence and expertise. Arguably, the vast majority of publications on savants stand at fault for failing to integrate findings within more generalised areas of psychological study, thus failing to convey the importance of savant research.

Rate of incidence. There are two studies, widely cited in the literature, which have attempted to establish the rate of incidence of savant syndrome. Hill (1977) surveyed 300 residential facilities in the United States and received replies from 111 of these centres, serving approximately 90,000 mentally handicapped individuals. From this population, 54 individuals were identified as savants. Thus, Hill estimated a rate of 0.06%, or one in every 2,000 mentally handicapped residents. In the second study, Rimland (1978) administered detailed questionnaires to the parents of 5,400 autistic children. Included in the questionnaires were items relating to any "special abilities" the child may display. From parents' replies, 531 cases (9.8%) were judged to be sufficiently outstanding to warrant the savant classification. Thus, Rimland's estimate of approximately 10% of the autistic population differs markedly from Hill's estimate.

A number of points can be raised regarding the discrepancy between these two estimates. First, Rimland used the reports of parents, Hill sought the help of the residential centre staff. It may be suggested that parents are less likely to be objective when reporting the achievements of their child, and may even exaggerate. For this reason, Rimland's figure of 10% may be a slight overestimate. Similarly, the low response rate obtained in Hill's study may indicate that 0.06% is an underestimate. Furthermore, neither study obtained objective verification of the individual's ability, relying solely on others' reports. Thus, we can conclude that these studies are far from reliable as measures of the true incidence rate of savant ability. However, the key point to note relates to the difference in frequency of savant ability according to the diagnosis of the sample. Hill's survey sample comprised individuals of differing diagnoses. Rimland used a solely autistic sample. Thus, it would appear that special abilities are markedly more prevalent among the autistic population. This important link between autism and special ability will be discussed in more detail later in the present chapter.

Savant talent and gender. In a review of the savant literature, Hill (1978) noted the marked relationship between the sex of the individual and the development of a special skill. He reviewed 63 publications and noted that of the 105 individuals classified as savants, 89 were male and 14 were female. No determination of gender could be made for the remaining two cases. This results in a 6:1 male:female ratio. From the questionnaire data referred to above, Rimland noted a much less marked male:female ratio of 3.54:1. Again, this discrepancy between estimates may result from a difference in the diagnoses of the individuals concerned. Autism is a disorder which affects predominantly males. We would therefore expect an inflated male:female ratio among Rimland's group of autistic savants. Indeed, the male:female ratio in Rimland's base population was 3.16:1 which is only slightly below the 3.54:1 ratio he reports in the savant sample. However, Hill's estimate would seem to suggest that there is a much more marked relationship between talent and gender which extends beyond that found in a solely autistic sample. The link between gender and savant ability, to date, remains unexplained.

Classifications of savant skill. Treffert (1988, 1989) has suggested that savants can be classified into two groups according to the level of their ability. *Talented* savants are those individuals whose skills are remarkable given their low level of intellectual functioning. *Prodigious* savants show an ability which would be viewed as outstanding even if it were to occur in individuals of average intelligence. Treffert estimates that fewer than 100 documented cases would fall into this latter category.

Theoretical Explanations of Savant Syndrome

Summarising across most of the existing review articles, it is possible to group the various accounts of savant syndrome into a number of general theoretical explanations. One of the earliest hypotheses suggested that savants skills were *genetically determined*; the mental handicap of the savant restricted the development of an individual who otherwise would have become a genius in the area of ability. In a frequently cited paper, Rife and Snyder (1931) suggested that savants were individuals who had received two sets of hereditary factors purely by coincidence, "those for feeble-mindedness and those for special ability". Although Treffert (1989) states that hereditary factors are seen in some cases of savant talent, it is not clear how he supports this assertion. An observation of the tendency of savant skills to run in families, for example Rimland (1988), would not seem adequate support. The incidence of an ability in the child of a similarly talented parent could still be accounted for by an environmental explanation. For example, a musical savant with musician parents would have been exposed to the relevant stimuli from a very early age, musical instruments would have been available, appropriate instruction together with encouragement may have been provided. Thus, without a study that controls specifically for the role of genetics and the environment in the development of talent, hereditary factors cannot be regarded as an explanation of savant ability.

Sensory deprivation and *social isolation* have also been suggested as possible explanations for savant syndrome (e.g. Nurcombe and Parker, 1964; Hoffman, 1971). Sensory deprivation could be taken to result from physical handicap such as deafness or blindness, or as a result of the individual being placed in a sensorily and socially unstimulating environment (Treffert, 1988). Due to the restricted range of sensory input, the individual concentrates on very narrow and specific activities. This may lead to the development of bizarre or trivial preoccupations and rituals such as memorizing obscure facts. This particular explanation was popular during the 1960's and 1970's when most mentally handicapped individuals were institutionalized. There are however a number of problems with this hypothesis. First, most mentally handicapped individuals do not reside in sensorily deprived environments. Rather, they attend training centres and facilities which aim to provide a range of stimulating and engaging activities. Second, social isolation and the tendency to focus on a restricted, repetitive interest may simply be a feature of the individual's diagnosis rather than a *cause* of savant talent. Social difficulties and repetitive behaviours are of course characteristics of autism. The third point relates to the fact that most individuals who are sensorily deprived (i.e. through blindness or deafness) or have a diagnosis of autism do *not* develop savant talents. Thus, sensory deprivation and social isolation may be features that occasionally characterise the talented individual, and may even predispose towards the development of savant ability (O'Connor and Hermelin, 1991), but they are not sufficient to *explain* it.

The use of *eidetic imagery* or outstanding visual image memory can also be rejected as an explanation of savant syndrome. In her doctoral thesis, Duckett (1976) compared a group of 25 savants with 25 control subjects matched on age, sex, diagnosis and length of institutionalization. She found that none of the savants displayed visual image memory and only one savant showed any evidence of eidetic imagery. Both Hill (1978) and Howe and Smith (1988) tested their calendar calculating subjects for the presence of eidetic imagery and found no evidence to support this interpretation of performance. Finally, Rubin and Monaghan's (1965) study of a congenitally blind calendrical calculator effectively rules out eidetic imagery as a universal explanation of savant ability.

Cerebral lateralization and savant ability. It has been noted by several authors (Rimland, 1988; Treffert, 1989; Tanguay, 1973) that savant skills are generally associated with right brain function. Musical, artistic and arithmetical skills are typically regarded as right hemisphere abilities. Thus, several researchers have suggested an explanation of savant syndrome relating to right brain specialization. For example, Brink (1980) described the case of a nine year old boy whose development had been normal prior to a gunshot wound to the left hemisphere. The injury left him deaf, mute and paralysed on the right side. Following the injury the boy developed an outstanding mechanical skill, including superior design and constructional abilities. Brink accounted for this finding in terms of left brain damage with compensatory development of the right hemisphere. Also, Dorman (1991) presented the case of an 18 year old male (with a verbal IQ of 81 and a performance IQ of 81) who began to calendar calculate following a left hemispherectomy at the age of 8 years.

Treffert (1988; 1989) enthuses about the contribution of Geschwind and Galaburda's (1987) findings to our understanding of the biological basis of savant syndrome. From a range of animal and human studies, Geschwind and Galaburda noted that the left hemisphere normally develops later than the right hemisphere and is therefore subjected to prenatal influences for a longer period of time. One of these influences is a male-related factor, possibly circulating testosterone, which can slow growth and impair neuronal migration and assembly in the more vulnerable left brain. In turn, this may result in an actual enlargement and shift of dominance to the right brain which consequently may favour talents associated with right hemisphere skills. An explanation in terms of hormonal effects on brain structure could account for the suggested predominance of males with savant skills. However, this interpretation remains speculative and as yet unsubstantiated with regard to savant ability.

For a number of reasons, this frequently stated relationship between savant skills and right hemisphere functions may be an oversimplification. First, although rare, there are examples of savants displaying outstanding language-related abilities. Christopher, the savant studied by Smith and Tsimpli (1995), has an extraordinary capacity for second language learning. Similarly, Dowker, Hermelin and Pring (1996) presented the case of Sue, a young female with a suggested diagnosis of Asperger's Syndrome, who was able to produce creative and emotive poetry. Second, whilst a savant talent such as musical ability may generally be regarded as right brain function, a closer examination of the individual components of the talent may give rise to a more complicated picture. For example, all of the musical savants studied by Miller (1989) were observed to have absolute pitch. The ability to recognise and label a single note may well subserve their ability to reproduce entire musical pieces by ear. However, research by Schlauger (1995) has recently linked absolute pitch with structural changes in the left hemisphere. Thus, certain components of an outstanding ability generally regarded as right hemisphere function, may actually be linked to left hemispheric processing. A final objection to the link between savant skills and right brain function relates to isolated cases in the literature which offer a conflicting interpretation of findings. In the single case study of Burling, Sappington and Mead (1983), their mentally handicapped, right handed subject was required to answer questions about the day of the week of 16 different dates. It was noted that 15 of these questions were accompanied by lateral eye movements to the right. The authors interpret this finding as support for left hemisphere specialization of calendar calculation. Of course, these findings are specific to this one subject and have not been replicated with other savant calculators. Thus, it may be that the degree of hemispheric specialization is specific to the individual subject and may also depend on the strategy by which the subject performs his skills.

To summarise, the link between savant talent and cerebral lateralization may be more complex than was previously assumed. Lateralization may be specific to the individual subject, to the respective talent, even to the individual cognitive processes which subserve the skill.

Conclusion. With regard to the various theoretical explanations reviewed, it would appear that there is no single, universal hypothesis which would explain savant syndrome in all cases. Perhaps it would be rather simplistic to assume that a single underlying etiology could account for the variety of talents observed amongst the mentally handicapped population. Arguably, a much more informative approach to the study of savants is to concentrate on each of the talents ***individually***.

Areas of Savant Talent

Treffert (1989) lists the range of savant talents as follows:

1) Calendar calculation (the ability to supply with speed the day of the week of a given date)
2) Musical ability (confined largely to the piano)
3) Artistic ability (drawing, painting, sculpting)
4) Lightning calculation (feats of mental arithmetic)
5) Outstanding memory performance
6) Mechanical skills (model construction, design ability)
7) Miscellaneous (including extrasensory perception, fine sensory discrimination)

Absent from this list, are the rare examples of savant language-related abilities. Investigations of such cases include Smith and Tsimpli (1995), Dowker, Hermelin and Pring (1996) and O'Connor and Hermelin's (1994) study of two autistic savant readers.

The two introductory chapters of the thesis will be concerned with the first five of the above talents. Calendar calculation, which is the subject of the thesis, will be discussed at length in Chapter 2, together with a review of the relevant literature from general cognitive psychology. Research concerning savant musical, artistic, mental calculation and memory skills is judged to be highly relevant to the current thesis and is reviewed in some detail within the present chapter.

Methodology. Before reviewing the key studies pertaining to the different savant abilities, it is important to note the methodological contribution made by two particular researchers. Beate Hermelin and Neil O'Connor were really the first investigators to introduce a tightly controlled, systematic approach to the study of savants. A number of features are notable about their experimental design. First, many of their studies involved groups of at least six savants. This represented a marked departure from the single case studies which dominate the literature. Second, Hermelin and O'Connor chose to study groups of savants sharing the *same* talent. Although a very small number of existing studies have examined groups of savants (e.g. Duckett, 1976; Spitz and LaFontaine, 1973), these groups consisted of individuals demonstrating a variety of different talents. The approach taken by Hermelin and O'Connor permits the identification and exploration of the cognitive processes common amongst similarly gifted savants; cognitive processes which can thus be judged to subserve the specific skill. This approach also reflects that adopted generally in the normal population when individuals are studied according to the specific ability they possess, for example Smith's (1983) work on the great mental calculators. Third, O'Connor and Hermelin made effective use of control groups. Studies would often include a subject group matched to the savants on the basis of talent but not intelligence, and another group would be matched on IQ and diagnosis, but not talent. Thus, any difference between savant experimental performance and that of the other groups could be attributed to the effect of either talent or intelligence.

Musical ability

A study by Charness, Clifton and MacDonald (1988) investigated the musical ability of a severely mentally handicapped, blind, right hemiplegic male. The subject, J.L. was reported to be a highly skilled keyboard player capable of transposing a piece to a different key, transposing notes or chords to different octaves and engaging in jazz improvisation. J.L. also exhibited absolute pitch. Charness et al. began by studying J.L.'s recall of melody. They discovered that he was clearly sensitive to musical structure. His recall of musical sequences was enhanced for structured patterns when compared to more random arrangements of notes. Structured sequences are described by Charness et al. as a hierarchical set of patterns which comprises lower level configurations of 3 or 4 notes which are then repeated on each element of a higher order sequence. Within this experiment, J.L. was also shown to be sensitive to temporal grouping. When pauses were introduced between the groups of notes within a structured sequence, this served to enhance J.L.'s levels of recall. A further experiment with J.L. examined his ability to recall and reproduce chords. The authors presented a series of conventional and unconventional chords. The conventional group of stimuli included major and minor, dominant seventh and supertonic seventh chords. Unconventional chords were created by altering any nonduplicated note of a chord by a semitone, with the result sounding dissonant to a Western listener. Results revealed that J.L.'s recall was superior for the conventional when compared to unconventional chords. The authors interpret this to suggest that conventional chords may be more extensively represented in long-term memory (LTM) and thus can be recalled as a whole. However, the unconventional chords may well have been recalled as a series of unrelated notes. The authors report that J.L. is clearly sensitive to tonal features such as scale, and temporal features such as rhythmic grouping. His representation of musical structure is thus similar to that of normal skilled musicians. They conclude that intense practice, together with an intact neurological substrate for coding a musical symbol system are sufficient to explain J.L.'s performance.

The above findings of Charness et al. are representative of the recent, experimental investigations of savant musical ability. This research can be summarised as follows. Music has a pattern and structure. The perception of, and memory for, music as well as improvisation and composition is dependent on the way in which such musical patterns and structures are internally represented. Savant musicians are shown to be able to access and use such a representational system of relevant musical rules, comparable with that of normal, skilled musicians. Thus, a high, or at least average level of general intelligence is not essential for extracting, remembering and using familiar, rule-based musical structures. Furthermore, rather than being deliberately or consciously acquired, this knowledge may be the result of continuous exposure and practice.

In a series of experiments, Hermelin and O'Connor investigated the reproductive and generative capacities of a number of musical savants. An early study examined the reproduction from memory of tonal and atonal musical pieces by a savant musician (Sloboda, Hermelin and O'Connor, 1985). The savant, N.P. was autistic, sighted, and had a WAIS verbal IQ of 62 and a performance IQ of 60. N.P. was reported to have a wide repertoire of classical piano pieces and to be able to learn a new sonata-length piece after three or four hearings. His performance was compared to that of a professional pianist of at least average intelligence, who was broadly comparable with N.P. in terms of age and length of piano playing experience. The two piano pieces presented for reproduction from memory were Op. 47 no. 3, from Grieg's Lyric Pieces and an extract from Book 5 of Bartok's Mikrokosmos. The tonal composition by Grieg is characterized by conventional diatonic harmony. The Bartok piece is mildly atonal due to the exclusive use of whole tone scales. The results revealed that with the tonal piece, the control's error rate was ten times that of N.P. even though the control subject had attempted to reproduce from memory only half as much material as N.P. However, the pattern of performance was reversed for the atonal extract. N.P.'s error rate for reproducing the piece was four times that of the controls subject. Based on this analysis the authors concluded that N.P.'s musical ability is structurally based, and thus, akin to the ability of high IQ musical prodigies. As support, they cite the fact that N.P.'s errors were overwhelmingly structure preserving for the tonal piece. As he appeared to code the music in terms of tonal relations, his ability did not transfer to an atonal piece. Following very closely the procedure of the Sloboda et al. (1985) study, Young and Nettelbeck (1995) performed a single case study with a musically gifted 12 year old autistic boy. Their conclusions were consistent with those of Sloboda et al., suggesting that the savant's memory for music is well organized and structurally based, consistent with that of a pianist with normal IQ. However, Young and Nettelbeck's subject differs from most other musical savants reported in the literature in that he has a full scale IQ of 100 and has received formal musical training from an early age.

Further studies (Hermelin, O'Connor and Lee, 1987; Hermelin, O'Connor, Lee and Treffert, 1989) were concerned with the generative abilities of savants; specifically improvisation and composition. As distinct from composition, for which the ideas themselves have to be produced, improvisation requires the invention of new musical sequences which may vary and change the given model but must take into account the basic characteristics of the original musical piece. The 1987 study investigated the generative capacity of five musically gifted savants. Three of these subjects were blind and both sighted savants were autistic. The verbal IQ's of the group ranged from 50 to 69. Their performance was compared to that of a control group comprising six normal children who had all received musical tuition for at least two years. A number of tasks were administered which included the continuation of a tune, invention of phrase or tune and the improvisation in jazz or contemporary idiom. Results revealed that the savants were superior to the normal children both in terms of their musical inventiveness and musical competence. Their inventions were judged to show a better sense of timing, better balance and more complexity. Hermelin, O'Connor, Lee and Treffert's (1989) study represents a further investigation of savant improvisational skill. This involved two subjects; a blind male with atonic diplegia who has an IQ of 40, and a professional musician who acted as a control. Following from the Sloboda et al. (1985) study described above, the same tonal and atonal musical pieces were presented. The subjects were then asked to improvise on the basis of the music rather than reproduce it. An analysis of their performance revealed that for the tonal piece, there was a greater richness and freedom in the playing of the savant compared with the control. For example, the savant incorporated a greater number of transitions and true cadenzas. However, he returned to the central theme of the piece as frequently as the control. For the Bartok piece, the performance of both musicians stayed much closer to the original piece, remaining in the whole tone scale for 90 percent of the time. The results of these studies were interpreted as support for the savants' access and use of representational systems of relevant musical structures and rules, comparable with that of normal musicians.

The outstanding research of Miller (1989) on musical savants supports the findings of the studies described above. For example, in a 1987 study he investigated a five year old savant's sensitivity to tonal structure. The subject who had received no formal musical training was asked to repeat passages on the piano. His performance did not represent a literal nonselective repetition of all notes heard. Rather, notes usually given a central role in melody and scale definition were reported much more accurately. The young savant's performance was reported to show impressive sensitivity to the rules governing composition, particularly the role of different notes in determining (diatonic) key structure. Miller's (1995) latest work with musical savants investigated their processing of musical cadence. Cadential patterns are most commonly expressed in terms of different chord progressions that provide a harmonic context for the development of melody. Importantly, certain fundamental cadential patterns are suggested to underlie the structure of musical composition within Western "classical" music. Thus, sensitivity to musical cadence would suggest an appreciation of musical structure. Within this study, a group of eight musical savants and eight control subjects were required to replicate a series of chord sequences of varying length and musical structure. It was found that there was no difference between groups in terms of their ability to reproduce the chord sequences. However, the recall of both groups was enhanced for the more structured sequences in which chords were linked according to conventional cadence, when compared to the random sequence of unrelated chords. Miller goes on to speculate about the link between musical savant skill and general cognitive capacity. Although comprehensive data on subjects' IQ's was not available, he notes that neither digit span or vocabulary scores were predictive of the savants' performance on the chord recall task. All of the subjects, regardless of their level of functioning, showed the effects of structure in their recall performance.

Conclusion. Both reproductive and generative savant musical ability is judged to be based on a system of mental representation which reflects the rule-governed structure of music. Furthermore, this system of structured representation is comparable with that of normal IQ musicians. In the absence of explicit musical instruction or deliberate, conscious acquisition, such an ability is believed to develop from exposure and practice.

Artistic ability

The most famous account of savant artistic talent is Selfe's (1977) study of Nadia. This excellent though largely descriptive book details the outstanding skills of a young autistic girl, capable of producing drawings of the highest artistic quality. Arguably, however, the most significant contribution to our understanding of savant artistic ability is the work of O'Connor and Hermelin, research which is now continued by Pring and Hermelin. Through the use of appropriate control groups matched on talent and intelligence levels, a greater understanding of the cognitive and motor components of savant graphic ability have been achieved. The findings of this series of studies, involving a group of eight savants, are summarised below. As described in the summary, the talented control group comprised normal children matched with the savants on non-verbal mental age. These children were judged to fall into the top two percent of their school in terms of their artistic ability. The IQ matched control group comprised individuals with the same diagnosis and comparable non-verbal IQ as the savants.

Savant artistic ability: Summary of the research of Hermelin, O'Connor and Pring.

Visual and graphic abilities (O'Connor and Hermelin, 1987)

Savants were superior to IQ matched controls on:

1) the ability to copy Rey-Osterrieth figures

2) the ability to reproduce from memory line drawings of objects and of non-representational, scrambled figures

3) the identification of incomplete, degraded pictures taken from the Peabody Picture Vocabulary Test.

There was no group difference between savants and IQ matched controls on:

1) the reproduction of Rey-Osterrieth figures from short-term memory

2) paired associate learning for Persian letters (requiring no graphic component).

Visual memory and motor programmes (O'Connor and Hermelin, 1987)

1) no difference between savants and IQ matched controls for the recognition and matching of abstract geometrical shapes

2) talented controls significantly better than savants on the recognition and matching of these abstract figures

3) savants superior to IQ matched controls and equivalent to the talent matched controls when required to copy or reproduce these abstract shapes from memory.

The recognition failure and graphic success of idiot-savant artists (O'Connor and Hermelin, 1990)

Visual-visual recognition memory. No difference between IQ matched controls and savants on same/different judgment tasks for abstract line drawings.

Talent matched controls were better than savants on the same task.

Visual-kinaesthetic matching task. Subjects were required to judge whether a visual presentation of a common object was the same as another stimulus constructed of raised lines and available only for tactile inspection. The savants were significantly better than IQ matched controls. There was no difference between talented controls and savants on the same task.

Visual-kinaesthetic recognition memory. Same procedure as above task except that the tactile stimuli were presented after a 10 second delay. Same/different judgments were required. No difference between savants and IQ matched controls. Talented controls were superior to the savants on this task.

Reproduction from memory following visual presentation. This task used pictures of common objects. No difference between savants and talented controls. Savants were superior to the IQ matched controls.

Memory reproduction after tracing. Subjects were required to touch and trace the raised line representations of named common objects. Immediately after this, subjects drew the traced stimulus. There was no difference between the savants and talented controls. Savants were superior to the IQ matched controls.

Art and accuracy: The drawing ability of idiot-savants (Hermelin and O'Connor, 1990a)

Subjects were presented with a complex 3-D model of a configuration of toy animals, figures and objects. They were required to reproduce this from memory, copy directly from the model, directly from the model but assuming a different viewpoint, and from a photograph of the scene. Ratings of drawings were obtained. Talented controls were superior to the savants in terms of their accuracy levels. However, there was judged to be no difference between these two groups in terms of the artistic merit of their drawings.

Bottle, Tulip and Wineglass: Semantic and Structural Picture Processing by Savant Artists (Pring and Hermelin, 1993)

This study investigated whether the reproduction from memory of a series of pictures would be affected by semantic or structural similarities between the picture items. Results revealed that for both the savant group and the talented controls, target pictures were more memorable if they shared a conceptual rather than structural link with the other items. Thus, for both groups the semantic processing of visual information predominated over the processing of structural features. This was also confirmed using an encoding task which did not require any graphic output. Both groups sorted target pictures together with their conceptual match rather than with a structurally similar picture. Thus, semantic organization is suggested to play an integral part in the picture processing of both normal and mentally handicapped artists. Arguably, however, this experiment would have been strengthened by the inclusion of an IQ matched control group, particularly for the encoding task. A *difference* between savants and such a control group would have suggested that a conceptually determined picture processing tendency is independent of IQ and therefore related to talent. A failure to find a difference between these two groups would suggest that, even for subjects with general cognitive impairments, picture processing is influenced by semantic organization, independent of artistic talent.

Visual and motor functions in graphically gifted savants (Hermelin, Pring and Heavey, 1994)

There was no difference between savants and an IQ matched control group on their ability to draw between two existing lines forming either a curved track or a series of geometric shapes.

Savants were superior to the same control group on:

1) their ability to draw shapes viewed only as mirror images

2) the speed and accuracy at which they could guide a circular loop along a convoluted wire track

3) a further test of motor control which required subjects to insert a metal rod into holes of varying sizes without touching the side of the holes
4) the speed and accuracy at which they could assemble picture puzzles from memory.

Figure 1.1 below, represents a further attempt to summarise the above research, specifically in relation to talent and intelligence levels. From this summary, two general points can be made:

1) savants show an enhanced ability to process pictures of *common objects* and familiar items in comparison with IQ matched controls. This is indexed by superior visual-tactile matching, copying and reproducing from memory, rapid identification of incomplete pictures and the assembling of picture puzzles from memory. One possible interpretation of these findings relates to the mental representation of such items in long-term memory. In comparison to controls, savant artists may possess a richer, more detailed, highly accessible internal "image lexicon". This would permit the efficient extraction of the essential features of familiar items, thereby enhancing the subsequent identification, reconstitution and graphic reproduction of such designs.

2) With unfamiliar abstract line drawings (for which there would be no pre-existing representations in LTM), the superior ability of savants to process and retain such images is confined solely to tasks requiring motor output. Matching and recognition tasks, requiring no graphic response, appear to be dependent on level of intelligence. Thus, for the savants, graphic output programmes must provide increased access to the mental images of such abstract figures, which may fail to be retrieved on tasks which do not require drawing as the response output.

Tasks not requiring graphic output

IQ - dependent (unrelated to talent)	IQ - independent (talent-related)
Paired associate learning of Persian letters	Incomplete picture identification
Recognition and matching of abstract shapes/line drawings	Visual-tactile matching
Visual-tactile recognition memory	Visual-motor control tasks
	Assembly of picture puzzles from memory

Tasks requiring graphic output

IQ - dependent (unrelated to talent)	IQ - independent (related to talent)
Reproduction of Rey-Osterrieth figures from short-term memory	Copying Rey-Osterrieth figures
Tracing between existing lines	Reproduction from memory of objects and non-representational shapes
	Reproduction of common objects after tactile presentation
	Mirror drawing

Figure 1.1 Summary of the research on savant artists (studies by O'Connor, Hermelin, Pring and Heavey, 1987-1994).

Savant artistic talent and autism

The most recent study in this series of experiments (Pring, Hermelin and Heavey, 1995) chose to address a specific question: why are so many savant artists autistic? Within the sample of eight savants involved in the above studies, six were diagnosed as having autism with the remaining two subjects showing autistic tendencies. This relationship between autism and special talent is particularly relevant to the current thesis. Of the sample of 10 calendrical calculators involved in the present research, seven have a diagnosis of autism. The other three subjects show autistic features. Thus, there is a need to determine the aspects of cognitive processing, specific to autism, which would predispose towards the development of an ability such as art or calendar calculation. Before describing the findings of Pring, Hermelin and Heavey (1995), a brief description of autism is necessary.

Autism

Autism is a biologically based disorder, characterised by social and communicative deficits, together with repetitive behaviours and interests. The rate of incidence of the disorder is estimated by most studies to be between 4 and 10 cases per 10,000 live births. As stated previously, autism is a predominantly male disorder, affecting approximately three males for every one female (Steffenburg and Gillberg, 1986). Roughly three-quarters of individuals with autism have IQ's below 70. Although a specific etiology has yet to be established, the high rates of mental handicap and epilepsy among autistic individuals, strongly implicates brain damage. In addition, increasing emphasis is placed on the genetic basis of autism. For example, a recent twin study showed that 60% of monozygotic twins were concordant for autism compared with no dizygotic pairs (Bailey et al., 1995).

Unlike other conditions associated with mental handicap, such as Down's Syndrome, autism does not simply represent a delay in development. Rather, the disorder represents a *deviance* in development. For example, within the area of social impairment, children with autism may fail to show an interest in the existence and feelings of others, they may not engage in imitation or pretend play and they may fail to seek the comfort of others when in distress. Deficits in communication may include the limited use of gestures, abnormal eye contact and the stereotyped and repetitive use of speech. The restricted repertoire of activities and interests, which are highly characteristic of autism, may include preoccupations with particular objects and marked distress over trivial changes in the environment and personal routines.

Current psychological theories of autism

Since the pioneering work of Hermelin and O'Connor in the 1960's, there has been a growing interest in the nature of the cognitive deficit(s) suggested to underlie the behavioral features of autism. Would it be possible to account for the range of social and communicative impairments together with repetitive behaviours in terms of a single underlying psychological impairment? Alternatively, are the features which constitute the autistic syndrome explicable only in terms of several cognitive deficits? Outlined below are three of the most influential psychological theories of autism.

1) Theory of Mind Deficits

Many studies in the literature have shown that individuals with autism have difficulty in understanding the mental states of others. They are suggested to lack a "theory of mind" i.e. they are unable to attribute independent mental states to themselves and others in order to explain behaviour. This was famously illustrated by Baron-Cohen, Leslie and Frith (1985) using the Sally-Ann task. Successful performance on this task requires subjects to appreciate the false belief of a story character. In contrast to the control groups of Down's Syndrome and normal young children, 80% of the autistic children failed this task, basing their responses on current reality rather than the character's mistaken beliefs.

The mentalizing deficit theory has been successful in explaining many of the features of autism, particularly impairments in play, social interaction and verbal and non-verbal communication. For example, Happé (1994a) revealed how differences in the mentalizing ability of autistic individuals related closely to their communicative understanding of concepts such as white lie and double bluff. However, this theory does not convincingly account for other features of autism, such as repetitive behaviours, restricted interests, even savant abilities (Happé, 1994b). This has led researchers to propose additional or alternative psychological deficits.

2) Executive Function Deficits

Executive function is defined as the ability to maintain an appropriate problem-solving set for the attainment of a future goal. It includes behaviours such as planning, inhibition of prepotent but incorrect responses, set maintenance, organized search and the flexibility of thought and action (Ozonoff, Pennington and Rogers, 1991a). A number of studies in the literature have shown that individuals with autism experience difficulties on tasks measuring executive function (Ozonoff et al., 1991a; Ozonoff, Rogers and Pennington, 1991b; Hughes and Russell, 1993; Hughes, Russell and Robbins, 1994). Interestingly, Ozonoff et al. (1991b), in their investigation of individuals with Asperger Syndrome, found that even those subjects capable of solving mentalizing tasks still experienced problems on tests of executive function. In view of the rigid, inflexible, repetitive behaviour which characterises autism, an explanation in terms of executive function deficits may seem tenable. However, executive dysfunction is by no means specific to autism and is found in several other conditions, including attention deficit hyperactivity disorder (Pennington and Ozonoff, 1996). Thus, for this theory to convincingly account for the behaviours *specific* to autism, future research must establish which of the mental operations, encompassed within the umbrella term of executive function, differentiate between individuals with autism and those with other conditions.

3) Weak Central Coherence

In 1989, Frith introduced an impressive and comprehensive theory to account not only for the psychological deficits but also the *assets* observed amongst individuals with autism. Frith suggests that normal information processing is characterised by the tendency to integrate information at different levels, to interpret information in a global fashion. This enables us to derive meaning from diverse information and to take account of context. This facet of cognitive processing, *central coherence*, is suggested to be impaired in individuals with autism, resulting in a tendency to process information in a piecemeal rather than global way. Support for this theory has been derived from a number of sources. For example, Shah and Frith (1983) demonstrated the superiority of autistic children over both normal and learning disabled controls, on an embedded figures test. This involved locating a hidden figure (e.g. triangle) within a larger meaningful drawing (e.g. pram). The successful performance of the autistic group suggests a tendency to resist the "gestalt" of the larger figure in order to focus on the individual component parts. Similarly, Shah and Frith (1993) demonstrated that the superiority of autistic individuals on the block design test, from the Wechsler Intelligence Scales, derives from their ability to see parts over wholes within the given figures. Block designs require subjects to mentally decompose the designs into their logical units. The figure must then be reconstructed to form a whole, using cubes to represent the individual parts. Importantly, the block design test typically represents a peak within the intellectual profiles of individuals with autism. Shah and Frith's (1993) study showed that the autistic subjects were superior to both normal and mentally handicapped controls when the block designs were presented as wholes. However, when the designs were pre-segmented this superiority disappeared. Thus, the superiority of individuals with autism is suggested to be due to an ability to mentally segment the designs, thus resisting the predominance of the whole. Further support for this theory comes from early studies on the recall performance of autistic individuals (Hermelin and O'Connor, 1970; Frith, 1970a; 1970b). These studies showed that the presentation of related or structured lists of items facilitated the recall of both normal and mentally handicapped controls to a much greater extent than that of individuals with autism. For the autistic subjects, lists appeared to be processed as series of individual items, rather than as interrelated wholes. These findings are relevant to the present thesis and are discussed in more detail in Chapter 5. Finally, although this theory originally encompassed the findings relating to failure on false belief tasks, it is now acknowledged that an explanation in terms of *both* weak central coherence and mentalizing deficits is necessary to account for the full range of autistic features (Frith and Happé, 1994; Happé, 1994b).

Conclusion. Although there continues to be debate regarding the nature of the psychological deficit(s) in autism, our understanding of autistic cognitive processing has greatly increased over recent years. Due to the close link between autism and savant talent, this increased understanding of the disorder is fundamental to an insight into the nature of savant ability.

Returning to the Pring et al. (1995) study, this experiment aimed to investigate the relationship between savant artistic talent and autism. Relevant to this study are the following findings. First, the block design superiority of autistic individuals was shown to be due to an enhanced ability to mentally segment the designs into their constituent parts (Shah and Frith, 1993), thus serving as support for Frith's (1989) weak central coherence theory of autism. Second, gifted art students can solve a "hidden figure test" more efficiently than non-gifted controls (Getzels and Csikszentmihalyi, 1976). Third, savant artists with a diagnosis of autism, were faster to complete picture puzzles than their IQ matched autistic controls (Hermelin et al., 1994). Taken together, these findings suggest that a tendency towards segmentation may play a part not only in our understanding of autism, but may also be relevant to artistic talent. This interpretation may help to account for the high numbers of savant artists with autism.

Pring et al. (1995) investigated the ability to reconstruct puzzles in four subject groups; savant artists with autism, IQ matched autistic controls with no talent for drawing, artistically talented normal children and normal children judged not to show graphic ability. Two types of puzzles were presented for completion. The first involved pictures of scenes involving a famous storybook character. The other type of puzzle comprised non-representational figures based on the Wechsler block design test. Thus, unlike the first group of puzzles, this second group did not contain meaningful cues and could only be solved using a perceptually dominated strategy. Importantly, the results revealed that the talented groups were significantly faster at completing both types of puzzle than the non-talented groups. Thus, the facility for seeing wholes in terms of their constituent parts appears to be enhanced among those with an artistic talent. In addition, with the block design items, the autistic control subjects were faster than the normal, non-gifted controls. This experiment thus serves to replicate Shah and Frith's (1993) findings concerning the superior performance of individuals with autism on such non-representational designs. To summarise the Pring et al. findings; the facility for processing local elements of a global figure appears not only to characterise those with autism but also those with artistic talent. Weak central coherence may therefore be the facet of cognitive processing which predisposes individuals with autism to develop special abilities.

A similar idea had earlier been proposed by Mottron and Belleville (1993). Their subject, E.C., showed an outstanding talent for drawing. He was described as having high-level infantile autism. His full scale WAIS IQ was 88, with the highest scores achieved on block design and object assembly. Importantly, E.C.'s perceptual ability was reported to display a lack of hierarchical organization; specifically, in terms of processing information at the local and global levels. E.C. was presented with a series of hierarchical stimuli comprising a larger unit (global level) and smaller parts (local level) (Navon, 1977). The two levels may be congruent (e.g. a large letter C made of smaller c's) or incongruent (e.g. a large C made of smaller o's). Like the normal controls, E.C. displayed a global advantage, that is, he could detect the global level faster and more accurately than the local level. However, when presented with incongruent stimuli, E.C. made more errors at the global rather than the local level. This suggests that E.C., unlike the controls, showed an interference of local over global form level. An additional task showed that E.C. experienced difficulties in perceiving the geometrical "impossibility" of figures that are locally congruent but globally incongruent. Finally, an analysis of E.C.'s drawing style revealed that, in contrast to controls, E.C. did not draw the outline of a figure first. Rather, he attended to the individual features and details of the designs. In summary, E.C.'s perceptual abilities are suggested to show an absence of special status for the global level, together with an absence of interconnection between global and local information and between local parts. In addition, such a deficit in processing parts and wholes is suggested by the authors to underlie not only E.C.'s artistic ability but also many of the behavioral features observed in autism in general. This explanation in terms of a defect in global/local processing is clearly related to Frith's (1989) theory. However, these authors do not propose an impairment in global processing. Rather, they suggest that an *equivalent* status is given to the local and global elements of a figure (Mottron and Belleville, 1995).

The final study to be included in this summary of research on savant artists is that of Mottron and Belleville (1995). They investigated subject E.C.'s exceptional use of perspective. Not only was he able to draw objects rotated in three-dimensional space more accurately than trained controls, he was also superior to controls in being able to detect a perspective incongruency between an object and a landscape. Importantly, however, an analysis of E.C.'s experimental performance together with a sample of his free drawings revealed that he does not rely on any known perspective system of rules. This finding is again interpreted in terms of a "hierarchization defect". According to the authors, global perception is associated with high level cognitive processes. When drawing, high level processes may influence the individual to reproduce what he/she *knows* about the figure rather than what is directly available to visual perception. However, a defect in hierarchical organization may prevent such top-down processes from influencing low-level perceptual representations, thereby enabling an accurate reproduction of what is directly perceived. In this way, it would be easier for an autistic artist to draw what he sees, rather than what he knows.

Conclusion. Over the past 10 years, artistic ability has been the subject of some of the best experimental investigations into savant talent. For this reason, the area has been reviewed in some detail. From these studies, a number of conclusions emerge. First, savants are suggested to possess a superior picture/object "lexicon". They are able to access such LTM representations more speedily and efficiently than IQ matched controls. Second, such mental representations are organized according to the semantic relationships between objects and pictures. Third, research has indicated the important role played by motor output programmes in savant cognitive processing. In certain tasks, graphic output provided increased access to images retained in memory. Finally, research in this area has taken an important step towards accounting for the prevalence of autism amongst savant artists. Such investigations relate our increased knowledge of the psychological deficits of autism (specifically weak central coherence), to our developing understanding of the cognitive components of artistic talent. Whether this exciting hypothesis can be applied to the other savant talents is the subject of ongoing research (Pring and Hermelin) and is certainly relevant to the current thesis.

Numerical calculation

The ability of cognitively impaired individuals to perform outstanding feats of mental calculation, has long since been noted. Perhaps the earliest record of such an ability concerns the savant, Jeddidah Buxton, a mentally handicapped farmhand. Forestl (1989) quotes a publication from 1751, which describes Buxton as being able to multiply a 39 digit number by itself, accurately producing the 78 digit answer.

More recent investigations of savant numerical calculators have examined the ability to identify prime numbers. Sacks (1985) reports on the famous calculating twins, George and Charles, and describes their verbal exchanges of prime numbers, up to 20 digits in length. Although their accuracy was never verified for numbers of this length, they were found to be correct for 10 digit primes. Their memory for numbers was also shown to be remarkable. Sacks reports the ease with which they could repeat a series of 300 digits. Famously, the twins were able to identify in an instant the number of matches spilled on the floor: "111" they cried, "37...37...37". This suggests an immediate recognition of numerical quantity, followed by the factorization of the total sum. However, this appears to represent an isolated example of such a skill, as the literature contains no further accounts of similar incidents involving the twins. Amazingly, these numerical feats are reported to co-exist with an inability to perform simple addition, subtraction, multiplication and division[1].

To account for such a discrepancy in numerical ability, Sacks proposes the following explanation. The twins have access to "an immense mnemonic tapestry, a vast...landscape in which everything [numbers] could be seen, either isolated or in relation" (Sacks, p. 190). They are not calculators, they do not "operate" with numbers. Rather, their numeracy is "iconic", they see numbers directly as a vast natural scene.

White (1988) suggested a specific structure to the twins' mental representation of numbers. Their skill with prime numbers is suggested to derive from the representation of "number series" in LTM. White states that complex organized representations can be built on the simple relational properties of numbers. For example, an addition series generated by the rule "add 7" could produce "7, 14, 21, 28...". Once such a series is established as a route in LTM, it can be the subject of mental manipulation. For example, tracing the same route backwards would generate a "subtract 7" rule. In this way

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[1] Horwitz, Deming and Winter (1969) give a contradictory report of George's arithmetical skills, noting that he could add and subtract two digit numbers.

numbers are represented in LTM as items within an independent number series. As numbers can be members of various sequences, then the series can form "interpenetrating" or cross-secting classifications. The recognition of a prime number simply requires the knowledge that the number does not belong to an addition series other than "add 1" and "add (itself)". This offers an interesting conceptualisation of LTM representation which can be acquired through a process as simple as counting, and which does not require calculation per se in order to generate primes.

O'Connor and Hermelin have conducted several experimental investigations in this area. In their first study (Hermelin and O'Connor, 1990b), the authors explored the ability of an autistic individual (M.A.) to factorize numbers and to recognise and generate primes. His performance was compared to that of a control subject who held a degree in mathematics. The subjects were required to perform the following tasks: (1) factorize three, four and five digit numbers, (2) recognise prime numbers of the same three magnitudes from a list of non-primes, and (3) produce three, four and five digit primes between stated limits. Results revealed that not only did subjects make a similar number of errors, they tended to make mistakes on the same items. A further analysis of errors indicated that both subjects were using a similar strategy for the identification of primes; specifically, the elimination of numbers divisible by 3 and 11. However, while both subjects appeared to adopt the same rule-based strategy, the speeds at which they achieved their performance differed significantly. The savant was much faster than the control.

In an inventive follow-up study, Anderson, Hermelin and O'Connor were able to specify M.A.'s strategy for dealing with prime numbers (reported in Anderson, 1992). M.A. was required to identify a series of primes from three types of distractors; (1) easy non-primes (divisible by 2 and 5), (2) computable non-primes (divisible by 3, 7 and 11) and (3) difficult non-primes (divisible by 13, 17, 19 etc). His performance was compared to that of a computer, programmed to identify primes using two different strategies. The first was based on the rote memorisation of prime numbers. This approach would predict that prime numbers are easier to identify than non-primes. The second strategy was based on a process of calculation using the method discovered by Eratosthenes. This involves obtaining the square root of the target number and then dividing the number by all the prime numbers less than the square root. If the target is not divisible by any of these numbers then it is prime. Importantly, the use of this strategy would predict a very different pattern of results to the memorisation approach. Calculation of the numbers would mean that primes take much longer to identify than non-primes. A comparison of M.A.'s response times with those generated by the computerised simulations revealed that his performance mapped closely onto the calculation-based strategy. Thus, M.A.'s performance indicates the use of sophisticated mental operations in the form of calculation rules, comparable with those adopted by high IQ prodigies when calculating primes (Smith, 1983).

Numerical ability and knowledge representation

The ability of M.A. thus appears to contrast with that of the calculating twins, George and Charles. M.A.'s skill involves numerical calculation. Yet the arithmetical operations of addition and subtraction were allegedly beyond the capabilities of the twins. However, the ability of all three savants, like that of intellectually able mental calculators, must involve the high-level representation of numerical information in LTM; that is, the knowledge of, and familiarity with, the relationships between numbers and the structure of the number system. This may be in the form of many number series (White, 1988) or derived from exposure to more formal devices such as times tables. The great mental calculator, Wim Klein, was noted to have learned the multiplication table up to 100 x 100, not deliberately, but on the basis of repeated exposure. Such familiarity with number relationships and combinations would then allow ready access to this store of knowledge. For example, Klein states "It is logical if you know that 2,537 is 43 times 59 and you're doing a little show... and they ask you for 43 times 59, you recognise straight away 2,537" (Smith, 1983, p. 288). Such an interest in, and preoccupation with, numbers and their internal relationships is typical of many of the great mental calculators (Smith, 1983). The twins undoubtedly showed a preoccupation with numbers. Unfortunately, the extent of M.A.'s interest in numbers is not reported.

Another important point regarding savant numerical calculation relates to the conscious accessibility of such processes. The twins were unable to report their method for generating primes. The extent to which M.A.'s strategy rests on conscious/unconscious processes was not reported and would indeed be difficult to establish, given that he was completely non-verbal. Smith's (1983) account of Colburn, the calculating prodigy, is relevant. At the age of six, Colburn could rapidly find the factors of any number up to a million or more. However, he was quite unable to say how he did this. At the age of nine, he was reported to have woken in the middle of the night and announced to his father, "I can tell you how I find the factors". He was then able to state his methods, from which the rules governing Colburn's tables for identifying factors were derived. Thus, it would appear that conscious access to calculation rules may not be necessary for their effective use. This may help to account for why so many numerical calculators were child prodigies and why numerical ability can also be found in those of low intellectual status (Hermelin and O'Connor, 1990b).

Conclusion. Feats of savant numerical calculation, like those of the great mental calculators, are suggested to involve the use of a highly structured knowledge system. This is acquired from exposure to numerical information and a preoccupation with the properties of numbers. Conscious access to the rules which govern numerical operations and relationships is not always necessary for their effective use. Of course, high level numerical calculations involve mental computations and operations which extend beyond the retrieval of number relationships from LTM. Undoubtedly, however, the knowledge base which subserves mental calculation is characterised by the regularities and structures that exist within the number system. This is illustrated by the famous quote from Wim Klein, "Numbers are friends to me, more or less. It doesn't mean the same for you, does it, 3844? For you, it's just a three and an eight and four and a four. But I say, "Hi, 62, squared"' (Smith, 1983, p. 5).

Memory as a savant talent

Impressive feats of memorization are reported to be relatively common amongst savants (Howe, 1989). In Rimland's (1978) survey, memory skills were the most frequently reported savant ability after musical skills. Examples include the memorisation of TV programme credits after one exposure and the ability to recall routes taken as part of a journey. Such accounts are, of course, not uncommon among those with a diagnosis of autism. Thus, whether it is appropriate to describe these as savant skills is questionable. However, there are isolated cases described in the literature which undoubtedly deserve the label of *savant*. In a famous account, Jones (1926) describes the skills of a savant who knew the population figures for every town in the U.S.A. He could recite statistical information concerning 3,000 mountains and rivers and details of over 2,000 discoveries and inventions.

To date, there has been only one systematic experimental investigation of savant mnemonism. O'Connor and Hermelin (1990) explored the memory organization of a group of six autistic individuals with an impressive knowledge of local bus routes and timetables. The performance of the group on a paired associate learning task, together with their generation of items in response to novel bus number cues (i.e. lures) suggested that their pre-experimental memory for buses is structured, with individual buses categorised according to the garages in which they are housed. For example, subjects were better at learning pairs of buses from the same garage than bus pairs from different garages.

In the same paper, the authors compared the *general* memory performance of the savants (i.e. for material unrelated to bus numbers), with that of a control group matched on diagnosis, verbal and non-verbal IQ. The tests included face and object recognition tasks, tests derived from Wechsler's Memory Scale (1945) and a task requiring the reproduction from memory of an abstract design. The results revealed that on all of these general memory measures there was no difference between groups. This contrasted with findings relating to the above experiment, in which the savants were superior to controls at recalling bus numbers. Thus, in conclusion, savant mnemonists do not appear to possess a more efficient general memory ability. Rather, their memory superiority appears to be confined to their area of interest, which is shown to be organized according to the relationships between, and characteristics of, the familiar bus routes.

Overview of Savant Talent: The Importance of LTM Organization

Without doubt, our understanding of the mental processes which underlie the various savant abilities has made significant progress over the past 10 years. This research has served to indicate how these abilities depend on very different psychological and motor functions. For example, savant artistic ability was related to superior visual retention and motor output programmes, whereas numerical skills can involve the use of sophisticated mental operations in the form of calculation rules. The diverse nature of these talents is supported by the fact that savants rarely possess more than one of these abilities.

Despite this diversity, it is possible to establish an underlying theme which characterises all of the savant abilities reviewed in the present chapter. These abilities depend, in part, on access to structured representations in LTM. Savant musical knowledge was found to reflect the rule-governed structure of tonal music. Savant artists can access an efficient, semantically organized picture "lexicon". The knowledge base which subserves savant numerical calculation is structured according to the regularities and relationships which exist within the number system. Finally, when the outstanding ability is memory itself, knowledge is organized according to the features which characterise the specific area of interest, e.g. bus routes. This suggestion, i.e. that structured representations underlie savant talents, is central to the current thesis. Specifically, this suggestion will be explored with regard to date calculation.

The remainder of this present chapter is concerned with the research areas within general psychology which may contribute to our understanding of savant ability. Particularly relevant is our knowledge of *expertise* in the general population. For example, what can we learn from individuals of normal or superior intelligence who also demonstrate outstanding ability in a limited area? How well do the current environmental/practice theories of skill acquisition account for savant ability? Finally, no review would be complete without considering the relevance of savant syndrome to theories of intelligence and the modularity of function.

Savant ability and the study of expertise

Experts are individuals who possess a body of tightly-integrated, domain-specific knowledge about a defined area such as chess or physics. Furthermore, this considerable store of knowledge is suggested to be organized according to the regularities and patterns extracted from the domain itself. It has been suggested within the thesis that savant abilities are subserved by highly organized stores of knowledge. Thus, savants may be compared with experts (Garnham and Oakhill, 1994). Importantly, the study of expertise has illustrated the effect of a vast, organized knowledge store on the perceptual ability, memory and the problem-solving skills of experts, with any advantage in these areas shown to be confined to the domain of excellence. Can these developments in our understanding of expert knowledge be applied to savants?

<u>Expertise and memory performance: the importance of structured knowledge</u>

De Groot (1965; 1966), in his classic studies on chess expertise, found an important difference between masters and weaker players in terms of their STM performance. Masters showed a remarkable ability to reconstruct a chess position almost perfectly after viewing it for only five seconds. The weaker players had marked difficulty with this. However, when the chess pieces were arranged randomly on the board (i.e. not in a familiar configuration) both groups of players did equally badly. This indicates that the performance levels did not depend on any general differences in memory ability. Chase and Simon (1973) supported this finding, indicating that chess experts only have better memories for meaningful, structured information in their knowledge domain. Chase and Simon also showed that chess experts perceive board positions in terms of relations between groups of pieces. Whereas the novice had to memorise the position of each individual piece, the expert was able to organize information into perceptual chunks, in accordance with the relational patterns resulting from the attack and defence moves that occur in the game. Simon and Gilmartin (1973) supported the proposal of these previous studies; specifically, that *board position knowledge* was the key to explaining such expert-novice differences. They estimated that master-level performance required a LTM of between 10,000 and 100,000 patterns.

Similar findings also emerge from other knowledge domains, perhaps more comparable to those found amongst savant mnemonists. Spilich, Vesonder, Chiesi and Voss (1979) compared individuals with extensive knowledge of baseball with others who had little knowledge of the game. Subjects listened to an account of a baseball match lasting five minutes. Afterwards, the high- and low-knowledge individuals differed in the extent and type of information they recalled as well as the nature of the errors they made. Free-recall protocols of high-knowledge subjects showed that they recalled more of the actions which produced significant changes in the outcome of the game; they remembered more goal-related actions and these were integrated into sequences. Low-knowledge subjects recalled less information and made more errors in which they confused the players or confused different actions. For people who knew little about baseball, particularly about how certain actions related to winning the game, memorising the commentary was like learning nonsense material. Importantly, however, the memory superiority of the "experts" did not extend to material unrelated to baseball. According to the authors, the baseball "experts" possess an extensive knowledge system, organized according to the goal of winning the game. Thus, any baseball information could be mapped onto these knowledge structures, thereby promoting the comprehension and retention of such material. In a similar study, Morris, Tweedy and Gruneberg (1985) demonstrated that individuals with high levels of football knowledge were better able to recall real football scores than those with little knowledge about the sport. Importantly, this memory advantage did not extend to common words or to simulated football scores. This finding, along with those described above, serves to indicate how high levels of domain-specific knowledge facilitate the acquisition of novel information relating to the area of expertise.

It is important to consider the *nature* of the organization that exists within these expert knowledge bases. Relevant to the present thesis is the fact that the knowledge organization often reflects the regularities and structure that occur within the domain itself. Chess knowledge comprises the mental representations of chess configurations from real games. Baseball knowledge is structured according to the relationship between changes in the state of play and the goal of winning the game. Similarly, Akin (1982) showed how the knowledge bases of architects were organized hierarchically. The lowest levels comprised small scale details relating, for example, to doors and walls. At the higher levels, mental representations reflected whole floor and building plans.

In turn, such organization within areas of LTM has specific implications for memory performance. As has been noted in relation to experts, memory is only facilitated for material that is meaningful, i.e. it reflects the structure of the knowledge base. In addition to the present examples, Charness (1979) noted that the superior recall levels of expert bridge players extended only to real game card hands and not to random arrangements. Similarly, as McKeithen, Reitman, Rueter and Hirtle (1981) found, the recall of computer programmes was superior for expert when compared with novice programmers. However, when the order within the programmes was scrambled, there was no difference between the two groups. Thus, it would appear that the structure of the material has to map the structure of the domain-specific knowledge in order for recall to be enhanced. Many of the findings from the savant literature are consistent with this. The musicians were better able to recall tonal rather than atonal music. Artistically gifted savants were better able to recall semantically related rather than conceptually unrelated pictures. Savant mnemonists showed superior retention for buses housed at the same garage when compared to different garages. The corresponding research in relation to calendar calculation will be investigated within the present thesis.

Thus, to conclude, the study of expertise has explored how an extensively organized knowledge base can underlie restricted areas of skill and excellence. Importantly, the research has highlighted how differences in recall performance can be used to explore the structure of these knowledge systems.

<u>The development of expertise: the role of deliberate practice</u>

If we are to assume a fundamental similarity between expert knowledge representation and that of savants within their area of ability, then we need to consider the *acquisition* process of expert skill. In other words, will research relating to the development of expertise be informative about the acquisition of savant ability? According to Ericsson and his colleagues, this would certainly be the case.

In a highly influential paper Ericsson, Krampe and Tesch-Römer (1993) put forward a theoretical framework to explain expert performance. The central claim was as follows; the level of performance attained by an individual is directly related to the amount of **deliberate practice**. Deliberate practice is defined as a highly structured activity, the explicit goal of which is to improve performance. It requires effort and is not inherently enjoyable. Optimal levels of three factors are essential for practice to be effective. These are (1) **resources** (e.g. time, energy, materials, tuition required), (2) **motivation** to improve performance and (3) sustained **effort** whilst avoiding exhaustion/burnout.

Within this framework, a period of at least 10 years of practice is required to achieve an expert level of performance. The authors cite a wide range of studies as support, concerning chess grandmasters, musicians, writers and scientists amongst many examples. This decade of intense preparation leads to the acquisition of an extensive, well organized knowledge base. It also leads to changes in basic perceptual, memory and motor abilities within the domain of skill. For example, research has shown how experts can acquire cognitive skills enabling them to circumvent the limits of STM capacity. Such studies of skilled memory have shown how experts can rapidly access relevant information in an extended working memory that relies on organized storage in LTM (e.g. Chase and Ericsson, 1982).

Importantly, Ericsson et al. explain expert performance in terms of acquired characteristics. Thus, they reject any important role for innate talent and ability. Any heritable differences which may contribute to high-level performance are suggested to relate to differences in motivation, emotionality and general levels of activity, which in turn would influence an individual's capacity to engage in sustained practice. These views are very much in line with those of Howe (1991).

Ericsson et al. argue that the outstanding abilities of savants are entirely consistent with the above framework. Indeed, Ericsson and Faivre (1988) cite the existence of the savant as proof of the acquired nature of exceptional ability. The authors give the following points as support;

1) the exceptional ability of the mentally handicapped individual is generally only outstanding given their overall level of performance; it rarely surpasses the range displayed by normal experts

2) the cognitive processes of savants, as revealed by their verbal reports, appear indistinguishable from those of normal subjects who have been trained with the same skill.

A number of criticisms follow from these conclusions. First, Ericsson and Faivre do not really explain how the first of these points supports their theory. Presumably, because normal experts are considered to achieve their level of performance by practice, then the savants must achieve their level of performance by practice. With regard to the second point, the authors actually state that savants are able to *retrospectively* report their thoughts during the performance of a skill. This is at odds with most of the savant literature which suggests that savants are unable to provide any verbal insight regarding the performance of their abilities. Indeed, examples of savant introspection are very rare.

The main point of criticism, however, relates to Ericsson and Faivre's assumption concerning savant skill and training. Specifically, the authors assume that because normals can be trained to perform a skill, then this must reflect the way in which the savant acquires the skill. They cite an unpublished study by Addis and Parsons who trained a college student to calculate dates. He was required to memorise a method of adding integers corresponding to the century, year, month and date in order to derive the weekday. Thus, he was provided with explicit tuition of a pre-formulated method. However, it is highly unlikely that savants will have access to such a contrived method, or that they will be tutored and encouraged to learn in a comparable way. To the present authors knowledge, there is not one study in the whole of the literature that suggests savants are ever trained and actively encouraged to learn date calculation. In other words, this study tells us nothing of the acquisition of savant calendar knowledge and thus the conclusions of Ericsson and Faivre are highly presumptuous. It must be argued that even when the product of the skill is the same between trained normals and savants, it does not mean that the acquisition process was the same.

Conclusion. No-one would disagree with the views of Ericsson and his colleagues regarding the important role played by practice in the development of ability. However, the framework described above does not yet convincingly account for the acquisition of savant ability. Furthermore, in regard to date calculation, this theory does not even begin to explain *why* savants perform this skill, particularly in the absence of training and encouragement. Thus, rather than theories of expert performance proving insightful for savant talent, the reverse may be true. An increased understanding of the development of savant ability will provide a specific test of these influential environmental/practice explanations. The study of savants indicates the need for any such theory to account for *why* a skill develops, for the important relationship between cognitive processing style (diagnosis) and ability and importantly, how these skills can develop at such low levels of intelligence.

Savant Syndrome: Implications for Theories of Intelligence and Modularity

Central to the study of savants is the question of how such individuals can possess remarkable abilities but at the same time be of low measured intelligence. For this reason, savants are widely held to challenge our traditional views on the nature of intelligence, particularly the concept of "g" (Spearman, 1904). This refers to the general intelligence factor suggested to permeate and even constrain performance on a range of mental tasks. Surprisingly, however, few theories of intelligence attempt to account for the existence of savant syndrome. Howe (1989; 1991), Hermelin and O'Connor (1988) and Anderson (1992) are exceptions and their views on savant ability and intelligence are summarised below.

Howe (1989; 1991): The autonomy and independence of human skills

Howe argues against the concept of general intelligence and denies that "g" has any explanatory role in our understanding of exceptional ability. He suggests that human abilities are genuinely distinct and independent rather than centrally controlled by a general ability factor. The fact that intra-individual correlations in mental test performance are often observed is not due to "g", but to the tasks containing either shared elements or being affected by shared personal traits.

Howe cites the existence of the savant as vital support for this view. Indeed, savants are regarded as "extreme instances of the permissible autonomy and independent functioning of any person's distinct mental skills" (Howe, 1989, pp. 71). He argues that the discrepancies in mental functioning that characterise savants may in fact be found in individuals of all levels of intelligence. However, such discrepancies may be less marked in normals, due to their increased ability to transfer, generalise and apply their existing skills to new circumstances and different contexts.

Hermelin and O'Connor (1988): The independence of abilities and the importance of "g"

A different view of savant talent and intelligence is taken by Hermelin and O'Connor (1988). They suggest that savant abilities can be seen as separate modules of function, each subserved by their distinct and separable cognitive processes. They also believe that, on the whole, these abilities function in the savant at a level which is independent of general intellectual status. However, these authors suggest that the manifestation of the talent, the degree to which the ability will ever be truly realised, is constrained by general intelligence. Thus, it is unlikely, for example, that a savant will ever obtain the level of ability of Mozart or Picasso (Hermelin, O'Connor and Lee, 1987).

To reiterate, as opposed to Howe, these authors allow for the concept of "g" and assume an interaction between general intelligence and intelligence-independent abilities in explaining the savant. Relevant to this argument is Hermelin and O'Connor's (1986) study which found that the calculation spans of a group of eight calendrical calculators were correlated with their IQ's. Thus, the savants' ability with the calendar was far superior to their skills in other areas and could therefore be suggested as a separate module of function. However, *within* the module of function, calculation range appeared to be related to, even constrained by, IQ. Interestingly, Hermelin, Pring and Heavey (1994) found a negative correlation between non-verbal IQ and the artistic quality of the drawings of savant artists, when rated blind. Thus, the best artists were the least intelligent artists. This illustrates that the relationship between savant talent and IQ is complex, and appears to vary according to the nature of the savant ability. An explanation of this complex relationship is attempted within the following theory.

Anderson (1992): A cognitive theory of intelligence and development

In 1992 Anderson put forward the *minimal cognitive architecture* proposed to underlie intelligence and development. Importantly, this model attempted to accommodate the existence of the savant, allowing for the diverse nature of the different abilities. This minimal cognitive architecture comprised three crucial mechanisms;

1) Basic processing mechanism. Anderson proposes that the low-level cognitive processes which underlie intelligent thinking are located in the basic processing mechanism. This is the major component of intelligence and is responsible for the phenomenon of psychometric "g", as it varies in speed among individuals in the population. The basic processing mechanism is responsible for implementing and constraining thought processes which in turn generate knowledge. The following two mechanisms are responsible for acquiring knowledge;

2) Modules. The key feature of modules is that their computations are unconstrained by the speed of the basic processing mechanism and therefore show no individual differences. Anderson's definition of a module is based on that of Fodor (1983). Modules are regarded as independent input systems, which present central thought processes with representations of the current state of the world. Modules are domain-specific, fast, hard-wired, mandatory and informationally encapsulated. The processes which underlie thinking are very different from those that underlie modules; modules are essentially complex but "dumb" (reflexive) mechanisms. Like Fodor, Anderson proposes perception (both auditory and visual) and language (e.g. encoding of speech) as examples of candidate modules.

3) Specific processors. These are knowledge mechanisms that *are* constrained by the basic processing mechanism. They are unlike modules in two ways. First, they contribute to individual variations in cognitive abilities and second, they deal with idiosyncratic knowledge acquisition. Anderson proposes two specific processors; one which is implicated in the acquisition of verbal/propositional knowledge (SP1) and the second which is implicated in visuo-spatial knowledge acquisition (SP2). Anderson's central hypothesis is that when we think, we are implementing a problem-solving algorithm generated by a specific processor. It is this implementation which is constrained by the speed of the basic processing mechanism.

Anderson argues that savant abilities represent cases in which generalised brain damage has selectively spared just one of the three crucial mechanisms. For example, he suggests that calendar calculation is based on a particularly powerful specific processor, most probably SP2. Thus, when so motivated, these individuals can generate a powerful code of such elegance and efficiency that it can be implemented even on a slow basic processing mechanism. Thus the suggestion that the ability involves cognitive processes which are constrained by "g", fits with the results of Hermelin and O'Connor (1986) showing a correlation between IQ and calculation range. The suggestion that calendar calculation is not based on the function of a spared module would also seem appropriate. Indeed, it would be difficult to imagine that we are in any way hard-wired to calculate dates. Savant abilities in the areas of art and music, would presumably be based on the spared function of a module, which is unconstrained by the basic processing mechanism. Again, this would account for the negative correlation between artistic talent and IQ as reported earlier (Hermelin et al., 1994).

<u>Conclusion.</u> It would appear that any convincing explanation of savant syndrome would need to allow for both the concept of general intelligence and for intelligence independent abilities. Moreover, such a theory needs to acknowledge that the role played by intelligence in the manifestation of savant ability *varies* according to the nature of the specific ability. Anderson's (1992) theory represents an impressive attempt to incorporate these points. However, it remains to be shown whether the cognitive mechanisms which underlie savant date calculation can best be regarded as "powerful codes" or "problem-

solving algorithms", as Anderson proposes. Relevant hypotheses regarding the cognitive basis of calendar calculation will be discussed in the following chapter.

CHAPTER TWO

CALENDAR CALCULATION AND MEMORY

CALENDAR CALCULATION

Definition

Calendar calculation refers to the ability to supply with speed the day of the week in response to a given date. Questions usually take the form of "What day was the 24th July 1968?" although some savants are able to give answers to "What was the date of the first Wednesday in July 1968?". Calculation spans can range from as little as one year, through to the more amazing 40,000 year range of the calculating twin George (Sacks, 1985, as reported in Chapter 1). It should be noted that the term calendar *calculation* is used somewhat for convenience. There is no assumption, at this stage, that the savant is "calculating" in a conventional sense.

Calendar calculation is arguably the most obscure of the savant talents and, unlike the other savant abilities, is rarely found amongst the general population. However, two groups of individuals represent exceptions. First, some professional mnemonists are able to calendar calculate, presumably through having memorised a published formula. Second, the great mental calculators are reported to find date calculation rather straightforward, being able to devise complex mathematical formulae which encompass the rules of the calendar (Smith, 1983). Whether savants adopt such methods is discussed below.

It was observed in Chapter 1, that the savant literature is dominated by descriptive single case studies which have little explanatory value. This is particularly the case for the date calculation research, with very few studies investigating the cognitive processes which may subserve, and indeed, explain the ability. In the following review, a number of the classic descriptive studies are included. However, an emphasis will be placed on the more systematic experimental investigations which are judged to contribute to our understanding of the ability. These studies will be discussed in terms of their relevance to the various explanations of savant date calculation.

Calendar rules and regularities. Prior to this review, it is necessary to describe the key features of the calendar. Our current Western calendar was introduced by Pope Gregory XIII, and was adopted by many European countries in 1582. Great Britain, however, did not adopt this format of the calendar until 1752, a process which resulted in the days between September 3rd and 14th being dropped for that year. It is essential to note that the calendar is a highly structured device, characterised by a number of rules and regularities. Importantly, the calendar repeats itself every 28 years and every 400 years. Thus, years which are 28 years and 400 years apart will be structurally identical. There are only seven possible monthly configurations depending on the day of the week on which the month begins. Furthermore, certain month pairs within the same year share the same calendar configuration. March and November are one such pair, so that the 1st of March will always fall on the same day as the 1st of November. There are 14 possible yearly configurations, or calendar *templates*. Seven of these relate to the yearly configurations produced by January 1st falling on each of the seven weekdays. The other seven templates correspond to leap years beginning on each of the seven weekdays. Leap years contain an extra date, 29th February, and fall every four years, although years at the beginning of each century, e.g. 1800, 1900, are not leap years. The exception to this are the years at the beginning of each century which are divisible by 400, e.g. 1600, 2000, and in these cases, the leap year status is retained. Leap years compensate for the fact that the true length of a year, which is defined by the Earth's orbit of the sun, is actually a little over 365 days long. In addition to these major features, the calendar is characterised by further internal consistencies. For instance, the same date will fall on successive weekdays, in successive non-leap years. It is hoped that these examples serve to illustrate the extent to which the calendar is regular, repetitive and highly structured.

Explanations of Savant Calendar Calculation

1) Use of formulas and algorithms

From the rules described above it is possible to devise various formulas, algorithms and tables which allow the user to generate the respective day of the week (e.g. Spitz, 1994). These methods are usually detailed and complex and can often be found in encyclopedias and almanacs. As was noted above, such methods probably underlie date calculation in normals. However, there is a general consensus among researchers in the area (with the exception of Ericsson and Faivre, 1988) that the savant skill of calendar calculation is *not* based on the use of published methods (Howe, 1989; Spitz, 1994; Spitz, 1995; O'Connor and Hermelin, 1984). Two main reasons are offered. First, it is unlikely that mentally handicapped individuals would ever have access to the relevant publications concerning these methods. Second, and most importantly, the mastery of such formulas requires a level of reading, comprehension, memory and numerical ability clearly beyond that of most savants. Certainly, most cases in the literature are reported to have only basic arithmetical skills (e.g. Hill, 1975; Hurst and Mulhall, 1988). Thus, an explanation in terms of the use of conscious complex formulas and algorithms is largely rejected.

Perpetual calendars represent an alternative, more feasible source from which savants may gain their knowledge. These are devices which display the 14 different calendar templates, as described above, in conjunction with the various years which correspond to each of the templates. Again, these can be found in reference guides and almanacs. However, the name is somewhat deceptive, and most perpetual calendars do not extend beyond 2400. Since the spans of certain savant calculators *do* extend beyond 2400, it would thus seem that additional explanations may be required (see Horwitz, Deming and Winter, 1969, below).

2) Visual imagery

In a famous study, Roberts (1945) describes the calendar calculating skill of a non-verbal, mentally and physically handicapped male, whose IQ was unmeasurable. In response to date questions between 1915 and 1943, the subject would gaze at the ceiling and make a noise when the appropriate weekday was read out to him. When Roberts presented dates coloured either red, green or black, the subject could identify the colours from memory, again after staring at the ceiling. Roberts concluded that this young man's ability was based on visual imagery.

In a more recent investigation, Howe and Smith (1988) reached a similar conclusion. Their subject, with an IQ of 50 and a calculation span of 70 years, was observed to repeatedly draw calendars for particular months in a characteristic style and specific colour, commenting on the similarity between his own drawings and his kitchen calendar. Howe and Smith report the subject's rapidity at generating all of the months within a given year range, which start on the same day. Also, when given impossible dates to calculate, such as 31st September 1977, his response indicating their impossibility was somewhat delayed. These findings are taken as consistent with the subject accessing information relating to the seven monthly calendar configurations, in the form of visual images. However, it should be noted that the authors did not record actual response times. Therefore, comparisons in terms of perceived variations in speed of calculation and its implications for the subject's method should be treated with caution. Furthermore, when the authors provided the subject with 28 random numbers in the form of a calendar configuration, he was able to recall only three of these items after a four minute study period. This indicates that the subject's ability did not rely on eidetic imagery.

An important study which illustrated that visual imagery does not provide a universal explanation for calendar calculation, was that of Rubin and Monaghan (1965). Their subject, with a verbal IQ of 51, had been blind from birth. Furthermore, she had never had access to a braille calendar. There are a number of factors which suggest that her method was based on the memorisation of the calendar. First, her calculation range of five years was very limited and thus could feasibly be committed to memory. Second, she was reported to practice with dates at any spare moment. Third, she could give the answer to dates instantly. Finally, she was able to give information about events that had occurred on each of the dates within her span. It would thus appear that, through practice, she had committed to memory all of the dates within her limited range. Whether such an explanation in terms of memorisation and practice can be used to account for more extensive calculation spans will be discussed below.

3) Anchor Dates

Rosen (1981) reported the date calculation skills of two psychiatric patients, the first with an IQ of 79 and the second subject with an IQ of 97. Interestingly, both had began calculating at the age of six, with the first savant stating that he had taught himself from a perpetual calendar. The size of their calculation ranges is not reported. On the basis of the calculation speeds for a series of dates over a 15 year span, Rosen concluded that both subjects were using a similar strategy. This involved the memorisation of a specific weekday for each year, in this case the date was suggested to be 1st December, and using this date to "key off", i.e. count forwards or backwards from this date. This counting process also involved the knowledge of the systematic changes within the calendar in order to arrive at the correct date.

Hill (1975) had earlier tested for the use of anchor dates. The subject, "B", had an IQ of 54 and was not reported to be autistic. Tests suggested no evidence of eidetic imagery or an enhanced short-term memory (STM) capacity. Furthermore, an examination of his reaction times to date questions over a 23 year period indicated these times were consistent across all dates and months within a year. For the anchor date hypothesis to be supported, certain dates and months within a year should be quicker to calculate than other dates within the same year. Hill concluded that the only remaining explanation was in terms of "a rote memory process, similar to the memory of adolescents who learn statistical information pertaining to their favourite sports...his "special ability" seems to be that of concentrating for extended periods of time" (Hill, 1975, pp. 560).

4) Rote memorisation

In two classic studies, Horwitz, Kestenbaum, Person and Jarvik (1965) and Horwitz, Deming and Winter (1969) documented the outstanding calendar skills of the twins George and Charles, whose numerical abilities were reported by Sacks (1985) and reviewed in Chapter 1. Their IQ's were placed in the 60-70 range and they were believed to have an hereditary form of mental handicap. Horwitz et al. (1969) presented the twins with 300 dates for calculation. This revealed that George's span approached a 40,000 year range, while Charles' span did not extend far beyond the present century. Calculation speeds were not reported as the twins were described as responding "in a flash". Interestingly, when six years old, George was observed to spend hours pouring over an almanac which contained a perpetual calendar. However, because George's range extends far beyond such a calendar a further explanation of his ability was required. The authors proposed that the twins began by memorising a conventional calendar. They noted that one month began where another left off and eventually became familiar with the subpatterns within the range of 400 years. George eventually mastered a span of 400 years and could then connect any day and date by subtracting multiples of 400 until the date fell within his memorised span of 400 years. This rests, of course, on George knowing about the cyclical nature of the calendar. The authors conclude that "this feat of memory is not creative, but rote" (Horwitz et al., 1969, pp. 414). It should be noted, however, that the rote memorisation of 400 years of the calendar represents an incredible feat, corresponding to the storage of approximately 146,000 separate items of information in LTM.

Hurst and Mulhall (1988) describe a 38 year old male, whose behaviour in childhood together with his presenting features strongly suggest autism. His IQ was measured as 71 and he was found to be able to calculate across the present century. The authors found no evidence of eidetic imagery and noted that their subject was capable only of very simple arithmetic. They concluded that his ability was unlikely to be based on either imagery or calculation. Rather, rote memorisation seemed the most probable explanation.

Notably, all of the authors who propose an explanation in terms of rote memorisation fail to define what they mean by this term. Generally, however, rote memory is taken to refer to a verbal memory system/process in which information is stored in an unorganized, uninterpreted form and recalled verbatim. The term also implies that knowledge is gained through effort and deliberate practice. Certainly, the authors who cite rote memory as the explanation of savant date calculation, refer to the extensive period of time the savant has devoted to studying the calendar. Indeed, Horwitz et al. (1969) note that the twins had "devoted their time to practically nothing else since they were nine years old" (pp. 414).

5) The use of rules and regularities

In 1984, O'Connor and Hermelin performed the first group study of savant calendrical calculation, involving eight subjects. On the basis of calculation speeds to a range of dates (from 1963 to 1993) the authors concluded that rote memorisation was an insufficient explanation of the ability for a number of reasons. First, how would this explain the calculation of future dates, for which the appropriate calendars have yet to be published? Second, as noted above, the storage capacity required to memorise even a moderate span of the calendar would be considerable. Third, and of key importance, the authors found an increase in both error rate and calculation speed in response to dates extending further into the past and future from the date of testing. This finding, supported by Dorman (1991), is not consistent with a pure memory based operation; why would a date from 1973 be more difficult to retrieve than a date in 1983 if these are both stored as individual encodings in LTM? Indeed, it may be proposed that the more distant dates would be *easier* to retrieve as they are likely to be more practised than recent dates. This finding, that distant dates take longer to generate, indicates that savant date calculation involves mental operations additional to retrieval from memory. Specifically, the knowledge of rules, regularities and redundancies in the calendar may contribute to the performance of savant calculators. As noted above, the calendar is a highly organized device, governed by many structural rules. In 1986, Hermelin and O'Connor set out to investigate whether savant calendrical calculators make use of these rules to aid calculation.

Hermelin and O'Connor (1986) presented eight savants with a series of dates selected so that variations in calculation speeds would illustrate the use of calendar rules. The first of their experiments tested for the "corresponding monthly rule", i.e. that certain month pairs share the same monthly structure. Subjects were presented with pairs of dates, taken from the same year within a pair, sharing either an identical or non-identical month structure. The rationale was as follows. If subjects were using this corresponding monthly rule, for the pairs of dates which conformed to this rule, calculation of the second date should be faster than the calculation of the first date in the pair. This would be because the second date falls on the same day as the first date and calculation would thus be facilitated. The results confirmed the hypothesis in that six out of the eight savants showed a significant decrease in reaction time for calculating the second member of an identical month pair. These results contrasted with those found in the non-identical pairs, when in some cases an *increase* in calculation time was observed for the second date in a pair.

Another experiment within the same paper investigated the 28 year rule. This refers to the fact that the Gregorian calendar repeats itself every 28 years. For example, 1960 has the same yearly structure as 1988 and 1961 shares the same relationship with 1989. Given that the year of testing was 1984, dates were presented for calculation in the years 1956 and 2012, i.e. 28 years away. As a control condition, dates were also presented from the years 1966 and 2002. The inclusion of these dates rests on a finding from the previous O'Connor and Hermelin (1984) study; that temporally more remote dates take longer to calculate than less remote dates. If the savants were utilizing the 28 year rule then they should be quicker at calculating the 1956 and 2012 dates even though they are more distant years. However, if the rule was not adopted then the more recent dates would be the most speedily calculated. The obtained results suggested that the rule was utilized but as part of an elective strategy. For the familiar and well practised past, dates from 1966 were calculated faster than those from 1956, which did not suggest reliance on the rule. However, a very different pattern of results was observed for the future dates; the 2012 dates were calculated faster than those from 2002. Thus it seems that a rule-based strategy is necessary for the calculation of future years, which are much less familiar, perhaps never having been studied directly from the calendar. In addition, the paper revealed that those subjects who were able to calculate over a longer time period, particularly future dates, were those subjects with the higher IQ's. Thus, even though the savants are able to perform calendar feats at a level which is much higher than would be predicted from their general level of cognitive functioning, it would appear that IQ plays a role in the use of rule-based strategies relating to the calendar.

In an important study, O'Connor and Hermelin (1992) investigated the date calculation skills of two 10 year old boys, over an 18 month period. This paper is relevant to the views of Ericsson and his colleagues, regarding the role of deliberate practice in the development of ability (see Chapter 1). One of the boys was diagnosed autistic and both had IQ's of 90. In addition, both subjects were reported to have developed an interest in the calendar at the age of six years old. In the study the boys were presented with a series of dates taken from past and future decades. These included items which were 28 years into the future from the date of testing. Equivalent dates were given on four occasions over a 18 month period. The results revealed three important findings. First, even at the age of 10 years old, the calculation speeds of the two boys were equivalent to those of the adult calculators reported in O'Connor and Hermelin (1984). Second, over the period of 18 months, there was no discernible improvement in terms of either calculation speed or accuracy levels. Third, the reaction times to dates 28 years in the future revealed that both subjects were indeed making use of the 28 year rule. Clearly, these findings are not consistent with an explanation of savant date calculation solely in terms of practice and deliberate memorisation. For example, if the skill was based entirely on practice then an improvement in terms of speed and accuracy would have been predicted over time. Rather, the study serves to confirm the important role played by the use of calendar rules in savant date calculation, even in such young calculators.

A more recent experimental study by Young and Nettelbeck (1994) also revealed the extent to which savant calculators make use of calendar structure to facilitate calculation. The study involved three subjects, with IQ's of 76, 72 and 65. Two subjects had a diagnosis of autism. In a replication of Hermelin and O'Connor's (1986) finding, the authors noted that calculation was facilitated for dates conforming to the "corresponding monthly rule" but only in leap years. Interestingly, it was found that subjects took longer to calculate dates falling in leap years than in non-leap years when years were equated for temporal remoteness from the date of testing. A second experiment within the same paper examined the savants' knowledge of the 14 yearly calendar templates. Blocks of dates were presented for calculation, half of which contained dates from years sharing the same calendar configuration and half which contained dates from different yearly configurations. Month and date were held constant within each block. Calculation speeds were found to be significantly faster for dates taken from the same calendar configuration, even when these were leap years. Thus, the subjects were suggested to use their knowledge of identical year structures in the calculation process. From their study, Young and Nettelbeck conclude that savant calendar calculations are automatic responses which to a limited extent are rule-based, resulting from intense practice and the rote learning of these rules. It is worth noting, however, that the authors do not suggest *how* these rules are first acquired.

In 1991 Ho, Tsang and Ho investigated the calculation performance of a Chinese calendar savant with a verbal IQ of 66 and a performance IQ of 91. Their subject, Kit, was able to calculate correctly across the 20th and 21st centuries. When presented with a series of dates to calculate, it was noted that Kit would use a pencil and paper to subtract in multiples of 28 from the given year. Thus, he appeared to make use of the 28 year rule. He was able to recognise the 14 yearly templates of the calendar and could generate different years which would match the templates. He was also shown to have good visual retention as indicated by his above average performance on the Benton Visual Retention Test and a visual digit span of 12 items. The authors concluded that a combination of good visual retention, satisfactory basic arithmetic skills, a knowledge of calendar regularities and the rote memorisation of the 14 yearly calendar configurations was sufficient to explain their subject's performance.

Lack of insight. One important characteristic of calendar savants is their lack of insight into the process by which they perform their calculations. In response to questions concerning their methods, savants often give statements such as "I just do it" or "use me head" (Howe, 1989). Even though several studies have now shown that savant calculators make use of calendar rules, very few of these subjects can report even the most fragmentary information relating to the regularities. Perhaps this is not such a surprising finding given the difficulty experienced by most individuals when trying to give an account of the grammatical rules which govern language. Even though we make implicit use of these regularities to structure the way in which we use language, most of us would be unable to verbally state these rules. Thus, an inability to formulate rules does not preclude their use, as demonstrated in Hermelin and O'Connor (1986). This is illustrated in the growing cognitive literature regarding learning without awareness. This research on implicit learning and memory is highly relevant (Spitz, 1995) and will be reviewed later in the present chapter.

Overview: The Importance of Memory in the Date Calculation Process

Over the years, a number of explanations have been proposed to account for savant date calculation. These include visual imagery, rote memorisation of calendar information and the use of calendar rules and regularities. As the more recent experimental investigations have suggested, the process may well depend upon a combination of these different explanations, with various cases relying to a differing extent on the proposed strategies. For example, individuals can achieve small calculation spans on the basis of practice and rote learning. However, savants with larger spans appear to make efficient use of calendrical regularities, particularly the more intelligent calculators. Access to perpetual calendars may also give rise to a strategy involving visual imagery, although the evidence supporting this is far from conclusive. In addition, evidence relating to the acquisition process, particularly the role of practice, is very mixed. Some savants in the literature are reported to have practised constantly, whereas the investigation of other date calculators suggests that practice does not play a key role in the development of their skill (O'Connor and Hermelin, 1992). Thus, savant calculators may vary in terms of the acquisition process of their ability and the means by which they perform their skill. Regardless of this heterogeneity, however, it is possible to identify an aspect of cognitive functioning which is central to all of the suggested explanations. *The process of calendar calculation is subserved by memory, by the retention of calendar information in LTM.*

In view of the fact that memory is implicated in all of the reviewed explanations, it is therefore surprising that there has been no direct investigation of memory function in the savant calendrical calculator. If we are to further understand this unusual ability, specifically by exploring the cognitive processes which underlie date calculation, then a systematic study of memory ability is absolutely necessary. A paper by Spitz and LaFontaine (1973) may thus be relevant. Their findings indicated that the immediate memory spans of a group of savants, all with different abilities, was superior to that of mentally handicapped controls. However, these two groups were not closely matched for IQ or for diagnosis. The current thesis includes an attempt to investigate the STM performance of a group of savants, all with the same skill, together with appropriate controls.

Importantly, all of the previous studies in the literature have examined the savant's knowledge of dates by requiring them to *calculate* the items. An investigation of memory ability would provide an alternative, more exhaustive means by which savant date knowledge can be explored. For example, requiring subjects to *recall* rather than calculate dates permits the use of a control group. This would represent the first study in the literature to compare the cognitive functioning of a group of savant calculators with appropriate controls. Will this reveal a superior *general* memory in the savants, which may thus explain why these particular individuals can acquire extensive calendar information? Alternatively, will the memory superiority of the savants be confined to calendar related items, thus akin to the domain-specific superiority of experts and savants in other areas? Furthermore, a comparison of the memorability of different dates may prove insightful regarding the organization of savant calendar knowledge. It was suggested in Chapter 1 that other savant talents, together with domains of expertise in the normal population, are subserved by highly structured knowledge bases. It thus seems appropriate to investigate whether savant date calculation is based on organized mental representations in LTM.

A paper by Norris (1990) is relevant. This represented an attempt to develop a connectionist network which modeled the process of savant date calculation. The principles underlying connectionism will be described in more detail later in the present chapter. Importantly, the simulation could only learn to generalise to new dates, for which it was not directly trained, if it adopted a highly structured approach. Specifically, the net had to be trained at three different levels corresponding to the knowledge of days, months and years. At the first level, the model learned the day-date pairings in a particular month. At the second level, it learned how various dates in one month related to dates in another month. This included knowledge concerning the number of days in each month. At the final level, the net was trained with a few anchor dates in each year and thus learned the connections between dates in different years. In this way, the network was shown to be able to calculate dates without having performed mental arithmetic, and without having any explicit knowledge of calendrical information. Rather, all of the internal "calculations" took the form of simple mappings between dates. This offers an interesting conceptualisation of the knowledge base which underlies savant calculation. Specifically, it suggests a highly organized, relational structure to the savants' LTM for dates. Moreover, it may be precisely this knowledge of how one date relates to another date which gives rise to the calculation process. It would thus appear that an investigation of savant calendar memory, and of the calendar-specific knowledge base, is essential to an increased understanding of the date calculation process.

MEMORY: RELEVANT THEORY AND RESEARCH

As the present thesis aims to investigate memory in the savant calendrical calculator, it is important to have an understanding of the relevant research and theory regarding memory in the normal population. The following review will be brief, encompassing only the general principles relating to (1) the distinction between different types of knowledge, (2) an explanation of why certain items may be more memorable than others, and (3) the nature of long-term memory (LTM) organization.

1) Divisions of Knowledge/LTM

Knowledge can be regarded as forming the content of LTM, an extensive database of acoustic, visual and semantic information. Given the sheer volume of information stored in LTM, the following distinctions are often suggested as a means of distinguishing between separate types of knowledge.

a) Episodic and Semantic Memory

In 1972, Tulving proposed a distinction between two long-term stores of information. Semantic memory is described as factual knowledge which is not dependent on a particular time or place. It is organized knowledge concerning the relationships between words and other verbal symbols, the knowledge of rules, algorithms and formulas. Episodic memory refers to personally experienced events and autobiographical information which is tied to specific contexts. To give an example, "last Friday I visited the dentist" would be regarded as episodic knowledge, whereas "a dentist works with teeth" is semantic, factual knowledge. For the savant, knowledge relating to dates may well be conceptualised using a similar distinction. For example, the ability to provide the corresponding days for a wide range of dates may be regarded as factual information independent of context and thus akin to semantic knowledge. In addition, savants are often able to provide calendar-related autobiographical information, such as the dates of every holiday they have been on. This could be compared to episodic memory. However, such a distinction between different types of calendar-related knowledge has yet to be demonstrated experimentally.

b) Procedural and Declarative Knowledge

Declarative knowledge refers to explicitly accessible, factual information and is said to correspond to Ryle's (1949) concept of "knowing that", e.g. stating that Paris is the capital of France. Procedural knowledge corresponds to "knowing how" and is said to underlie the performance of skilled actions without the involvement of conscious recollection, e.g. riding a bicycle. This distinction between declarative and procedural learning has been observed in amnesic individuals, who are suggested to have near-normal procedural but impaired declarative learning (Cohen and Squire, 1980). Could such a similar procedural/declarative distinction be applied to savant calendar knowledge? Savant calendar calculators are for the most part unable to provide insight into the operations which underlie their ability. Could the operation of knowledge mechanisms which subserve the skill best be conceptualised as procedural? Nissen (1992), however, has noted the tendency to equate the phenomenon of procedural learning with *motor* skill learning[2]. Given that the ability to date calculate is based on cognitive operations and does not involve motor or skilled *actions* a more useful conceptualisation of date knowledge, relating to conscious and unconscious processing, is that of implicit/explicit knowledge.

c) Implicit and Explicit Learning

Implicit learning is defined by Seger (1994) as the acquisition of complex information without complete verbalizable knowledge of what is being learned. This is in contrast to explicit learning in which subjects are aware of and are able to report the information acquired. Perhaps the archetypal example of implicit learning is language learning, which

[2] This distinction between procedural and declarative knowledge may be particularly relevant to savant artistic talent.

is assumed to involve the unconscious abstraction of grammatical rules. Our inability to verbally formulate or even be aware of these grammatical rules, suggests their implicit acquisition and nonconscious use. Artificial grammar acquisition is a related task which has been used to experimentally investigate implicit learning. In a typical experiment, subjects are required to memorise strings of letters which conform to the rules of the artificial grammar, although they are not told what the rules are. This constitutes the training phase. They are then presented with a series of letter strings to be classified as grammatical or nongrammatical (test phase). It has been found that subjects classify these strings significantly above chance, although they cannot describe the rules they are using (Reber, 1989). Similarly, Berry and Broadbent (1984) introduced a task in which subjects were required to manage a sugar production factory in order to achieve a certain level of sugar output. Although subjects learned to perform this task at a high level, they were unable to explain the factors underlying their performance. Interestingly, there appeared to be a dissociation between the subjects' ability to verbally report the principles of performance and the actual level of task performance, i.e. those subjects with the least verbal knowledge of the principles governing task performance were the subjects who performed the best on the task.

To reiterate, implicit learning refers to learning in the absence of conscious awareness. In order to test the subjects' awareness of what has been learned, many experimenters rely on verbal reports. However, Shanks and St John (1994) are critical of this procedure and argue that verbal report is not an exhaustive index of conscious information. They note that subjects may be unwilling to report fragmentary information, believing rules should be reported. Also, because the test of awareness usually provides a completely different retrieval context to the performance test then the same level of conscious information may not be tapped. Within this critical article, Shanks and St John suggest a meaningful distinction in knowledge acquisition is that between abstract, rule-based learning and learning based on separate fragments or instances. Reber (1989) among others has argued for the abstractness of implicit knowledge, suggesting that in artificial grammar tasks subjects' performance largely reflects the underlying grammatical rules and not the studied stimuli. Alternatively, much evidence has been offered in favour of an instance-based view of learning. This proposes that the actual exemplars seen during training are memorised and judgments are based on the similarity between test items and stored instances. Such support has also come from artificial grammar learning (Perruchet, 1993) where performance is accounted for by knowledge of specific bigrams and initial and final letters.

In conclusion, the growing literature on implicit learning may be relevant to an understanding of savant calendar knowledge. These studies have illustrated how knowledge which is inaccessible to conscious awareness, can nevertheless operate to influence performance. This would seem to be the case for savant calendar calculators; although they make use of calendar rules to facilitate calculation, they are for the most part unable to verbally report these rules. Specifically, the characterisation of implicit knowledge into rule-based and instance-based learning may be pertinent to the acquisition of calendar knowledge. For example, do the savants abstract the rules and regularities directly from the calendar or does their knowledge build from the memorisation of individual day-date pairings, along the lines suggested by Norris (1990)? Finally, it is important to bear in mind Shanks and St John's (1994) criticism of verbal report as an inadequate measure of awareness. Savants are individuals with low verbal IQ's and communication difficulties. Thus, their failure to provide an adequate description of their method of calculation may not be sufficient evidence to assume that calendar knowledge is necessarily implicit. This remains to be investigated.

2) Factors Affecting Memory

The present thesis requires the memorisation of a range of words and dates. It is therefore important to attempt a theoretical explanation of factors which operate to influence memory performance. For example, how might differences in the memorability of various dates be interpreted? How might any difference in recall performance between the savants and controls be explained?

Depth of processing. The fact that different types of encoding process can influence retrieval was famously illustrated by Craik and Lockhart (1972) in their levels of processing studies. To summarise their ideas; incoming stimuli are subjected to a series of analyses that begin at a shallow sensory level and proceed to a *deeper*, more complex, semantic analysis. The term "depth" is taken to denote the meaningfulness extracted from the stimuli. The deeper the level of analysis, the more elaborate and longlasting the memory trace produced. Against a background of criticisms of this theory, including problems in measuring processing depth, one important generalisation of human memory has emerged; deeper, richer semantic processing usually leads to better learning and memory. So why does deeper processing lead to better retention?

Elaboration. Anderson (1990), among others, suggests that rather than using the term "depth" to reflect how fully the subject processes the meaning of items-to-be-learned, a more appropriate interpretation would be in terms of the number of elaborations the subject generates. Elaboration is a process of relating the to-be-remembered event to other information known about the event. Specifically, we may process a target item in relation to other target items and in relation to relevant prior knowledge (Mandler, 1980; 1988). The item is therefore easier to retrieve due to an increased number of retrieval cues, i.e. items which would remind us of the target, and an increased number of retrieval pathways. An associated finding is that concerning the *generation effect.* Studies have shown that memory is enhanced for words that have been generated by the subject when compared to words that have simply been read (e.g. Slamecka and Graf, 1978). In comparison to reading the word, the process of generation is suggested to lead to a more elaborated form of encoding thus providing a greater number of retrieval routes (Reardon, Durso, Foley and McGahan, 1987).

Distinctiveness. It has been suggested (Eysenck, 1979) that we are more likely to retrieve a memory trace that is in some way unique or distinctive than to retrieve a memory trace showing a resemblance to a number of others. In Eysenck's (1979) experiment, subjects were required to attend to the sound patterns of words as an orienting task. However, in one condition subjects were given atypical pronunciations of the words. Since these pronunciations would not have been shared by other words, they were therefore judged as distinctive and predicted to facilitate memory. Subjects in this non-semantic condition were found to remember the words as well as a group given a semantic orientation task involving processing the meaning of the words. Eysenck's results therefore appear to suggest that the unique and distinctive features of an item serve to aid retrieval from LTM.

To summarise, memory is enhanced for items that receive elaboration and result in a more distinctive memory trace. Ellis and Hunt (1993) even suggest that elaboration is effective because it produces distinctiveness. Both of these factors may be relevant in interpreting the recall performance of the savants. It may be suggested that savants find dates more memorable than a control sample due to their elaborative encoding of these items, i.e. they can relate the target items to additional dates stored in LTM. Also, specific dates may be more memorable to the savants due to their distinctiveness, e.g. leap years when compared to non-leap years.

3) The Organization of LTM

Network theories. Perhaps the most widely held assumption concerning LTM is that information is stored in an organized format. One very influential view of LTM organization depicts knowledge as a vast network of associated concepts. Facts are connected to other facts in a nonrandom way; one word is connected to another word related in meaning. This associationist view has been encapsulated in various computational models of cognition (e.g. Collins and Loftus, 1975). In these models, words and concepts are represented by nodes in a network and relations are represented by links which join these concepts. These associative links between nodes can be of various kinds. They may represent general relations (e.g. *is-similar-to)*, specific relations such as class inclusion (e.g. *apple-fruit)* or more complex links (e.g. *plays, hits*). These same links also vary in strength of association. For example, we would expect the concept *fire engine* to be more closely associated with *ladder* and less closely associated with *uniform*. Retrieval of a word or concept from the network takes place through a process of *spreading activation*. This begins with the activation of the item itself with activation then spreading through the network. Most network models assume that this activation will vary with the strength of the association between the nodes and will decline in strength the further it moves from the original node. As the activation spreads from the original node, each additional representation which receives activation is a candidate for retrieval. Within the Spreading Activation Model (Collins and Loftus, 1975), the strength of association between a cue and another item is represented by the distance between the two in the associative network, i.e. by the length of the link between the two concepts. Thus, the strength of association is fundamental to retrieval because it is the items closest to the original node which will receive activation and are therefore more likely to be retrieved. In other words, the effect of semantically priming concepts is achieved, i.e. partial activation of related concepts making subsequent access to these concepts easier.

Although there are other influential models of knowledge representation, for example, production systems (Anderson, 1983) and schema theories (e.g. Bartlett, 1932), network representation may be an appropriate theoretical framework within which to conceptualise savant calendar knowledge. Individual dates may be represented as nodes within a network interconnected with other related dates. The activation of one date through calculation may lead to the partial activation of another associated date, resulting in the second date being calculated at a quicker speed. This would fit Hermelin and O'Connor's (1986) findings relating to the calculation of corresponding monthly pairs. However, more recent developments in this research area may be relevant to our understanding of savant calendar knowledge. Most notably, connectionist networks now represent the most important and influential means of conceptualising and modelling the representation of knowledge.

Connectionist networks. In contrast to the semantic networks described above which were based on a computer metaphor, connectionism is said to be "neurally inspired", i.e. it is based on a brain metaphor with processing being parallel rather than serial. A connectionist network consists of simple processing units or nodes each with its own level of activation. The connections between units have different strengths, known as weights, and these can be either positive or negative/excitatory or inhibitory. Networks are organized into a number of different layers of units which perform separate functions. In general, there are input units (which receive input from sources external to the system), intermediate or "hidden" units and output units (corresponding to the response to the input - the "answer").

There are two important points to mention regarding connectionist networks. The first concerns the representation of knowledge. Knowledge is not stored in the actual units themselves, but in the strengths of the interconnections between units. Further to this, rather than knowledge being concentrated in the connections of a specific unit, most connectionist networks exhibit the distributed representation of knowledge across many units. Thus, it is the pattern of activity over the sets of units which corresponds to the main unit of analysis in the connectionist approach. The second point concerns the ability of connectionist networks to learn. There is often no need for the researcher to set the weights of the connections between units. The network will effectively "program itself" by the use of local learning rules. For example, the network can initially compare incorrect output patterns to the required response pattern and then subsequently backpropagate activation through the system, adjusting the weights between units so that eventually the correct output will be produced.

It has been noted that connectionist networks may be better applied to the modelling of more opaque cognitive processes which operate automatically and are not available for observation or control (Baddeley, 1990). McClelland (1988) had earlier made a relevant point. He argued that knowledge in the weights of a connectionist network should be completely inaccessible to introspection or report because the knowledge is inextricably embedded in the machinery of processing. Thus, in these models, a natural assumption would be that the connection weights constitute a person's implicit knowledge that is difficult to verbalize (Berry and Dienes, 1993). On the other hand, the patterns of activation that they make possible and that they transform can be accessible to other parts of the system, i.e. the output is consciously accessible. It may thus be appropriate to conceive of savant calendar calculation within the framework of connectionism (Norris, 1990). Certainly, the date questions and answers are fully accessible to conscious inspection, but the intervening thought processes which give rise to the weekday answer may be unavailable to conscious awareness. Furthermore, this inaccessible knowledge may be in the form of interconnected representations corresponding to different dates.

Conclusion. To date, there has not been a systematic experimental investigation of the role of memory in savant calendar calculation. This is surprising given that memory is implicated in all of the proposed explanations of the ability. In the present chapter various aspects of general memory research have been reviewed and their relevance to an understanding of savant calendar knowledge was noted. It is necessary to now establish precisely what can be learned from an experimental investigation of memory in the calendar savant. However, before outlining the experiments, a description of the intellectual and calculation abilities of the savants will be given.

CHAPTER THREE

THE INTELLECTUAL AND CALCULATION ABILITIES OF THE SUBJECT GROUP

Overview

The present chapter provides a comprehensive investigation of the cognitive abilities of all 10 savant calendar calculators tested in the following experiments. This represents one of the most in-depth explorations of such a sizeable group of savant calendar calculators and thus should prove informative with regards to any common features which characterise these talented individuals. Specifically, details will be given in the following areas:

1) Background information; details pertaining to diagnosis, educational and employment history and relevant information relating to other family members.

2) Calendar knowledge; the age at which the subject first began to calculate, details on the subject's access to calendrical material, their calculation speed, accuracy rates and calculation spans.

3) Intellectual assessment; four subtests from the WAIS-R (Wechsler, 1981) and the WISC-III (Wechsler, 1992) were selected. These were vocabulary, comprehension, block design and object assembly. These subtests often represent the extremes of performance on the Wechsler intelligence scales for an individual with autism, particularly the comprehension and block design tasks (Happé, 1994c). The two verbal subtests are often amongst the lowest scores and the two nonverbal tests amongst the highest. Subjects' performance is reported in terms of scaled scores, which range from 1 to 19 with an average of 10. Scaled scores permit a direct comparison between the performance of the subjects on each of the individual subtests. IQ's from the Peabody Picture Vocabulary Test and Ravens Progressive Matrices Test were also obtained, as were digit spans forwards and backwards.

4) Assessment of reading ability; the Wechsler Objective Reading Dimensions or W.O.R.D. (Rust, Golombok and Trickey, 1992), was presented from which standard scores and equivalent reading ages were obtained. The ability to read words associated with the calendar was also tested by presenting all of the days of the week and months of the year in the order shown below in Table 3.1. Words were presented on A4 paper, printed in Times Roman 20pt size. Subjects were required to read the words aloud.

Table 3.1 ***List of calendar words presented for subjects to read.***

December	Tuesday	February
Wednesday	July	Monday
August	May	Sunday
January	March	June
Thursday	Saturday	November
April	September	Friday
October		

5) Basic arithmetical ability; examples of the problems shown below in Table 3.2 were presented to subjects. These were printed on A4 paper in Times Roman 30pt size. The calculations were to be performed without pen and paper. On occasions when the subject was finding the task extremely difficult, the experimenter would also read out the sums, e.g. "10 take away 7", "24 shared by 3". These sums were intended to give an idea of the subject's ability to perform basic addition, subtraction, multiplication and division problems.

Table 3.2 ***Basic arithmetical problems presented to subjects.***

2 + 2 =	25 - 14 =
4 + 5 =	2 x 3 =
7 + 11 =	3 x 8 =
5 - 1 =	4 x 25 =
10 - 7 =	24 divided by 3 (presented with traditional symbol)
8 + 6 =	36 divided by 4 (presented with traditional symbol)
12 - 5 =	

6) Judging the intervals between years and numbers. This was intended as an exploratory investigation of the modular nature of savant calendar ability. When presented with two years, such as *1995* and *1973*, will the savant be able to calculate the difference between the two years? Importantly, will this ability extend to general numerical items such as *1,995* and *1,973*, or will it be confined specifically to calendrical items? In addition, if the savants *do* make use of the 28 year rule, this would suggest that they possess knowledge relating to the intervals between years within the present century, or at least are able to rapidly calculate the difference between years. Subjects were presented with a series of numbers and years, each printed in Times Roman 30pt size, on a separate piece of card. The items were divided into three groups:

a) years from the present century and two years from the 19th century (*1882* and *1887*)

b) numbers which correspond to the above years presented in the form *1,995* and *1,973*

c) numbers which comprised only the last two digits, e.g. *95* and *73*.

The order of presentation of these three types of item was varied from one subject to another. Two of the items were placed in front of the subject, one above the other rather than side by side. Within the individual subject descriptions, *Item 1* denotes the number or year placed in the top position, *Item 2* indicates the number or year placed in the lower position. The subject was asked questions along the lines of "How many between these two? What is the difference?". On initial presentation of the items the subject was not informed whether these items were intended to represent years or numbers. Actual responses together with response times are given in the individual subject descriptions. The results of this investigation are not reported as an experiment within the thesis because the presentation of conditions, and items within conditions, varied considerably from one subject to another. The experimenter needed to adjust the order of presentation of the items according to the ability level of the subject and, importantly, according to their previous response. For example, several subjects were clearly unable to perform the tasks with the number items and the task was discontinued. Although this investigation was somewhat exploratory, nevertheless, the findings indicate the ease with which savants process the intervals between years, even if they are unable to perform the same task with numerical information.

Subject Recruitment.

Four of the 10 savants in the present sample had participated in the previous studies of O'Connor and Hermelin (1984) and Hermelin and O'Connor (1986). These were subjects

M.W., J.B., G.C. and D.K. However, the remaining six savants, including H.P., were recruited by the experimenter. Various advertisements had been placed in publications by MENCAP and the National Autistic Society (N.A.S.). In addition, the experimenter had contacted a large number of Adult Training Centres to enquire about clients with calendar skills. Although the MENCAP advertisements received no replies, approximately 20 parents and carers responded to the N.A.S. advertisement. However, most of these replies concerned individuals with an interest in dates rather than a genuine calculation ability.

Individual Subject Descriptions.

P.M.

Background information. P.M. was born on the 23rd May 1951. As a child he attended various ESN schools. He currently attends two adult training centres for clients with learning disabilities. In the past, there have been short intervals when P.M. was employed in unskilled manual labour. For example, he spent some months helping to move produce on a fruit and vegetable market. He has always lived at home with his mother. Very little additional information was available on P.M. Neither of his current A.T.C.'s have any records on diagnostic or intellectual assessment. These were destroyed six years ago. None of the staff have ever queried whether P.M. may be autistic, or at least show some autistic features. Several attempts were made to forward letters via the A.T.C.'s to the mother of P.M. in order to enquire about his behaviour in childhood and additional information relating to his interest in dates. However, none of these enquiries received a reply. Certainly, there are aspects of P.M.'s behaviour which do suggest autism. For example, he has difficulty with eye contact and there is evidence of delayed echolalia and the use of stereotyped utterances. After calculating each of the dates he would say "we can patch it up, can't we?". A staff member also remarked on P.S.'s behavioural problems at home which sometimes relate to disruptions in his routines. However, without information relating to P.M.'s childhood, any suggestion that his behaviour indicates autistic tendencies is speculative.

Calendar knowledge. Although, his family did not provide any information about the acquisition of calendar skills, P.M. himself was able to report some details. When asked about how old he was when he was first able to give the day of the week for a date, he stated clearly to the experimenter (in 1994) that it was "in January 1968... 26 years ago last January". When asked about his knowledge of dates in 1967 and other earlier years, he stated "I might have had a calendar, but I didn't take much notice about the months". Further questioning revealed that P.M. had received his first diary in January 1968 and he has had a diary for every year since. In response to whether he had ever seen a calendar which spanned at least 100 years, P.M. stated quite categorically that he had not. He then went on to inform the experimenter that some of his diaries had three years in them (most one year diaries also contain the calendar structure of the previous and the following year). The same questions concerning the acquisition of calendar knowledge were posed to P.M. on a number of different occasions, and he always responded consistently. Although, this is hardly conclusive evidence, this would appear to suggest that P.M. has never had access to a perpetual calendar. Of key importance is the fact that P.M. can calculate dates before 1968 and into the future. Indeed, his calculation range falls between 1870 and 2040. His accuracy levels and response times are shown below in Table 3.3. P.M. is unable to answer date questions in the form "What was the first Monday in June 1984?" Interestingly, on several occasions, he appeared to be making use of the 28 year rule. For example, after calculating a date in 1993, he stated spontaneously that this "was the same as 1974". When the experimenter commented that there was an interval of 28 years between these two years, P.M. stated "yes, the calendar's the same". P.M. is reported by the staff at his day centre to possess an outstanding memory for calendar-related information. For example, he remembers all of their birthdays and the dates on which they took their holidays in the previous years. His knowledge of the calendar also extends to the dates of Easter Sunday over many years. P.M. can name the current weekday and date.

Table 3.3 *P.M.'s date calculation speed and accuracy rates.*

Date	Response time (in seconds)	Accuracy
1st April 1850	85.9"	Incorrect (gave "Thursday" instead of Monday)
5th November 1873	35.4"	Correct
23rd May 1896	47.3"	Correct
17th September 1903	13.1"	Correct
1st October 1914	7.3"	Correct
25th August 1925	6.5"	Correct
5th July 1939	4.2"	Correct
30th March 1951	5.3"	Correct
15th December 1964	3.9"	Correct
22nd June 1979	4.7"	Correct
3rd January 1993	2.9"	Correct
14th February 1998	3.8"	Correct
4th August 2002	3.1"	Correct
8th July 2016	45.2"	Correct
13th January 2033	48.5"	Correct
11th September 2050	-	Unable to answer

Assessment of intellectual ability.

WAIS-R scaled scores:

Vocabulary	2
Comprehension	1
Block Design	4
Object Assembly	1

Digit Span. P.M. has a digit span length of 4 items forwards and 0 items backwards.

Peabody Picture Vocabulary Test. P.M. achieved a verbal IQ of 55.

Ravens Progressive Matrices Test.

P.M.'s non-verbal IQ was measured as 58.

Assessment of reading ability.

W.O.R.D. Test

Raw score 0

Standard score 0

(P.M. was unable to read any of the items on the test)

Calendar words.

P.M. could read all of the days of the week and months of the year.

Assessment of arithmetical ability.

P.M. was able to give the correct answer to the following problems. Time taken is given in parentheses.

2 + 2 (6")

4 + 5 (14")

2 + 3 (7")

The following items were answered incorrectly:

7 + 11 = 19 (1'37")

5 - 1 = 3 (1'09")

10 - 7 = 6 (1'10")

8 + 6 = 16 (39")

The remaining items were not presented. Attempts at arithmetical calculation were often accompanied by P.M. counting on his fingers. It is clear that he can only solve very simple addition problems and is not able to subtract.

Difference judgments.

P.M. was presented with the following items, and asked "How many between these, what is the difference?". Item 1 denotes that the number was placed in the above position, Item 2 was placed in the lower position.

Item 1	Item 2	Answer	Accuracy
1,995	1,984	8 (20")	Incorrect
1,995	1.986	8 (16")	"
95	84	4 (17")	"
95	88	4 (13")	"

P.M. was clearly counting the number of digits in both the items in each trial. Further instructions were given including "These are two numbers ___ and ___, how many numbers between them? Can you count between them?" P.M. could clearly not perform this task with any of the numerical items, which may well have resulted from his failure to comprehend task instructions. However, he was then presented with the items 1995 and 1984. He was not informed that these represented years. The experimenter posed exactly the same question as above, "How many between these, what is the difference?" and P.M. responded with "11 years" in 1.4 seconds. He was presented with the following 17 trials, the first 10 of which involved the current year of testing, 1995. The remaining 7 items involved years, neither of which represented the current year of testing.

Table 3.4 *P.M.'s judgment of the difference between years.*

Item 1	Item 2	Answer	Accuracy
1941	1995	54 years (9.4")	Correct
1995	1960	35 years (1.7")	"
1955	1995	40 years (7.7")	"
1912	1995	83 years (17.3")	"
1995	1929	66 years (2.7")	"
1906	1995	89 years (25"3)	"
1937	1995	58 years (3")	"
1995	1924	71 years (5.5")	"
1882	1995	104 years (40.6")	Incorrect
1995	1890	90 years (52")	Incorrect
1955	1960	5 years (12")	Correct
1941	1961	20 years (22.7")	"
1984	1912	72 years (24.6")	"
1929	1975	46 years (19.5")	"
1961	1906	55 years (17.2")	"
1876	1882	6 years (27.1")	"
1941	1882	59 years (42.2")	"

Summary description of P.M. Although regarded as having a general mental handicap, certain features of P.M.'s behaviour are suggestive of autistic tendencies. He reports that he became interested in the calendar when 16 years old. He can calculate from approximately 1870 to 2040 and shows some evidence of rule use regarding the repetitive structure of the calendar. He can only read words relating to the calendar. His basic arithmetic is limited to simple addition problems, although he has no difficulty in calculating the difference between two years within the present century.

R.D.

Background information. R.D. was born on the 17th August 1969. He attended the local primary school where his teachers began to remark on his lack of social interaction with the other children. R.D.'s mother reports that she had always felt that something was different about him. His speech developed late (he was older than two years old when he spoke his first word) and he showed a marked lack of interest in other people. His eye contact was also noticeably poor. He would often insist on lining up all his toy cars from one side of the room to the other. At the age of 7 years, R.D. was diagnosed as autistic, although he remained at his local school for two more years. At 9 years old, he was moved to a residential National Autistic Society (N.A.S.) school, where he remained until he was 18 years old. This was followed by a move to an adult N.A.S. unit, where R.D. found it extremely difficult to adjust to the change in his lifestyle. Six years ago, R.D. was transferred to a nursing home, close to his parents, where he remains to this day. He continues to display social difficulties and routinised behaviour. For example, on shopping trips with his mother, he will only visit a certain set of shops, in a specific order. In several of the testing sessions, R.D. refused to cooperate with the cognitive testing. Indeed, on one visit he refused to see the experimenter at all. Given that R.D. lives nearly two hundred miles away, it was difficult to arrange additional testing sessions. However, it was clear that he enjoyed the tests in which dates were presented and happily cooperated with all of the memory experiments involving calendar material.

Calendar knowledge. According to his parents, R.D. began to calendar calculate from the age of nine years old. He showed a marked interest in other people's birthdays and would proudly inform them of the day on which they were born. R.D.'s mother reports that she has always bought him a one year calendar and to her knowledge, he has never seen a calendar spanning the present century. R.D. has a prodigious event-related memory. For example, he can name the dates of all of his previous day trips, even as a young child. He can also name the dates of Easter Sunday over many years. Initially, R.D. was reluctant to answer date questions pertaining to years before he was born. However, when encouraged to guess at dates before 1969 he was invariably correct. His calculation span ranges from the early 1900's to the late 1990's. R.D. can name the current weekday and date.

Table 3.5 ***R.D.'s date calculation speed and accuracy rates.***

Date	Response time (in seconds)	Accuracy
1st April 1850	-	Would not attempt
5th November 1873	-	"
23rd May 1896	-	"
17th September 1903	15.2"	Correct
1st October 1914	6.3"	Correct
25th August 1925	4.3"	Correct
5th July 1939	5.1"	Correct
30th March 1951	4.9"	Correct
15th December 1964	3.7"	Correct
22nd June 1979	1.2"	Correct
3rd January 1993	0.9"	Correct
14th February 1998	4.2"	Correct
4th August 2002	-	Would not attempt
8th July 2016	-	"
13th January 2033	-	"
11th September 2050	-	"

Assessment of intellectual ability.

R.D. refused to do the subtests from the WAIS-R on more than one occasion.

Digit Span.

R.D. has a digit span length of 4 items forwards and 3 items backwards.

Peabody Picture Vocabulary Test. R.D. achieved a verbal IQ of 64.

Ravens Progressive Matrices Test.

R.D. obtained an non-verbal IQ of 73.

Assessment of reading ability.

W.O.R.D. R.D. refused to do the W.O.R.D. test. However, he does possess a range of different books and from an early age would sit pouring over the dictionary for hours.

Calendar words. R.D. is fully able to read all of the days of the week and the months of the year.

Assessment of arithmetical ability.

R.D. answered the following items correctly, with response times given in parentheses:

2 + 2 (1.8")

4 + 5 (5.2")

2 + 3 (2.4")

5 - 1 (7.7")

10 - 7 (9.1")

However, he gave the answer to *7 + 11* as *19* in 12.4". R.D. stated that he could not do the remaining items.

Difference judgments.

R.D. was presented with the following selection of years and asked to calculate "How many between these, what is the difference?". He was not informed that these items were years. The numbers of trials presented was kept to a minimum in order to ensure R.D.'s sustained concentration and motivation. The current year of testing was 1995.

Table 3.6 ***R.D.'s judgment of the difference between years.***

Item 1	Item 2	Answer	Accuracy
1995	1974	21 years (5.9")	Correct
1959	1995	36 years (7.2")	"
1995	1931	64 years (5.2")	"
1917	1995	78 years (19.3")	"
1972	1942	30 years (8.1")	"
1980	1916	64 years (11")	"

Any trials which involved years outside of the 20th century were not attempted by R.D. He simply stated that he did not know the answer. After the above items had been presented, the two numbers *1,995* and *1,960* were placed in front of R.D. and he was told "I am going to give you something new to do. Here are some different cards. How many between these two?". R.D.'s response was "35 years" indicating that he had continued to treat the numbers as years. However, when he was informed that these were not years but numbers, he stated that he could not perform the task, he did not know the answer. Also, he would not attempt the task when the lower numbers were substituted, i.e. *96, 73*.

Summary description of R.D. R.D. was diagnosed as autistic at 7 years old. He has been able to calendar calculate since he was 9 years old and he can calculate over most of the present century. Although his reading could not be assessed, he can certainly read all of the words involved in the calendar. He is able to perform basic addition and subtraction problems and can calculate the difference between years within the present century.

G.C.

Background information. G.C. was born on the 13th March 1963. During his childhood he attended a series of schools for pupils with learning difficulties. After leaving school he attended his local A.T.C. and later joined a Y.T.S. training scheme from May 1982 to August 1983. This involved painting and decorating with a group of other learning disabled employees. After the scheme ended, G.C. rejoined his local A.T.C. where he remained until it was recently closed. He now attends Adult Basic Education classes to improve his numeracy and literacy skills. G.C. currently lives independently as part of a council supported scheme. He has his own flat and a social worker visits him twice a week. Contact with his previous keyworker confirmed that G.C. does not have a formal diagnosis of autism. Rather, he is regarded as having "social and communication difficulties". This is certainly consistent with the experimenter's interaction with G.C. For example, he rarely initiates conversation and although he will answer the experimenter's questions, he does not build on these answers to continue the conversation. Occasionally, he has difficulty sustaining eye contact. The experimenter has also encountered examples of his social immaturity and inappropriate social behaviour. In addition, he collects, somewhat obsessively, huge jars of powdered fruit tea which fill his kitchen cupboards. G.C. is also fascinated by buses and the tube transport system. He can link any two destinations in London with the appropriate sequence of buses and tubes. Tentatively, it may be suggested that there are certain aspects of G.C.'s behaviour, from his pragmatic difficulties to his slight repetitive tendencies, which appear reminiscent of autism.

Calendar knowledge. G.C. reports that he began looking at calendars when he was 14 years old. This interest originated at school with a calendar in a book. G.C. then stated that he began to learn "about the mathematical years". He expanded on this statement by saying "the 28 years repeat" and "the 24th February 1963 fell on a Sunday and this was the same day as in 1935". G.C. is adamant that he has never seen a calendar that covers at least 100 years. He was unable to state the number of possible configurations of the calendar, i.e. 14 different templates. G.C. has two calendars for the present year in his flat. He also saves all of his old diaries. Table 3.7, below, shows G.C. speed and accuracy rates for date calculation between 1850 and 2050. Further date questions indicated that G.C.'s full span ranges from approximately 1840 to 2099. He is also able to calculate date questions in the form "What is the date of the first Wednesday in July 1972?". He has an excellent event-related knowledge of the calendar. For example, he can remember the exact dates of all of the experimenter's previous visits and can provide the dates of Easter Sunday over a wide range of years. He can name the current day and date.

Table 3.7 ***G.C.'s date calculation speed and accuracy rates.***

Date	Response time (in seconds)	Accuracy
1st April 1850	58.8"	Correct
5th November 1873	14.4"	Correct
23rd May 1896	14.2"	Correct
17th September 1903	6.9"	Correct
1st October 1914	3.3"	Correct
25th August 1925	2.1"	Correct
5th July 1939	1.1"	Correct
30th March 1951	1.4"	Correct
15th December 1964	1.1"	Correct
22nd June 1979	2.0"	Correct
3rd January 1993	1.1"	Correct
14th February 1998	0.9"	Correct
4th August 2002	1.8"	Correct
8th July 2016	2.0"	Correct
13th January 2033	6.9"	Correct
11th September 2050	15.0"	Correct

Assessment of intellectual ability.

WAIS-R scaled scores:

Vocabulary	5
Comprehension	4
Block Design	11
Object Assembly	9

(Interestingly, G.C.'s pattern of WAIS-R scores appears typical of an individual with autism)

Digit Span. G.C. has a digit span of 7 items forwards and 3 backwards.

Peabody Picture Vocabulary Test.

G.C.'s verbal IQ was measured at 79.

Ravens Progressive Matrices Test.

His non-verbal IQ is 100.

Assessment of reading ability.

W.O.R.D.

Standard score: 84

Reading age: 12 years 4 months

Calendar words. G.C. is able to read all of the weekdays and months of the year.

Assessment of arithmetical ability.

G.C. was able to answer all of the problems administered in the basic arithmetic test. His slowest response was for the item *25 - 14*, taking 5.8".

Difference judgments.

G.C. was presented with the following item pairs and asked "What is the difference? How many between?". G.C. instantly identified the items as years and was able to respond speedily and accurately.

Table 3.8 *G.C.'s judgment of the difference between years.*

Item 1	Item 2	Answer	Accuracy
1995	1937	58 years (3.2")	Correct
1929	1995	66 years (1.9")	"
1995	1912	83 years (0.9")	"
1882	1995	113 years (2.4")	"
1984	1906	78 years (1.3")	"
1933	1961	28 years (3.9")	"
1882	1960	78 years (1.6")	"

G.C. was then given a series of trials which involved item pairs such as *1,954* and *1,876* and was asked to calculate the difference. He continued to respond as if the items were years, i.e. his answer would be "78 years". However, when the experimenter informed

G.C. that the items were meant to be numbers and not years, he attempted to work out the difference between *1,984* and *1,906*. Although correct, his response took 12.4 seconds. Exactly the same problem had been given previously in the context of the calendar, and G.C.'s response in terms of years took only 1.3 seconds. However, this task was not continued as G.C. suddenly announced that he would "still think of the numbers as years". In other words, it had been established that G.C. can calculate the difference between years and as he was determined to treat the remaining items as calendar items, further testing would not have proved informative about his judgments, specifically in regard to numbers.

Summary description of G.C. Although not formally diagnosed as autistic, G.C. displays social and communicative difficulties together with some repetitive tendencies. He reports taking an interest in the calendar at the age of 14 years and is able to give fragmentary insight into the use of calendar rules. G.C.'s range spans from 1840 to 2099. His basic arithmetic skills are good and he is able to rapidly and accurately calculate the difference between any two years in the present century .

<u>**D.K.**</u>

Background information. D.K. was born on the 6th October 1957. He was diagnosed as autistic at the age of 4 years old. According to D.K.'s mother, his behaviour was noticeably abnormal from the age of 10 months. For example, he was socially withdrawn and did not take an interest in other people. For several years he was preoccupied with red drainpipes, and would insist on trying to search for them in new places. He would place all of his small toys in a specific arrangement on a certain tray and he would often carry strange objects, such as a clothes peg, around with him. After being diagnosed, D.K. attended one term at an ESN school before moving to a small educational unit with two other autistic boys. Since the age of 16 years, he has attended various A.T.C.'s and has been at his current centre for approximately 20 years. D.K.'s life continues to be dominated by verbal rituals and routines. Every morning before he leaves for the centre, his mother must engage in the same verbal interchange with D.K. Varying this discourse by one word will result in his refusal to attend the centre. Every evening, his mother must sit and read through the menu of food served at the centre that day. Disruption of routines will often result in destructive and self-injurious behaviour by D.K. Previously, D.K. has shown a strong interest in the telephone directory and a specific "A-Z" map printed in 1973, which he still talks about.

Calendar knowledge. According to D.K.'s mother, he was first able to provide the day of the week for a given date when he was 12 years old. She has never seen him study a calendar. However, D.K. describes having seen a 100 year calendar in a book, at home. This was at the age of 10 years old. D.K. was adamant that this calendar did not contain dates before 1900 or after 2000. Interestingly, as shown in Table 3.9 below, D.K. can calculate beyond the present century. Specifically, his span ranges from 1870 to 2020. After D.K. was presented with one of the dates, the experimenter asked him how he had worked out the answer by enquiring "what did you think of when I asked you that question?" and "how did you know that it was Monday?". D.K.'s answer was simply "I just knew". Like the other members of the group, D.K. has an excellent memory for calendar-related events, such as the dates of holidays and people's birthdays. He also knows the dates of Easter Sunday within the present century. D.K. was able to answer questions such as "What was the date of the first Thursday in June 1940?". He can name the current day and date.

Table 3.9 ***D.K.'s date calculation speeds and accuracy rates.***

Date	Response time (in seconds)	Accuracy
1st April 1850	-	Unable to answer
5th November 1873	0.5"	Correct
23rd May 1896	3.1"	Correct
17th September 1903	4.5"	Correct
1st October 1914	2.0"	Correct
25th August 1925	2.3"	Correct
5th July 1939	1.4"	Correct
30th March 1951	1.7"	Correct
15th December 1964	1.1"	Correct
22nd June 1979	1.0"	Correct
3rd January 1993	0.9"	Correct
14th February 1998	0.3"	Correct
4th August 2002	2.4"	Correct
8th July 2016	5.4"	Correct
13th January 2033	-	Unable to answer
11th September 2050	-	Unable to answer

Assessment of intellectual ability.

WAIS-R scaled scores:

Vocabulary	2
Comprehension	3
Block Design	5
Object Assembly	6

Digit Span. D.K.'s forward digit span was 7 and his backwards span was 3.

Peabody Picture Vocabulary Test. D.K. obtained a verbal IQ of 66.

Ravens Progressive Matrices Test. His non-verbal IQ was 76.

Assessment of reading ability.

W.O.R.D.

Standard score: 68

Reading age: 9 years 0 months

Calendar words. D.K. could read all of the calendar words.

Assessment of arithmetical ability.

D.K. was able to solve the following problems:

4 + 5 (8.3")

7 + 11 (1'02")

5 - 1 (4.2")

10 - 7 (7.6")

8 + 6 (5.3")

He stated that he did not know the answer to any further problems.

Difference judgments.

D.K. was first of all presented with pairs of numbers, such as *95* and *45*. He was asked "How many between these two? What is the difference?". D.K. appeared not to understand the question. He was then presented with the year items below and exactly the same questions were asked. No indication was given that the items represented years.

Table 3.10 ***D.K.'s judgment of the difference between years.***

Item 1	Item 2	Answer	Accuracy
1995	1984	11 years (1.9")	Correct
1960	1995	35 years (4.3")	"
1995	1912	"Don't know"	Incorrect
1932	1995	63 years (6.4")	Correct
1912	1924	12 years (1.9")	"
1882	1992	"Don't know"	Incorrect
1906	1924	18 years (2.7")	Correct

On the whole, D.K. was able to perform this task with years, although on a number of trials he was unwilling to attempt the task, particularly for more distant years. Following the presentation of the years, D.K. was again given the numbers *95* and *45*. For this pair and for several other trials, he announced that he did not know the answer for any of the numbers.

Summary description of D.K. D.K. is diagnosed autistic. He began to calculate at around the age of 12 years old and reports having seen a 100 year calendar at the age of 10 years. His calculation span ranges from 1870 to 2020. His arithmetical skills are limited to basic addition and subtraction. He is capable of calculating the difference between years within the present century.

J.B.

Background information. J.B. was born in 17th June 1947. She has always attended a series of schools and day centres for clients with learning difficulties. She currently attends her local A.T.C. several days a week and resides in a council-run home for individuals with mental handicap. As with several of the other subjects, it proved difficult to obtain background information on J.B. as there were no direct family informants. In addition, there were no records pertaining to diagnostic information or intellectual assessment held at her home. However, from conversations with staff, it was clear that J.B. had always been regarded as having a general mental impairment, with autism never having been suspected. However, much of J.B.'s behaviour is routinised and rather obsessive. For example, J.B. must have her breakfast cereals, cutlery, dish and napkin placed on the table in a precise arrangement at a specific time every night. This would then be ready for the following morning. She likes to write down the names of all of the songs and artists played on a certain radio station at the same time every day. J.B. also has to do her housework in a set routine, at the exact same time each day. J.B. will occasionally ask inappropriate questions, e.g. "what size shoe are you, dear?" after having just met the experimenter.

Calendar knowledge. J.B. is able to calculate across most of the present century, as shown in Table 3.11 below. Interestingly, J.B. is not always reliable with her calculations. For example, when given the question "What day was the 1st October 1914?", she responded "Saturday" which was incorrect. However, on the following visit she was able to give the correct answer of Thursday. J.B. was questioned about the first calendar she ever saw. She remembered seeing an advent calendar when she was 4 years old. Further questioning revealed that she has always had a calendar, depicting the current year. She also keeps old diaries. No information could be elicited to indicate that she had ever seen a calendar corresponding to the years before she was born. J.B. always volunteers many items of event-related memory in response to certain dates. For example, after calculating a date she remarked that another resident of her household was born in that year. J.B. will also spontaneously state how long ago each date was. For example, after calculating *30th March 1951*, she stated "that was 42 years ago, dear" (in 1993). J.B. is familiar with the dates of Easter Sunday and can name the current day and date.

Table 3.11 ***J.B.'s calculation speed and accuracy rates.***

Date	Response time (in seconds)	Accuracy
1st April 1850	-	Unable to answer
5th November 1873	-	"
23rd May 1896	-	"
17th September 1903	4.5"	Incorrect (responded "Thursday" rather than Monday)
1st October 1914	4.9"	Correct
25th August 1925	3.2"	Correct
5th July 1939	2.7"	Correct
30th March 1951	3.5"	Correct
15th December 1964	3.3"	Correct
22nd June 1979	2.1"	Correct
3rd January 1993	2.6"	Correct
14th February 1998	4.1"	Correct
4th August 2002	-	Unable to answer
8th July 2016	-	"
13th January 2033	-	"
11th September 2050	-	"

Assessment of intellectual ability

WAIS-R scaled scores:

Vocabulary	1
Comprehension	4
Block Design	1
Object Assembly	1

Digit Span. J.B. has a digits forward span of 6 and a backwards span of 4.

Peabody Picture Vocabulary Test. J.B.'s verbal IQ is 59.

Ravens Progressive Matrices Test. This was measured as 48.
(J.B. had been previously tested by Hermelin and O'Connor on the performance scale of the WAIS-R. Her non-verbal IQ was 44).

Assessment of reading ability.

W.O.R.D. Test

Standard score: 54

Reading age: 7 years 0 months

Calendar words. J.B. could read all of the months and days of the week.

Assessment of arithmetical ability.

J.B. correctly answered the following problems.

2 + 2 (3.1")

7 + 5 (4.5")

15 + 10 (3.4")

37 + 6 (5.5")

However, she was unable to solve the following problems. Her answers are shown below.

10 - 3 = 13

7 - 4 = 11

4 x 3 = 16

It would thus appear that J.B.'s arithmetical skills are confined to addition and she is unable to perform subtraction.

Difference judgments.

J.B. was initially presented with *1,995* and *1,960* and asked "What is the difference? How many between these two?". She responded, "35 years, dear" in 1.2 seconds. Presenting the smaller numbers such as *95* and *55* also resulted in J.B. treating these as years. When she was informed that these were not years but numbers she simply read out the numbers rather than offering an answer. However, when J.B. was presented with the year items she obtained the following responses (with 1995 being the current year of testing).

Table 3.12 ***J.B.'s judgments of the difference between years.***

Item 1	Item 2	Answer	Accuracy
1995	1935	60 years (1.8")	Correct
1929	1995	66 years (1.5")	"
1995	1979	16 years (0.9")	"
1882	1995	113 years (6.4")	"
1960	1984	24 years (1.7")	"
1954	1937	17 years (5.0")	"
1929	1947	18 years (1.7")	"

Interestingly, when J.B. was given the two years *1882* and *1933* to calculate the difference, she announced that she could not do this. Rather, she informed the experimenter that one of the years was 113 years ago and the other was 62 years ago. So although she could calculate the difference between a number of year pairs, neither of which represented the current year, she was far better at calculating the difference in relation to the current year of testing.

Summary description of J.B. J.B. does not have a diagnosis of autism, although she does show some repetitive behaviours. Her calculation span ranges across the present century. There is little information regarding her acquisition of calendar knowledge. However, it is known that she has always had one year calendars and she will save old diaries. Although her arithmetical skills are limited to simple addition, she is proficient at calculating the difference between years within the present century.

P.E.

Background information. P.E. was born on the 15th March 1952. There were no problems with his delivery. As a baby, he would cry incessantly. As he grew older, his parents noticed that he appeared to be completely isolated and "would look through people rather than at them". P.E. was an active child and would often wander off. He did not speak his first single words until 4 years old. P.E.'s overwhelming and life long obsession is with tins. This began at the age of two and a half years old when he would go and look through the kitchen cupboards of neighbours and friends. This obsessional interest persists although his parents have limited his collection to antique items. P.E. has to lay out all of his tins in a specific arrangement and will notice instantly if any are disturbed. He will sleep with a number of favourite tins. P.E. is clearly autistic, although he has never received a formal diagnosis. He was one of the first pupils at the Sybil Elgar School in Ealing where he remained until he was 17 years old. Since leaving school, he has attended a series of A.T.C.'s and currently works at a local gardening centre where he pursues his interest in horticulture.

P.E.'s family background is interesting and worthy of mention. His father is an engineer by profession. His mother has been actively involved in the National Autistic Society for over 30 years and has previously published a book on her experiences as the mother of an autistic child. P.E.'s younger brother, who is a civil servant, is dyslexic. P.E.'s father's brother is now regarded as having had Asperger's Syndrome. Interestingly, he would also calculate dates as a young child, although P.E.'s mother is certain that P.E. could not have learned his skills from his uncle.

Calendar knowledge. P.E.'s ability to calendar calculate first emerged at the age of 13/14 years. He had spent the Christmas prior to his fourteenth birthday with his grandmother. Rather than joining in the festivities, he spent the three day period pouring over a three year calendar. This was the only occasion that any of his family could ever remember seeing him study the calendar. Shortly after this, P.E. was able to give the day of the week for dates but not simply within this three year span. Ten years ago, P.E.'s mother bought him a perpetual calendar but this is reported to remain unwrapped. From Table 3.13, it can be seen that P.E.'s span ranges from approximately 1890 to 2050. In fact, P.E. will not calculate any further into the future than 2050. On the experimenter's last testing session with P.E., he stated "5, 6, 6, 11 is 28", after calculating several dates. This obviously refers to the 28 year rule and dates which fall at 5, 6, 6 and 11 year intervals do occasionally fall on the same day. This would suggest that the use of small recursive patterns within the calendar may form part of his calculation strategy. P.E. is equally able to apply his calendar knowledge to questions such as "What was the date of the first Thursday in June 1962?". P.E. can provide the dates of Easter Sunday over a wide range of years. He can name the current day and date. Finally, an anecdote may prove quite telling. Before my second visit to P.E., he was having difficulty in remembering the experimenter. My name did not appear to trigger any recognition. However, as soon as he saw me again for the second time his face lit up and he announced, with a sense of relief, "Aah, 24th July 1968!". He then preceded to inform me of the exact date of my previous visit, the weather on that day and of all the tasks I had asked him to perform. It would thus appear that the experimenter was "referenced" in LTM, not in terms of her name, but in terms of her date of birth. This indicates the degree of saliency and meaning attached to date information by P.E.

Table 3.13 ***P.E.'s date calculation speed and accuracy rate.***

Date	Response time (in seconds)	Accuracy
1st April 1850	-	Incorrect (answered "Thursday" rather than Monday)
5th November 1873	-	Incorrect (gave "Saturday" rather than Wednesday)
23rd May 1896	28.7"	Correct
17th September 1903	17.3"	"
1st October 1914	11.8"	"
25th August 1925	7.6"	"
5th July 1939	3.9"	"
30th March 1951	4.5"	"
15th December 1964	2.7"	"
22nd June 1979	3.4"	"
3rd January 1993	4.4"	"
14th February 1998	1.6"	"
4th August 2002	2.3"	"
8th July 2016	33.8"	"
13th January 2033	14.9"	"
11th September 2050	32.0"	"

Assessment of intellectual ability.

WAIS-R scaled scores:

Vocabulary	4
Comprehension	3
Block Design	10
Object Assembly	9

Digit Span. P.E. has a digits forward span of 6 and a backwards span of 5.

Peabody Picture Vocabulary Test. P.E. obtained a verbal IQ of 78.

Ravens Progressive Matrices Test. His non-verbal IQ was measured at 108.

Assessment of reading ability.

W.O.R.D.

Standard score: 82

Reading age: 12 years 3 months

Calendar Words. P.E. could read all of the months and days of the week.

Assessment of arithmetical ability.

P.E. could perform all of the arithmetical problems taking less than three seconds to solve each one. He even showed the experimenter how he was able to do long multiplication problems for which he needed a paper and pen to perform his calculations.

Difference judgments.

P.E. was given the following numbers and asked "What is the difference. How many between?". His response times are given below in parentheses.

Table 3.14 ***P.E.'s judgment of the differences between numbers.***

Item 1	Item 2	Answer	Accuracy
1,995	1,954	41 (6")	Correct
1,905	1,995	90 (5.0")	"
1,975	1,954	21 (5.8")	"
1,882	1,924	42 (17.4")	"
1,933	1,906	27 (16.2")	"

Clearly, P.E. was able to accurately judge the difference between numbers. None of his answers referred to years. He was then given the items *1995* and *1936* and asked "How many between?". His answer was "59 years" in 4.4 seconds. The following year items were presented:

Table 3.15 ***P.E.'s judgement of the differences between years.***

Item 1	Item 2	Answer	Accuracy
1929	1995	66 years (5.4")	Correct
1942	1887	57 years (6.0")	"
1921	1976	55 years (4.3")	"
1882	1913	31 years(4.4")	"
1933	1906	27 years (4.2")	"

It would appear that for some of the year items, P.E.'s response times were comparable with the numbers given above. However, he was noticeably quicker on the last two items when given in the context of the calendar.

Summary description of P.E. P.E., like many of the other subjects in the sample, is autistic. He has been calendar calculating since he was 13 years old and has a span in the region of 1890 to 2050. He shows some fragmentary knowledge of the 28 year rule. Interestingly, he had an uncle who could calendar calculate. Both his reading and basic arithmetic skills are good and he is proficient at calculating the intervals between years which fall within the present century.

A.T.

Background information. A.T. was born on the 29th May 1963. He currently attends a local A.T.C. for clients with learning difficulties and resides in a council-run residential home for mentally handicapped individuals. A.T. has always attended schools and establishments which support his special needs and has never lived independently. Very little background information could be obtained on A.T. His careworker, who originally contacted the experimenter about A.T.'s ability, left her employment very soon after the research began. She did, however, confirm that A.T. had been diagnosed as autistic when a young child. Further attempts to gain additional background information were unsuccessful. Consistent with his diagnosis, A.T. is highly distractible, asks socially inappropriate and highly repetitive questions and is quite "famous" in the local area for walking up to strangers in the street and asking for many personal details including their birthdays. A.T. proved extremely difficult to test. He was often inattentive and distractible. Indeed, on two occasions he got up and walked out in the middle of a test. Data on A.T. is reported in the thesis only when he was judged to have been concentrating and making a genuine attempt to cooperate.

Calendar knowledge. A.T.'s calculation span encompasses the present century, as shown in Table 3.16 below. He is unable to answer questions of the form "What is the date of the first Tuesday in May 1992?" Although information could not be obtained from his family, A.T. himself volunteered some relevant information regarding his acquisition of calendar knowledge. When asked about the first calendar he ever saw, he stated without hesitation that it was in 1972 and "it was the kitchen calendar, for a whole year". He was then asked when he could first work out the day for each date, so that he did not need to look at the calendar. He stated clearly that it was in 1976 (at the age of 13 years). These same questions have been posed on a number of visits and worded in different ways. They have always received the same answer. In response to the experimenter questioning whether he had ever seen a calendar for 1905, 1998, 1932 etc. he stated that he had not and responded positively only for years which fell between 1972 and the present year. He then added that he had seen a calendar for the following year as it was contained at the back of his wall calendar for the present year. Therefore, A.T. is able to provide at least some information regarding his experience with the calendar and his reports suggest that he has never had access to a perpetual calendar, although this possibility cannot be discounted. Finally, A.T. has a good event-related memory regarding the calendar which he will often combine with his interest in pop music. For example, after being asked to calculate a date he will often inform the experimenter whether any famous musicians died in that year.

Table 3.16 *A.T.'s date calculation speed and accuracy rates.*

Date	Response time (in seconds)	Accuracy
1st April 1850	-	Would not attempt
5th November 1873	21.6"	Incorrect (gave "Tuesday" instead of Wednesday)
23rd May 1896	3.7"	Incorrect (gave "Monday" instead of Saturday)
17th September 1903	9.2"	Correct
1st October 1914	11.4"	"
25th August 1925	3.6"	"
5th July 1939	6.5"	"
30th March 1951	4.6"	"
15th December 1964	2.4"	"
22nd June 1979	4.1"	"
3rd January 1993	3.3"	"
14th February 1998	5.9"	"
4th August 2002	19.0"	"
8th July 2016	-	Unable to answer
13th January 2033	-	"
11th September 2050	-	"

Assessment of intellectual ability.

WAIS-R scaled scores:

Vocabulary	1
Comprehension	3
Block Design	1
Object Assembly	1

Peabody Picture Vocabulary Test. A.T. obtained a verbal IQ of 51.

Ravens Progressive Matrices Test. A.T. could not seem to grasp what he was supposed to do on this test and pointed randomly at the choice of answers.

Digit Span. A.T. has a digits forward span of 4 and a digits backward span of 2.

Assessment of reading ability.

W.O.R.D. Test

Standard score: 55

Reading age: 7 years 0 months

Calendar words. A.T. had no difficulty in reading the months and days of the week.

Assessment of arithmetical ability.

A.T. answered the following sums correctly. Response time is given in parentheses.

2 + 2 (4.5")

4 - 1 (7.3")

7 - 2 (12.4")

A.T. gave the following incorrect answers.

3 + 4 = 9 (15.8")

11 + 7 = 17 (22.2")

13 - 9 = 1 (15.6")

It is clear that A.T. is able to perform only the most simple arithmetical calculations. He has to count on his fingers to work out every answer and for the sums which involved counting above 10, he got hold of the experimenter's fingers to continue his counting.

Difference judgments.

The pairs of year items shown below in Table 3.17 were placed in front of A.T. and he was asked "How many between these two? What is the difference?". A.T.'s responses indicated that he had immediately perceived the items as years. 1995 represented the current year of testing.

Table 3.17 *A.T.'s judgment of the difference between pairs of years.*

Item 1	Item 2	Answer	Accuracy
1960	1995	35 years (6.4")	Correct
1995	1971	24 years (9.0")	"
1942	1995	53 years (11.3")	"
1991	1947	44 years (16.8")	"
1939	1977	37 years (1'00")	Incorrect
1959	1921	36 years (1'22")	"

A.T.'s responses indicate that he can calculate the difference between years much more efficiently than his performance on the basic arithmetical problems would predict. Also, when calculating the difference between the years, A.T. made no attempt to count on his fingers. However, he was not able to calculate all of the trials and offered close but incorrect answers for two trials which did not involve the current year of testing. A.T. was then presented with the items *1,995* and *1,973* and asked "How many between these? What is the difference?". He responded that he "did not know numbers" and would make no attempt on any of the trials, even for the lower numbers such as *95* and *65*.

Summary description of A.T. A.T. is diagnosed as autistic. He is an able calendar calculator whose span ranges from 1900 into the early years of the 21st century. From his own reports, he became interested in the calendar at the age of 13 years. His arithmetic skills are very basic and he needs to count on his fingers in order to solve simple addition and subtraction problems (and will often miscount). However, his ability to generate the difference between years within the present century contrasts with his less able performance in the numerical domain.

J.P.

Background information. J.P. was born on the 30th November 1965. He was diagnosed as autistic at the age of four and a half years old. He showed a marked lack of interest in social interaction and speech was delayed with first words spoken after the age of 2 years. As a young child, he would line up toy cars from one corner of the room to the other. At the age of 5 he became highly preoccupied with dustbins and would cross the street, irrespective of the danger, to look inside any dustbins he had spotted. His life was dominated by routines. For example, if his mother took him a different route to school, he would sit on the pavement and scream. J.P. has attended various ESN schools and two units for autistic children. Since leaving his last N.A.S. school at the age of 19 years old he has attended a number of A.T.C.'s.

Calendar knowledge. J.P. can calculate from 1850 to approximately 2020, as shown below in Table 3.18. J.P. was reported to have always shown an interest in people's birthdays and the calendar in general. J.P.'s mother also observed that he was very interested in anything to do with numbers. At the age of 17 years old, he was given a perpetual calendar. This spanned the years 1850 to 2050. Shortly after receiving the calendar, J.P. was observed to sit and copy out pages of calendar configurations. In an attempt to explore J.P.'s insight into the calculation process, he had been asked on several occasions "What did you think of when I asked you that date? How did you know that it was a Saturday?". For the most part, J.P. would be unable to answer. However, during the last testing session several of his answers are important to note. For example, after calculating ***30th March 1951***, he was asked the above questions regarding his method. He answered "it's like 1979, it's on page 10". J.P. gave a very similar answer about a date in 1964, "it's like 1992". J.P. is therefore aware that certain years (at 28 yearly intervals) share the same calendar structure. References to page numbers would also suggest that J.P. has memorised the format of his perpetual calendar and retains the representations of the different calendar templates in LTM. Interestingly, J.P. is the only calculator in the group who, when unable to give an answer to a date question, will say "I can't *remember*". The other savants will say "I don't *know*" or "I can't *do* that one". However, it should be noted that, in general, J.P. takes longer to calculate dates which are further away from the present day. O'Connor and Hermelin (1984) regarded this as evidence against a strategy based purely on memorisation. In the case of J.P., it could be argued that dates closer to the present day represent more practised items and thus the calendar configurations which correspond to these years are located much more rapidly in LTM. J.P.'s lack of interest and practice with distant dates is confirmed by the fact that he is unable to calculate dates in 2033 and 2050, years which are both included in his calendar. Also, it should be noted that J.P. was unable to answer date questions in the form "What was the date of the first Monday in July 1933?". Finally, J.P. has an impressive memory for events related to dates. He is familiar with the dates of Easter over the present century. He can also remember all of the dates of the experimenter's visits and her date of birth. He can name the current day and date.

Table 3.18 ***J.P.'s date calculation speeds and accuracy rates.***

Date	Response time (in seconds)	Accuracy
1st April 1850	10.0"	Correct
5th November 1873	13.0"	Incorrect (gave "Saturday" instead of Wednesday)
23rd May 1896	50.1"	Correct
17th September 1903	9.7"	"
1st October 1914	5.6"	"
25th August 1925	4.4"	"
5th July 1939	2.4"	"
30th March 1951	4.5"	"
15th December 1964	3.7"	"
22nd June 1979	4.1"	"
3rd January 1993	3.3"	"
14th February 1998	15.6"	"
4th August 2002	9.9"	"
8th July 2016	42.2"	"
13th January 2033	-	Unable to "remember"
11th September 2050	-	"

Assessment of intellectual ability.

WAIS-R scaled scores:

Vocabulary	3
Comprehension	3
Block Design	4
Object Assembly	3

Digit Span. J.P. obtained a digits forward span of 5 and a digits backward span of 5.

Peabody Picture Vocabulary Test. J.P. obtained a verbal IQ of 44.

Ravens Progressive Matrices Test. J.P.'s non-verbal IQ was 58.

Assessment of reading ability.

W.O.R.D.

Standard score 64

Reading age 8 years 8 months

Calendar words. J.P. could read all of the months and weekdays.

Assessment of arithmetical ability.

J.P. answered the following sums correctly. Response times are given in parentheses.

4 + 5 (2.2")

7 + 11 (8.8")

5 - 1 (0.8")

10 - 7 (0.9")

8 + 16 (10.2")

25 - 14 (20.4")

2 x 3 (6.1")

3 x 8 (10.4")

However, he gave the following incorrect answers:

4 x 25 = 30 (11.9")

24 divided by 3 = 27 (1.9")

36 divided by 4 = 40 (3.5")

Thus, J.P. possesses good basic arithmetical skills. However, these do not extend to the multiplication of larger numbers or to division problems.

Difference judgments.

Interestingly, J.P. was the only subject within the group unable to judge the difference between years. For example, when given 1995 and 1961 and asked "How many between? What is the difference?", he responded (incorrectly) "33 years" after 57.3 seconds. On another trial, when presented with *1939* and *1953*, he answered "35 years" in 1'02". J.P. was clearly counting the individual years between the two target items as he could be heard to say "1939, 1949, 1941..." until he reached 1953. This was accompanied by him counting on his fingers. His performance thus stands in marked contrast to that of the other subjects. When given the equivalent numerical items, J.P. adopted the same strategy of counting the individual numbers between the two items.

Summary description of J.P. J.P. received a diagnosis of autism as a young child. He is reported to have always shown an interest in numbers and dates and was bought a perpetual calendar at the age of 17 years. J.P.'s verbal reports suggest that he has memorised pages from this perpetual calendar. He has an impressive calculation span of 170 years. Although his basic arithmetical skills are competent, he is unable to calculate the difference between years in the present century.

M.W.

Background information. M.W. was born on the 25th December 1978. In approximately the eighteenth week of pregnancy his mother contracted rubella. As a baby, M.W. displayed poor feeding and sleeping behaviour. He did not speak his first words until the age of 4 years. At this time, M.W. was reported to be obsessed with exact times and his behaviour was extremely routinised. M.W. has been diagnosed as autistic and attends a school for children with behavioural problems and learning difficulties. His behaviour in class has on occasions been socially disruptive. M.W. was tested for the first two experiments in the present investigation. Whilst his cooperation could be obtained for any task involving date calculation, after Experiment 2, he was unwilling to participate in any more tests of memory. In addition, further attempts to gain access to M.W. proved problematic.

Calendar knowledge. M.W. was reported by his mother to have become interested in calendars at the age of 6 years old and at this age could provide the day of the week for a given date. He also became fascinated with numbers at the same time. His calculation span ranges from approximately 1880 to 2060. For example, he could calculate a date in *2057* but not in *2068*. His calculation span and response times are illustrated below in Table 3.19. M.W. can answer date questions of the form "What date was the second Tuesday in June 1992?" and can name the current day and date.

Table 3.19 ***M.W.'s date calculation speed and accuracy rates.***

Date	Response time (in seconds)	Accuracy
1st April 1850	-	Unable to answer
5th November 1873	-	"
23rd May 1896	6.9"	Correct
17th September 1903	7.3"	"
1st October 1914	4.7"	"
25th August 1925	7.2"	"
5th July 1939	2.9"	"
30th March 1951	3.2"	"
15th December 1964	1.9"	"
22nd June 1979	2.1"	"
3rd January 1993	2.3"	"
14th February 1998	3.9"	Incorrect (gave "Monday" instead of Saturday)
4th August 2002	4.9"	Correct
8th July 2016	5.2"	"
13th January 2033	4.8"	"
11th September 2050	-	"

Assessment of intellectual ability.

WISC-III scaled scores:

Vocabulary	6
Comprehension	1

Block Design	9
Object Assembly	10

Digit Span. M.W. obtained a digits forward span of 6 and a backwards span of 5.

Peabody Picture Vocabulary Test. M.W.'s verbal IQ was 76.

Ravens Progressive Matrices Test. His non-verbal IQ was 92.

Assessment of reading ability.

M.W. was not assessed using the W.O.R.D. However, he is known to be able to read all of the days of the week and months of the year.

Assessment of arithmetical ability.

M.W. was able to answer all of the arithmetic problems presented to him, including the multiplication and division sums. His longest response time was for *36 divided by 4* which took 3.8 seconds.

Difference judgments.

M.W. was given the following items which comprise both years and numbers. The number of trials was kept to a minimum to ensure M.W.'s continued cooperation.

Table 3.20 ***M.W.'s judgment of the differences between pairs of years and numbers.***

Item 1	Item 2	Answer	Accuracy
1992	1937	55 years (4.2")	Correct
1929	1945	16 years (2.9")	"
1882	1915	33 years (2.4")	"
1,992	1,978	14 (2.4")	"
1,903	1,981	78 (2.3")	"
1,944	1,887	57 (3.9")	"

Thus, M.W. appears equally able to calculate the difference between years and between numbers. Importantly, his responses indicated that he had not treated the numbers as if they were year items.

Summary description of M.W. M.W., diagnosed as autistic, is an efficient calendar calculator. He was reported to have taken an interest in the calendar at the age of 6. Although the youngest savant in the group, his speed and range of calculation appears to be comparable with that of the other subjects. His basic arithmetic skills are impressive and he is equally able to calculate the difference between year and number pairs.

H.P.

The final subject, H.P., is the most outstanding date calculator of the group. His calculation range far exceeds that of the other savants and rivals the spans of the most impressive cases in the literature. H.P. also possesses remarkable numerical skills.

Background information. H.P. was born on the 29th December 1965. There were obstetric complications resulting in H.P. being born placenta priva. He was an overactive child, needing no more that three hours sleep a night. At the age of two and half, H.P. was described as having an "incredible appetite to learn". He was taught to read at this age by his mother and he would prefer to read flash cards and books rather than play other games. He never played with other children, preferring to occasionally observe rather than ever approach them. He would seem oblivious to danger and at the age of three years was found walking on the apex of the garage roof. At the same age, he was discovered lying under the family car trying to find out how it worked. H.P.'s verbal communication was so limited that deafness was queried. As H.P. grew older his utterances were confined largely to his areas of repetitive interest. His speech was also characterised by echolalia and stereotyped phrases. At the age of four years, H.P. was referred to an educational psychologist who, on the basis of a series of cognitive tests, judged him to be a "normal child". From the age of four years, H.P. attended a mainstream school, where his teachers quickly noted his lack of interest in social interaction, describing him as being "in a world of his own". At seven years old, H.P.

was finally diagnosed as autistic. From this age, he attended a series of special schools for individuals with mild learning difficulties. At the age of 18 years, H.P. had managed to gain four C.S.E. qualifications in Mathematics, English, History and Geography. For the previous six years, H.P. has attended a local Adult Training Centre for individuals with learning difficulties. H.P.'s current behaviour remains highly typical of an individual with autism. His behaviour is often socially inappropriate, for example, he recently "tittered" through his grandmother's funeral. He obsessively collects vinegar, salt and sugar sachets from restaurants, which are stored in plastic bin liners in his bedroom. He repetitively picks at the surface of objects, removing tiny particles of fluff and dust. His verbal interchanges could never be described as conversational. Rather, they are confined almost solely to his repetitive interests.

Family background. H.P. has a brother, two years his junior, who has gained a BA in Sociology and a M.A. in Social Studies. He is reported to be good at Mathematics and Computer Studies. He is also dyslexic. H.P.'s mother's was previously a book-keeper and his father is a carpet shop manager. Neither report any outstanding numerical competence. A second cousin of H.P.'s has a Ph.D in physics.

Calendar knowledge.

Acquisition of calendar knowledge. Over the course of the experimenter's meetings with H.P., he has progressed from being unable to provide any form of verbal report regarding his method of calculation to providing the most highly informative statements about his strategy. When asked initially about the first calendar he ever saw, H.P. stated that he could not remember. However, the same question repeated at a later date yielded the following information. He remembered looking at the kitchen calendar for the year 1972. This was confirmed by H.P.'s mother who had noticed him looking at this calendar, although it was never removed from the wall. H.P. would have been 6 years old at this time. When asked what he had noticed about this particular calendar H.P. replied "that the 6th, 13th, 20th and 27th were on the same day... if the 6th fell on a Wednesday then the 31st would be on a Sunday...I wanted to look at February and March in 1971... for 1973 I just add on one day". H.P.'s mother does not remember seeing him ever studying any other specific calendar. From his statement, it would appear that H.P. had extracted a number of small regularities from the calendar concerning the patterns of dates. However, the possibility cannot be discounted that H.P.'s present knowledge of the calendar is influencing his recall of this early experience with dates. H.P. was reported to have began calculating dates in 1972/73.

Knowledge of calendar structure. H.P. possesses extensive factual knowledge concerning the structure of the calendar. When asked about months that share the same date structure he stated:

> "January is the same as October but not in a leap year..., February is the same as March and November but not in a leap year... April and July are the same... September and December are the same."

Concerning the change from the Julian to Gregorian calendar, as mentioned in Chapter 2:

> "In 1582 France and Italy changed... In 1752 England did it... Julius Caesar altered the calendar in 46BC, this was the 'Year of Confusion'... calendars were only the same in Europe in 1923... Turkey was the last to change."

Regarding leap years:

> "because the Earth's year is 365.24219878 days long... that is why we have to have an extra day every four years... I don't think we should have a leap year in 4,000 or 8,000 or every 4,000 years... I read this in the Guiness Book of Records".

Concerning cycles of the calendar:

> "400 years are the same... 28 years are the same".

When his knowledge of calendar templates was explored by asking questions such as "How many kinds of year are there? Think about how the different years begin on different days...". H.P. was unable to answer these questions even after he was given an example of a number of different calendar templates. With regards to Easter, H.P. can name the dates of Easter Sunday over a period of 447 years. He reports having "read it in a book" and his mother confirmed that they did have an almanac at home which lists each of the individual dates of Easter from 1753 to 2199. It is clear that H.P. possesses extensive knowledge of the structure of the calendar which he can verbally state. It would appear that most of his knowledge has been derived from books, although when he was asked how he knew about the 28 year repetition, he stated that he had "worked it out myself".

An interest in dates. H.P. has always been interested in people's birthdays and can remember the dates of all the holidays and trips he has ever been on. An unfortunate incident occurred when H.P. joined his current A.T.C. On his first day he wandered into the office and began to read the confidential records concerning the clients and staff. He quickly memorised all of the dates of birth for these individuals, together with the dates on which they joined the centre. He can still recite this confidential information today. He has always remembered the experimenter's birthday which was told to him only once on her first visit.

Calculation speed and range. Table 3.21 below shows the time taken for H.P. to calculate the different dates spanning 1850 to 2050.

Table 3.21 *H.P.'s date calculation speed and accuracy rates.*

Date	Response time (in seconds)	Accuracy
1st April 1850	2.3"	Correct
5th November 1873	3.0"	"
3rd May 1896	3.6"	"
17th September 1903	7.7"	"
1st October 1914	1.7"	"
25th August 1925	4.9"	"
5th July 1939	2.6"	"
30th March 1951	4.5"	"
15th December 1964	4.8"	"
22nd June 1979	1.5"	"
3rd January 1993	2.5"	"
14th February 1998	1.3"	"
4th August 2002	2.2"	"
8th July 2016	1.7"	"
13th January 2033	2.7"	"
11th September 2050	4.7"	"

In addition to the above examples, H.P. was presented with the following dates for calculation. These are shown below together with his verbal reports, elicited by the experimenter.

7th January 613. H.P. gave the correct response in 50.8". He was then able to provide the following details:
"976 is the same as 1972... 976 take away 420 is 556... add on 56 is 612 and add on another year... 613 is the same as 1973 but I wanted to do it for 1972". This may need a little clarification. The significance of *420* is that it is an extension of the 28 year rule and corresponds to 28 x 15. Also, *56* in H.P.'s calculation refers to the 28 year repetition. He clearly possesses knowledge of years which share the same calendar structure and utilizes multiples of 28 to aid the calculation. It was interesting that he

preferred to perform the calculation in relation to the year *1972* (which relates to the year of his first calendar) rather than *1973* which he reports shares the same calendar structure as 613.

2nd February 2222. H.P. gave the correct response in 3.0". He then stated "1974 was the same as 1822... 2222 was the same as 1974". This suggests that H.P. had utilized his knowledge concerning the links between certain years in terms of their calendar structure (i.e. 1974 and 1822) and he had then used the 400 year calendar repetition to generate the day in 2222.

3rd April 3090. H.P. gave the correct response in 4.2". After much prompting, he stated "1974 to 1890 add on 1,200". The difference between 1974 and 1890 is 84 which is divisible by 28. The difference between 1890 and 3090 is 1,200 which is divisible by 400. Thus, H.P. is again using his knowledge of the structure of more recent years (i.e. 1974) together with the 28 year and 400 year cycles to generate the answers.

10th September 1548. H.P. gave the correct answer in 11.6". He then stated "1536 and 1564 are the same as 1972... 1548 is the same as 1984".

23rd March 15,460. He gave the correct answer in 74". H.P. was unable to provide any insight into how he had performed this calculation. His answer revealed that he had not treated the years 4,000, 8,000 and 12,000 as leap years. This was consistent with his verbal report concerning calendar structure, listed above.

H.P.'s date calculation method. Further testing revealed that H.P. can calculate as far back as 10AD and would not attempt to calculate a date in the year *001AD*. His calculation abilities have been tested as far into the future as the year 25,000 and he was correct on all of these dates, once adjusted for his refusal to treat years at 4,000 year intervals as leap years. In the most recent testing session, H.P. also stated that he had memorised 28 years of the calendar, which he specified as being between 1972 and 2000. His verbal reports listed above would confirm the fact that most of his distant calculations are performed in relation to his knowledge of more recent years such as 1972 and 1974.

Using his knowledge of the 28 year and 400 year repetitions in the calendar he is then able to calculate the yearly structure of the target year in relation to years which fall within his familiar 1972 to 2000 year span. Importantly, however, H.P.'s date calculation abilities cannot be explained without reference to his extraordinary numerical abilities. Before a description of his arithmetical skills is given, his performance on the various intelligence measures will be noted.

Assessment of intellectual ability.

WAIS-R scaled scores:

Vocabulary	6
Comprehension	3
Block Design	10
Object Assembly	10

Digit Span. H.P. obtained a digits forward span of 8 and a digits backward span of 7.

Peabody Picture Vocabulary Test. H.P. obtained a verbal IQ of 80.

Ravens Progressive Matrices Test. He obtained a non-verbal IQ of 102.

Assessment of reading ability.

W.O.R.D.

Standard score: 93

Reading age: 15 years 4 months

Calendar words. H.P. had no difficulty in reading the months and days of the week.

Assessment of numerical ability.

An interest in numbers. Virtually all of H.P.'s interests involve numbers. In the past, he would memorise number plates and would be able to match licence plates with the area of the country from which they originated. He is able to name the circulation numbers of many newspapers. He is very interested in football and will often watch the sport with his father and brother. However, his interest is limited to the scores of each match and the times at which the goals were scored. H.P. can recite the F.A. cup final scores at least as far back as 1923.

Numerical calculation. H.P.'s numerical skills are extraordinary. As a young boy, he was reported to have been able to multiply three digit numbers as quick as an electronic calculator. Although his numerical ability has not been explored in the same detail as his calendrical skills, nevertheless, many examples of his current arithmetical performance have been noted. The following problems are among those presented to H.P. during the experimenter's visits. H.P. never uses a pencil and paper to perform his calculations. H.P. was correct on all of the following problems. Time taken to complete the sums is shown in brackets.

Table 3.22. ***Mathematical problems solved correctly by H.P. (time taken is given in parentheses).***

29 x 27 (2")
47 x 47 (3")
46 x 59 (8")
89 x 89 (7")
134 x 134 (15")
239 x 239 (20")
476 x 476 (22")
√841 (6")
√18,496 (2")
√233,289 (34")

Prime numbers. H.P.'s particular fascination is with prime numbers. He is aware that the experimenter possesses a list of prime numbers, generated as a computer printout, from which she checks his accuracy. He is captivated by this list and states that he never knew such things existed. Although he has read about prime numbers in his encyclopedia, this did not give a list of examples. After first seeing the list, H.P. attempted to construct his own by writing all of the primes from 1 to 2,000 around the corners of the front page of a newspaper. That he is able to calculate primes rather than memorise them from a list is illustrated in the following workings taken from his verbal reports. This work on prime numbers took place across a number of sessions. All of the following answers are correct unless otherwise stated and time taken to provide the answer is given in parentheses.

> When asked to give the prime number nearest to **2,000**, he was able to give 1,999 (3").
>
> For the nearest prime to **3,600**, he gave 3,601 which was incorrect. However, he could then provide the two correct answers of 3,593 and 3,607 in seconds.
>
> In 25", he was able to give the next prime after **5,000** which was 5,003.
>
> When asked if **3,367** was prime, he answered that it was not in 3.2".
>
> He was able to identify **4,517** as being prime in 34.7".

The following examples are all taken from the last two visits with H.P. Over the course of the investigation, the experimenter had made many attempts to probe the method used by H.P. to identify primes. For example, he was often asked "How do you know that was a prime?... What did you think of when I gave you the number?... Why isn't it a prime?" This constant questioning appeared to have been worthwhile, when on the last two sessions H.P. began to volunteer fragmented insights. These are transcribed below, along with the relevant problems.

> **6,907** - Identified as a prime in 5.5". H.P. stated that it "looked like a prime". When asked, he said that he had never come across it before.
>
> **6,867** - Identified as a non-prime in 11". This was his explanation. "7 will go into 343... 343 x 20 = 6,860... 6860 + 7 = 6,867". He later added that "3 will go into 684 and 6,840 + 27 = 6,867".

8009 - Identified as a prime in 13.7". H.P. reported that 3 "did not go into it", neither did 7 or 11. After this he said "it felt like a prime".

8,889 - Identified as a non-prime in 3.3". H.P. noted that "3 will go in it".

9,001 - Identified as a prime in 3". "I've calculated this one before" was the explanation H.P. gave for his speed of response.

9,859 - Identified as a prime in 11". H.P. gave the following explanation with the bracketed text provided by the experimenter; "3 and 7 won't go into it... 11 won't go into 9,870 (9,870 - 11 = 9,859)...13 won't go into 982 and 13 will go into 39 (982 x 10 = 9,820. 9,820 + 39 = 9,859). Thus, H.P. had attempted to divide the number by 3, 7, 11 and 13 before deciding it was a prime.

When asked for the nearest prime to **10,000**, H.P. said 9,991. Within five seconds he had corrected himself by saying "no, 97 and 103 will go into it". He then offered the correct answer of 9,973 within a further 10".

When asked to give a prime between **10,500** and **10,600**, he gave 10,511 in 5.7". H.P. explained that it was not divisible by 3 and 7. In reply to the question "How do you know it can't be divided by 11 and 13?" he replied, "13 will go into 611 and 10,511 - 611 = 9,900 and that can't be divided by 13".

H.P.'s numerical calculation strategy. It would appear from these examples that H.P. uses a combination of strategies. It is clear that he is able to apply Eratosthenes' method, by which the target number is divided by all of the prime numbers up to its square root (see Chapter 1). In this respect, he resembles the prime number calculator reported by Hermelin and O'Connor (1990b) and the great mental calculators (Smith, 1983). It is possible that H.P. has read about this method in an encyclopedia, as this is where he reports first reading about the label of "prime". However, the possibility that he worked out this method by himself cannot be discounted. It would also appear that he has an excellent ability to "segment" numbers into their constituent amounts and operates on determining whether these smaller units of the total number are divisible by the relevant primes. Without question he can rapidly access the factors of specific numbers, particularly those of the fragmented components of the target numbers. Thus, it would seem that memory plays an essential role, whereby H.P. is able to retrieve, at speed, information pertaining to the numbers which divide into certain figures. Along the lines of the reasoning suggested in Chapter 1, it can be suggested that H.P. possesses a highly organized LTM for numerical information, which is structured according to the number system; the properties of, and relationships between numbers. This has developed as a result of his preoccupation with numerical and statistical information from a very early age. Finally, H.P. appears to have a sense of intuition about certain numbers, reporting that "it feels like a prime". Interestingly, a similar facility is found in some of the great mental calculators (Smith, 1983).

Summary description of H.P. H.P. possesses detailed knowledge of the calendrical structure of certain years, specifically the 28 year period between 1972 and 2000. Importantly, his numerical skills appear to subserve his date calculation ability, in that he can rapidly calculate multiples of 28 and 400 to map apparently endless periods of the calendar. The use of these calendar repetitions would then match any distant date with an equivalent date within his well-practised 28 year span. In theory, H.P. possesses a calculation range which could extend into infinity. However, these sophisticated mental operations contrast markedly with H.P.'s skills in other areas. He is diagnosed as autistic, attends an A.T.C. for individuals with learning difficulties and has never been able to live independently.

Summary of Findings.

Table 3.23, below, represents a summary of the WAIS-R scaled scores, Peabody Picture Vocabulary IQ's, Ravens Progressive Matrices IQ's, digits forward and backward spans and the diagnoses of the subjects. Table 3.24, below, contains summary information relating to the calculation ability of each of the savants. This illustrates the age at which the subjects first began to calendar calculate, the mean response time taken to calculate dates across the 20th century and their calculation spans (in years). The mean calculation times were averaged from those listed in the individual subject descriptions. It should be noted that H.P.'s calculation span is given as 25,000 years which represents a rather conservative estimate.

The relationship between calculation ability and intelligence measures. Spearman's Rho correlation coefficients were calculated for the various IQ measures and digit span lengths with the savants' calculation speeds and ranges. The full intercorrelation matrix is given in Appendix A. A non-parametric test was selected because of the possible distorting effect of H.P.'s apparently infinite span. A significant correlation coefficient was obtained between calculation speed and digit span forwards (r = -.64, n = 10, p <.05). Calculation speed did not correlate significantly with any of the other IQ measures. The absence of a relationship between calculation speed and intelligence is consistent with previous findings by O'Connor and Hermelin (1984). Thus, it would appear that the most intelligent calculators are not necessarily the fastest calculators. The presence of a correlation between digit span forward and calculation speed is interesting. This indicates that an enhanced ability to retain numerical information in a short-term store aids the efficiency with which the appropriate weekday can be accessed or generated. The role played by STM in savant date calculation is explored further in Experiment 1.

Calculation range was found to correlate with the Wechsler vocabulary subtest (r = .89, n = 9, p<.01), the block design subtest (r = .76, n = 9, p<.05) and object assembly (r = .74, n = 9, p<.05). Contrary to the findings of Hermelin and O'Connor (1986), calculation range does not correlate with general measures of IQ. This suggests that specific aspects of processing information (such as that measured by the block design test), rather than *general* intelligence (as measured on the Ravens Progressive Matrices Test), may play a role in savant date calculation. This would certainly fit with the ideas of Pring et al. (1995) concerning the relationship between savant talent and autism. However, the correlation between vocabulary score and calculation range is more of a challenge to interpret. Specifically, it needs to be explained why the Wechsler vocabulary test and not the P.P.V.T. correlates with calculation range. A discussion of this point will be deferred until the final chapter.

Conclusions

What conclusions can be drawn from this investigation of the savants' intellectual and calculation abilities? Listed below are the summarised points:

1) The diagnosis of these individuals appears to be an important factor. Seven out of the 10 individuals are diagnosed as autistic, with another subject regarded as having "social and communication difficulties". The remaining two savants show some autistic-like tendencies. Furthermore, the intellectual profiles of most of the savants are consistent with the general pattern of performance displayed by individuals with autism, i.e. non-verbal measures are superior to verbal measures.

2) The age at which these individuals acquire their calendar skills appears to vary from the age of six to 17 years.

3) Only one of the subjects reports ever having seen a perpetual calendar. However, the possibility remains that some of the individuals, for whom parental information was not available, have previously had access to such a device and did not report this information.

4) The basic arithmetical skills of the group range from an inability to perform simple subtraction to the ability to generate five digit prime numbers.

5) Even if basic arithmetical competence is limited, the subjects are often able to calculate the difference between years within the present century, rapidly and accurately.

6) All subjects are able to name the current day and date.

7) All of the savants are able to read the days of the week and months of the year, even if they are unable to read any other words.

8) Every single member of the group is reported by parents or carers to possess an excellent memory for date related information.

9) A number of the savants are reported by parents to have always shown an interest in numerical information.

10) With regard to calculation ability, all of the subjects showed an increase in calculation time according to the distance of the date from the present day. This is consistent with the findings of O'Connor and Hermelin (1984).

11) There was no relationship between the intelligence levels of the savants and their speed of calculation. Again, this was consistent with previous findings (O'Connor and Hermelin, 1984). However, short-term memory performance, as measured by digit span forwards, was associated with faster calculation times.

12) The relationship between calculation span and intelligence was rather more complex. Size of span did not correlate with performance on the Ravens Progressive Matrices Test, often regarded as a pure measure of "g". Neither did size of calculation span correlate with verbal IQ as obtained on the Peabody Picture Vocabulary Test. Rather, calculation range was associated with performance on the vocabulary, block design and object assembly subtests from the Wechsler intelligence scales. This may provide tentative support for the suggestions of Pring et al. (1995) concerning the relationship between savant ability and specific aspects of cognitive processing (or processing style).

These summarised points will be discussed in the final chapter, in the light of the results from the following experiments investigating savant memory performance.

Table 3.23 ***Summary of subjects' performance on IQ measures, digit spans and details of diagnosis.***

	Wechsler Intelligence Scales Subtests (scaled scores)				IQ measures		Digit span length		
Subject	Vocab	Comp	B.D.	O.A.	P.P.V.T	Ravens	Forwards	Backwards	Diagnosis
P.M.	2	1	4	1	55	58	4	0	Not autistic
R.D.	-	-	-	-	64	73	4	3	Autistic
G.C.	5	4	11	9	79	100	7	3	Social and communication difficulties
D.K.	2	3	5	6	66	76	7	3	Autistic
J.B.	1	4	1	1	59	48	6	4	Not autistic
P.E.	4	3	10	9	78	108	6	5	Autistic
A.T.	1	3	1	1	51	-	4	2	Autistic
J.P.	3	3	4	3	44	58	5	5	Autistic
M.W.	6	1	9	10	76	92	6	5	Autistic
H.P.	6	3	10	10	80	102	8	7	Autistic

Table 3.24 ***Age at which subjects first began to calculate, mean calculation time for 20th century dates and calculation span.***

Subject	Age at which subject began to calculate	Mean calculation time for dates in 20th century (in secs)	Calculation range (in years)
P.M.	17 years	5.74	170
R.D.	9 years	5.01	100
G.C.	14 years	2.21	260
D.K.	12 years	1.66	150
J.B.	Not known	3.30	100
P.E.	13/14 years	6.35	160
A.T.	13 years	5.67	105
J.P.	17 years	5.92	170
M.W.	6 years	4.44	180
H.P.	7 years	3.50	25,000

CHAPTER FOUR

A PRELIMINARY INVESTIGATION OF MEMORY IN THE CALENDAR SAVANT

Overview

Over the years, several explanations of savant calendar calculation have been suggested. For example, visual imagery may be implicated in the methods of a small number of savants, others may utilize calendrical rules and regularities. However, *all* of the proposed methods depend to a large extent on the storage of calendar information in LTM. Indeed, for many authors, the skill is entirely explicable in terms of the rote memorisation of date information (e.g. Hurst and Mulhall, 1988; Hill, 1975). However, of key importance is the fact that none of these studies have gone on to further investigate the nature of the memory ability which underlies this unusual skill. Furthermore, all of the studies in the date calculation literature have required subjects to *calculate* the dates. Although this approach has been used ingenuously in several studies (e.g. Hermelin and O'Connor, 1986; Young and Nettelbeck, 1994), arguably, it is now limited with regards to furthering our understanding of date calculation. As a result, the present experiments seek to adopt an alternative research approach, requiring subjects to remember calendar-related information in the absence of the date calculation process. This may provide a valid and insightful means with which to explore savant calendrical ability.

Within the present chapter, three aspects of savant memory performance were investigated. First, short-term memory for both digits and words. This followed from Spitz and LaFontaine's (1973) finding of a savant superiority, in relation to mentally handicapped controls, for the forward recall of digits; a finding which suggests that enhanced STM may be one component of savant talent. Second, the long-term recall of both words and calendar-related information was explored. Importantly, both of these studies compared the performance of savant calendar calculators with that of an IQ matched control group. As was noted in Chapter 2, the use of a control group is unique in the date calculation literature and is possible only because memory rather than calculation is under investigation. However, the process of date calculation was included in the third experiment which examined the savants' memory for dates following both calculation and study conditions. Of interest was whether the calculation of a date would lead to better retention when compared to the study/reading of a date. Taken together, the results of these investigations are expected to contribute to a more detailed and integrated understanding of memory in the calendar savant.

Experiment 1: Short-term Memory for Digits and Words

Introduction

Short-term memory (STM) is generally taken to refer to the retention of information in a temporary store which is suggested to have a limited capacity (usually about seven items) and a limited duration. STM is often measured by span tests in which individuals repeat back a series of items immediately after they have been presented, retaining their exact order of presentation. Interestingly, a correlation was obtained for the present group of savants, between digits span forwards and calculation speed (see Chapter 3). This suggests that an enhanced ability to retain numerical sequences in a short-term store may play a role in savant calculation ability. The following important study by Spitz and LaFontaine (1973) suggested that superior STM performance is associated with savant ability in *general.*

In 1973, Spitz and LaFontaine attempted the first controlled group study of savant short-term memory performance, with the use of the forward digit span measure. Previously, the literature had contained contradictory reports of savant digit span lengths, derived solely from individual cases. The 1973 study compared the immediate recall of eight savants with that of two comparison groups; the first comprised 25 mentally handicapped individuals and the second consisted of eight individuals of at least average intelligence. It was found that the mean digit span of the savant group was significantly larger than that of the learning disabled controls, but did not differ significantly from that of the normal controls, falling within the 7 ± 2 range. Although this important study is still widely cited, there are a number of reasons why a further investigation of savant short-term recall is required.

First, the Spitz and LaFontaine (1973) study involved savants gifted for a range of *different* talents including music and constructional ability. It might be suggested, however, that for some savant talents such as art and constructional ability, short-term recall plays a minimal role in performance. On the other hand, for skills such as numerical calculation, verbal rehearsal may be an intrinsic aspect of the talent, even if only to retain the question often posed to test the ability, e.g. "What is 452 x 378?". In theory, this may even result in different levels of digit span performance between the various savant ability groups. Thus, it makes both theoretical and methodological sense to separate the different abilities and test short-term memory performance within these individual groups. In this way, it is possible to determine whether savants skilled *specifically* for calendar calculation differ in their immediate memory performance in comparison to appropriate control subjects.

The second reason why a further investigation of savant short-term recall is necessary relates to the rather "loose" matching procedure implemented in the 1973 study, specifically with regard to the mentally handicapped control group. The mean IQ of the savant group was assessed by either the Stanford-Binet or *one* of the Wechsler Intelligence Sub-Scales. This was compared to the mean *full-scale* IQ's of the intellectually impaired group, again measured on the Wechsler intelligence scales. Thus, it would appear that at least some of the savants were matched to controls on the basis of their non-verbal scores. As digit span is held to be an aspect of verbal rather than non-verbal intelligence, hence its inclusion as a subtest on the Wechsler verbal intelligence scale, then an improved experimental design would be to match the savants and controls according to their performance specifically on a verbal intelligence test.

Third, as a further point regarding the matching procedure of the 1973 study, there was no attempt made to control for the diagnosis of the subjects involved; indeed, there was no reference to the diagnoses of the subjects. This may be an important factor to consider within the present study, particularly with reference to a diagnosis of autism. This could work in two ways. First, given the propensity for echolalia and enhanced rote memory capacity often implicated in a diagnosis of autism, this may result in such individuals showing an increased ability to repeat back strings of items. However, in light of the fact that short-term memory is considered a component of executive function (Pennington and Ozonoff, 1996) and individuals with autism have been shown to fail certain executive function tasks, this also serves to confirm that the diagnosis of the subject is an important factor to consider. Thus, in the present experiment, unlike Spitz and LaFontaine (1973), savants were matched to their respective controls in terms of their diagnosis.

Finally, Spitz and LaFontaine (1973) chose only to compare groups in terms of their forward recall of digits. The present experiment extends the investigation of short-term memory performance in a number of further directions, all of which may hold possible interpretive value regarding the date calculation process. First, in addition to digits forward, a digit span backward condition was administered. The cognitive operations performed on a series of digits in order to retain their exact sequence followed by their mental reversal, may reflect some of the processes involved in calendar calculation. For example, questions regarding dates in the distant past may require not only the retention of the target date but the sequential process of counting backwards in multiples of 28, in accordance with the 28 year rule, to obtain the answer (Hermelin and O'Connor, 1986). Thus, the backwards span condition may capture an element of the mental manipulation of numerical sequences which occurs during the use of calendrical regularities.

In addition to investigating short-term recall for numerical information, two further conditions were introduced involving word items. Thus, not only was short-term memory tested for digits, but also for non-numerical, verbal items in the form of word span forward and backward tests. These measures were included to test for possible differences in savant immediate recall performance between numbers, which play an important role in the construction of the calendar and the representation of date information, and common nouns, none of which were relevant to the calendar or to the phrasing of date questions. One possible finding, therefore, may be the short-term memory superiority of savants over controls solely for numerical items, given the greater calendrical significance of digits and their role in calculation.

Finally, performance on all four memory tests may fail to significantly differentiate between groups. That is, on tests of memory which are general rather than truly talent-specific, i.e. do not involve actual date information, savants may show no advantage over controls. This would be in line with the research on expertise in the normal population which indicates that experts do not have a more efficient STM for *general* information. Rather, any advantages over novices are confined to the immediate recall of meaningful information related to their domain of expertise (e.g. Chase and Simon, 1973). Importantly, the failure to obtain a difference between groups in the current experiment would suggest that an enhanced STM is not an essential component of savant talent; it is not an aspect of cognitive functioning which distinguishes savant date calculators from individuals who do not demonstrate such a facility with the calendar.

To reiterate, the rationale for the current experiment was as follows. An investigation of the memory ability of savant calendar calculators was long overdue. The only study in the savant literature which is relevant to such an investigation was that of Spitz and LaFontaine (1973). These authors had demonstrated the superiority of savants over IQ matched controls on the digit span forwards test. Thus, one major component of savant talent may be a highly efficient STM. The present experiment aimed to improve on this study by comparing the STM performance of a group of savants all gifted for date calculation with that of a control group individually matched according to age, diagnosis and verbal IQ. Furthermore, additional STM measures were administered; digit span backwards, word span forwards and backwards. Differences between the two groups on any of these measures were judged to be insightful regarding the date calculation process. Alternatively, a failure to find any group differences would suggest that the development and operation of savant date calculation does not depend on a superior STM for either numerical or non-numerical items. Thus, the key difference between savants and controls may lie in other aspects of memory performance.

In line with the previous findings of Spitz and LaFontaine (1973) demonstrating superior STM performance in the savant group, a similar pattern of results is predicted within the current experiment. However, given the role played by numbers in both the format and the internal workings of the calendar, the superiority of savants over controls was predicted to be confined to the measures involving digits rather than words.

Method

Subjects. Eight calendar calculators took part in the present study. These were H.P., G.C., R.D., J.B., J.P., D.K., M.W. and A.T., whose full details are given in Chapter 3. Six of these individuals have a diagnosis of autism. The remaining two subjects (G.C. and J.B.) are regarded as having learning difficulties/mental handicap, although they are judged by the author to show some autistic features. The chronological ages (C.A.) of the savants ranged from 13.3 to 45.1 years, with a mean of 28.7 years (*SD* 9.00). Their verbal IQ's, as measured on the Peabody Picture Vocabulary Test (P.P.V.T.), ranged from 44 to 80, with a mean of 64.9 (*SD* 13.19).

Eight control subjects were individually matched to the savants on the basis of diagnosis, C.A. and verbal IQ. Thus, six members of the control group also had a diagnosis of autism. These individuals were selected from a National Autistic Society day centre and three N.A.S. residential homes. The remaining two subjects, with more general learning difficulties, were taken from a local authority adult training centre. The C.A.'s of the control group ranged from 13.9 to 46.2 years, with a mean of 29.1 years (*SD* 9.17). This did not differ significantly from the C.A.'s of the savant group ($t(14) = .07$, ns). The verbal IQ's of the control group, as obtained on the P.P.V.T., ranged from 44 to 81, with a mean of 66.8 (*SD* 12.74). Again, this did not differ significantly from that of the savants ($t(14) = .29$, ns). The mean C.A.'s and verbal IQ's of the two groups are shown in Table 4.1 below. The full list of subjects' C.A.'s and verbal IQ's is given in Appendix A.

Prior to the testing phase, the controls were assessed to show at least a minimal level of knowledge regarding the calendar. For example, they could name the days of the week in order and they could also select, from a list of candidate years, the current year of testing. However, none of the controls were able to calendar calculate, nor were they reported by carers as taking a marked interest in people's birthdays or in other calendar related events.

Table 4.1 ***Mean verbal IQ and chronological age (C.A.) of savants and control group (standard deviations in parentheses).***

	Verbal IQ	C.A. (in years)
Savants	64.88 (13.19)	28.74 (9.00)
Controls	66.75 (12.74)	29.06 (9.17)

Materials. *Digits.* The present experiment involved the use of the Digit Span subtest from the WAIS-R (Wechsler, 1981). This involves two parts; digits forwards and digits backwards. In the forwards test, the subject is given a series of number strings, composed of the digits 1 to 9. The first strings comprise three digits and gradually increase in length until they consist of nine digits. For each item length, the subject is given two trials, i.e. they are presented with two strings comprising the same number of digits. In this way, they have two attempts to succeed on the same item length. The items involved in the digits backwards test differ only in the length of the initial and final trials. The first item presented is two digits in length and the final item is eight digits long.

Words. The word span tests were constructed by matching a high frequency, one syllable word to each of the digits 1 to 9. These are displayed below in Table 4.2. Each of the words began with a different letter and care was taken to select phonologically dissimilar words in an attempt to reflect the lack of phonological resemblance between the digit labels 1 to 9. The sequences of numbers used in the digit span test were then reconstructed using the corresponding words. For example, the sequence *5-8-2* became *face-hat-dog*.

Table 4.2 *List of words used in word span tests together with corresponding digits.*

1	star
2	dog
3	egg
4	ball
5	face
6	tree
7	cup
8	hat
9	rain

Procedure. The order of presentation of the digit and word span tests was alternated between the savants together with their respective controls. Following from the WAIS-R presentation format, the forwards measure always preceded the backwards measure within the separate word and digit tests. In the forwards conditions, subjects were informed that the experimenter would read our some numbers/words and that they should listen very carefully. When the experimenter had finished, they should repeat exactly what the experimenter had just said. In the backwards conditions, the subjects were informed that the experimenter would read out some numbers/words, but this time they should say the items in the reverse order. Several examples were given of how to reverse both digit and word sequences.

In line with the standard presentation format, the items were read out at the rate of one per second. Both of the trials on each item length were administered and the test was discontinued following the subject's failure to repeat the item string correctly on *both* trials of the same length.

Arithmetic. In order to ensure that any obtained differences between groups on the digit span measures was derived from experience with the calendar, rather than from a higher level of general arithmetical competence, the arithmetic subtest from the WISC-III (Wechsler, 1992) was administered. The arithmetical skills of both groups, as a whole, were judged to be relatively basic and it was predicted that the use of the more age-appropriate WAIS-R arithmetic subtest would concentrate scores in a restricted, lower range. Thus, the WISC-III, which contains easier items, was selected for use and was predicted to result in a wider, more varied range of scores. The subtest was administered in line with the instructions from the test manual and subjects received one point for each item solved correctly within the given time limits.

Results

Digit and Word Span Tests. The subjects' digit and word spans were derived from the length of the last item-string correctly recalled. For example, if the subject recalled the sequence *4-9-6-8* in the digits forward condition, but failed the two trials on the following item length, a digits forward span of 4 was recorded. The mean span lengths of the two groups under each of the four conditions are displayed below in Table 4.3. The spans obtained by each of the individual subjects are shown in Appendix A.

Table 4.3 ***Mean span lengths of savant and control groups in all four conditions (standard deviations given in parentheses).***

	Digits		Words	
	Forwards	Backwards	Forwards	Backwards
Savants	5.88	4.00	4.63	2.63
	(1.46)	(1.60)	(0.92)	(1.30)
Controls	5.00	2.38	4.25	2.13
	(1.31)	(2.33)	(1.17)	(2.10)

In line with Spitz and LaFontaine (1973), the span lengths of the subjects were entered into a repeated measures analysis of variance (ANOVA) with one between-subjects factor of group (savants vs controls) and two within-subjects factors of item type (digits vs words) and direction of recall (forwards vs backwards). This revealed significant main effects of item type ($F(1,14) = 33.64$, $p < .001$) and direction of recall ($F(1,14) = 27.34$, $p < .001$). Thus, digits were found to be more memorable than words (means of 8.63 and 6.82, respectively) and longer spans were obtained in the forwards rather than backwards conditions (means of 9.88 and 5.57, respectively). There was no significant main effect of group ($F(1,14) = 1.72$, ns). The only interaction to reach significance was group by item type ($F(1,14) = 6.76$, $p < .05$). This interaction is illustrated below in Figure 4.1. Simple effects analysis revealed that, for the savants, digits were significantly more memorable than words ($F(1,14) = 35.28$, $p < .001$), whereas for the controls, this difference was not significant ($F(1,14) = 5.12$, ns). There was no significant difference between groups in either the digit condition ($F(1,14) = 3.10$, ns) or word condition ($F(1,14) = .51$, ns). It is important to note that the analysis adopted a more conservative significance level ($p = .01$) to take account of the number of possible comparisons.

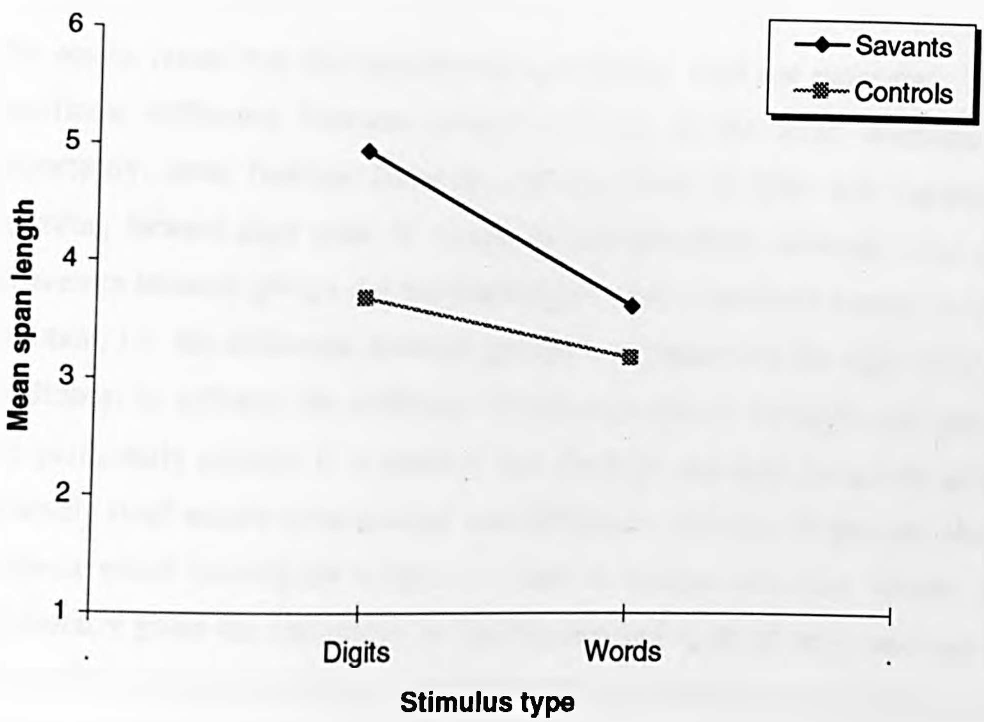

Figure 4.1. ***Mean spans of savant and control groups for digits and words.***

Arithmetic Test. The presentation of the WISC-III subtest did indeed result in a wide range of scores in both groups. For example, one subject from each group was able to complete only the first item. On the other hand, both a savant and a control subject were able to solve 19 of the items correctly. Neither subject gained a time credit for their last response. The full list of scores obtained by subjects is shown in Appendix A. The mean number of items correctly solved by the savants was 10.75 (*SD* 5.57) compared with a mean of 9.38 (*SD* 5.40) in the control group. This difference between groups was not significant ($t(14) = .50$, ns).

Discussion

The results reveal that the experimental predictions were not supported. There was no significant difference between groups on any of the STM measures presented. Importantly, these findings failed to replicate those of Spitz and LaFontaine (1973) regarding forward digit span. It should be acknowledged, however, that although the differences between groups did not reach significance, there was a trend in the predicted direction, i.e. the difference between groups was greater for the digit rather than word conditions. In addition, the difference between groups on the digits backwards measure was particularly marked. It is possible that the large standard deviations along with the relatively small sample sizes masked real differences between the groups. However, any research which investigates subjects as rare as savants may face similar difficulties, particularly given the variability in intelligence and level of skill observed *within* the group. This serves to reinforce the importance of selecting an appropriately matched control group. It is difficult to establish whether the 1973 study is subject to similar methodological shortcomings as the authors do not give the corresponding standard deviations for their groups. However, the number of savants involved in the present and 1973 study are comparable; both included eight savant subjects.

The failure to find a difference between groups may be attributable to a number of alternative, theoretically more interesting interpretations. First, in contrast to the 1973 study, the present experiment matched the two groups closely on verbal IQ and diagnosis and they were also comparable in terms of their arithmetical ability. Such a matching procedure may have served to remove any potential group differences. Thus, the difference between groups in the earlier study may have resulted from factors other than those relating to savant talent. A second point concerns the IQ's of the savant groups in both studies. The mean verbal IQ of the savants in the present experiment is 64.9 which is higher than that of Spitz and LaFontaine's savant sample, with a mean IQ of 48. However, the mean digit forward spans of both these savant groups, together with that of the current controls, fell within the 7 ± 2 range. Thus, it may be that at lower levels of ability, as in the 1973 study, a digit span within the normal range is necessary for developing and sustaining a savant talent. However, with more able individuals, as in the present experiment, such STM performance is in line with their general level of cognitive functioning and thus does not serve to separate savant and control groups.

The final point to note concerning the 1973 study relates to the fact that all of the current sample of savants shared the same ability. Thus, the sample did not comprise individuals whose abilities may depend to differing degrees on the role of STM. Importantly, therefore, as there were no group differences within the present study, we can conclude that the skill of calendar calculation is not subserved by an enhanced STM ability either for numerical or word items. More specifically, the findings would suggest that an individual does not become a calendar calculator because they show an enhanced ability to verbally rehearse and retain information, relative to other individuals of the same intelligence level and diagnosis. Rather, factors other than a superior STM must underlie the process by which these individuals acquire calendar information. This is consistent with the findings on expertise in the normal population which suggests that expert performance does not develop as a result of *structural* or "hardware" differences between individuals, e.g. differences in STM capacity and learning rate (Charness, 1988). In addition, the lack of a difference between groups in terms of their arithmetical skills would also confirm that savant calendar calculation does not develop from an advanced numerical calculation ability.

Although the present experiment failed to reveal any between group differences, the findings indicated that *within* the savant group immediate recall was superior for digits when compared to words. Such a difference in STM relative to item type can be interpreted in a number of ways. Deriving knowledge of the calendar and engaging in the calculation process, provides savants with extensive exposure to numerical information. Numbers are not only intrinsic to calendar structure and sequencing (e.g. 7 days in a week, 12 months in a year) and consequently to calendar rules (e.g. the 28 yearly repetition), they are also used to represent the labels denoting the basic elements of the calendar (e.g. *1st* July *1964*, *01.07.64*). Thus, when engaged in calendar calculation or even thinking about the calendar, the savant is mentally manipulating various forms of numerically related information. It is this experience which may well contribute to the observed superiority of digits over word items for the savants. Furthermore, at least one of the savants, H.P., has a very strong interest in the properties of numbers and is highly skilled at numerical feats such as the identification of prime numbers. Interestingly, his digit spans forwards and backwards were the longest in both groups. It is thus possible that the difference between digits and words in the savant group was inflated by the presence of savant numerical skills such as those of H.P. However, it is worth noting that the difference *between* groups in terms of both their arithmetic skills and their short-term recall of numbers was not significant.

The savants' superior immediate recall of digits when compared to words has one final, exciting implication. This apparent preference for numbers over words may not derive simply as a consequence of their familiarity with the calendar. Rather, it may be an important factor in explaining why savants first gravitate towards calendars. For some reason, these individuals are better able to retain and mentally manipulate numbers rather than other verbal items. Even though their actual levels of recall are no better than those of controls, the savants nevertheless appear to show a selectivity for numerical information. Thus, knowledge retained over time is more likely to favour numerically based information, possibly relating to calendars, birthdays and dates, than information comprising solely words.

As a final point, the correlation between the savants' digits forward span and calculation speed (as reported in Chapter 3) should be interpreted in the context of the present findings. As no group differences were found on any of the STM measures presented, it was suggested that STM does not represent a component of savant date calculation skill. Yet, the retention of number sequences in their exact order within a temporary store appears to be associated with the speed at which the savants can generate the answers to date questions. It is suggested that this relationship between digits forward span and calculation speed may simply be attributable to the savants' ability to retain the date question whilst performing the necessary mental operations involved in generating the answer. Therefore, a superior digits forward span does not relate to the actual cognitive operations which underlie the ability, simply to the measures used to test the ability. Furthermore, calculation speed may not be an ideal index of calculation ability. Some of the subjects have speech impediments and echolalia which slows their response.

Following from the present investigation of STM performance, Experiment 2 explores the long-term recall ability of the savant and control groups. As savant date calculation is assumed *not* to involve the use of mathematical formulae or algorithms and is therefore not a process of pure calculation (see Chapter 2), then the skill must depend, at least in part, on the representation of calendar information in LTM. Thus, there may be reason to predict that any differences between the present groups will be found only on measures of LTM. Furthermore, the specificity or generality of any such group difference is of interest. For example, will the savants show superior performance on all measures of long-term recall or will any advantage be confined solely to calendar-related information?

Experiment 2: Long-term Memory for Words and Years

Introduction

In any situation which requires the processing of specific information, individuals differ with regard to the amount of relevant prior knowledge they bring to the learning conditions. The extent to which these individual differences in existing knowledge and skill affect the acquisition of domain-related material has been extensively explored within the literature on expertise. Specifically, the research has revealed that individuals with high levels of knowledge and experience in a particular domain show marked advantages over controls for the acquisition of talent-related information. However, any superiority in memory performance is found to be domain-specific; it extends only to information relating to the area of expertise. Among the examples discussed in Chapter 1 was Morris, Tweedy and Gruneberg's (1985) study demonstrating that individuals with high levels of football knowledge were better able to recall real football scores than individuals who knew little about the sport. However, this memory advantage did not extend to simulated football scores or to common words. Similarly, Spilich et al. (1979) showed how individuals with extensive knowledge of baseball were better able to recall passages describing a baseball game than those subjects who knew little about the sport. Importantly, however, for passages which were unrelated to baseball, the controls were better than the "experts" at recalling the material. Such differences between high- and low-knowledge individuals are interpreted in terms of an extensively organized knowledge base which underlies the specific area of skill. Experts are better able to process information relevant to their area of excellence by relating it to their existing knowledge; thus engaging in elaborative processing (Mandler, 1988; Anderson, 1990). As was noted in Chapter 2, the process of elaboration promotes the memorability of items by providing an increased number of pathways by which the stored item can be accessed and retrieved from LTM. In contrast, novices do *not* possess an extensive knowledge base and are thus unable to relate domain-relevant information to their existing knowledge structures. This results in an inferior level of recall performance relative to expert individuals.

The present group of savants are all "experts" with the calendar. They can answer date questions spanning at least 100 years; a feat which suggests the involvement of an extensive knowledge base. The present control group can all be regarded as "novices" with the calendar. They have a very basic knowledge of calendar concepts but do not show a specific interest in dates nor do they calendar calculate. It would therefore be of interest to investigate whether their recall performance for talent related and unrelated material parallels that of experts and novices in other areas; specifically, whether the difference between groups, relating to their knowledge of the calendar, influences their ability to recall date related information. This represents the subject of investigation within the present experiment. In line with the expertise literature, it was predicted that the savants would be superior to controls in terms of their recall of calendar information from LTM.

Of key importance, however, is whether any such difference between groups is confined to the calendar or extends to more *general* measures of LTM. In order to investigate this, a series of word lists were presented for long-term recall. These lists comprised common nouns which were unrelated to the calendar or to the phrasing of date questions. If the savants were found to be superior to controls, not only in terms of talent-related information but also for general information, this would have important implications for our understanding of savant ability. For example, this would suggest that superior encoding, storage and retrieval processes may represent an important component of savant talent. However, there are a number of reasons for predicting that the LTM superiority of savants over controls does not extend to general material, unrelated to the calendar. First, the literature on expertise shows that the LTM advantage of experts is confined solely to the area of excellence and does not extend to general information (e.g. Spilich et al, 1979). Second, this was also shown to be the case for savant mnemonists (O'Connor and Hermelin, 1990, see Chapter 1). The savant group were superior in terms of recalling material relating to their area of interest (bus numbers). However, their performance did not surpass that of IQ matched controls on tests of general LTM function. Third, the findings of Experiment 1 indicate that savants do not possess a more efficient STM when compared to the control group. It may follow that the equivalent investigation of general LTM would reveal no basic differences between groups. Thus, an enhanced LTM and superior learning rate would not appear to explain why certain individuals become calendar calculators.

The final point to note concerns the items used to test calendar-specific memory. Given that the present experiment aimed to explore memory for calendar information in the absence of the calculation process, individual years were selected as the most appropriate stimuli (e.g. *1964, 1913, 1942*). Presenting actual dates (e.g. *1st January 1975*) would have provided the savants with the opportunity for calculation, which in turn, would have given them an additional processing advantage over the controls. It is possible that the cognitive operations involved in calculation serve to increase the memorability of a date. Thus, it was important to control for this difference between groups in the present experiment.

As an additional point of interest, two conditions involving calendar related information were included. The first comprised individual years taken solely from the 20th century. These were years which fell within the calculation ranges of all of the savant subjects. The second condition involved years taken from the 18th to the 21st century. These were years that fell, for the most part, outside of the savants' calculation spans. Of interest was whether years for which the savant is able to calendar calculate are better recalled than more distant, less familiar years. This provides a preliminary exploration of differences in recall *within* the area of talent, concerning the memorability of dates in relation to calculation ability. Due to the familiarity of the 20th century years, together with the fact that these years fall within the spans of *all* of the savants, it was predicted that the recall of the savants would favour the 20th century items.

To reiterate, the long-term recall ability of a group of savant calendrical calculators was investigated and compared with that of a control group. The savants were predicted to recall significantly more calendar-related items from LTM. However, on a test of more *general* LTM function there was predicted to be no difference between groups.

Method

Subjects. The present study involved the two subject groups who participated in the previous experiment. Their details are given within the subject section of Experiment 1.

Materials. The present experiment involved three conditions; the recall of words, 20th century years and years from the 18th to 21st century (mixed years). Within each condition, four lists of eight items were presented for recall. Table 4.4, below, displays an example of one of the lists from each of the conditions. All 12 lists are shown in Appendix A.

Table 4.4 *Examples of lists taken from Conditions 1, 2 and 3.*

Condition 1: Words	Condition 2: 20th century years	Condition 3: Mixed years
path	1941	1768
dress	1976	1997
salt	1933	1807
hand	1914	1713
girl	1982	2049
ring	1920	1952
cloud	1958	2010
box	1967	1885

Condition 1 comprised high frequency one syllable nouns, taken from Thorndike and Lorge (1968). From the subjects' performance on the Peabody Picture Vocabulary Test, these words were judged to fall within the vocabularies of all of the subjects. Condition 2 comprised years taken from the 20th century. Within each of the lists, the years were taken from a different decade and combined in a randomized, rather than chronological order. Condition 3 (mixed year condition) consisted of years taken from the 18th to the 21st century. Within each list, two years were taken from each century and placed in a randomized order.

Procedure. Subjects were informed that they were being given a test of memory. They were told that the experimenter would read them eight years/words and they should listen very carefully. After a short interval, they would be asked to remember as many of the years/words as possible in any order they chose.

The order of presentation of the three conditions was counterbalanced across savants. The controls always received the conditions in the same order as the savant to which they were individually matched. Care was taken not to present Conditions 2 and 3 in close succession, due to the similarity of the items involved, i.e. both involved 20th century years. Within each of the conditions, the four lists were presented in the order shown in Appendix A.

For all three conditions, items within each list were read aloud by the experimenter at the rate of one item every three seconds. Almost all of the subjects chose to repeat the items directly after the experimenter. This was consistent across all of the conditions. This was followed by a one minute filled interval, during which the subject was encouraged to talk with the experimenter in order to displace any verbal rehearsal. At the end of the interval, subjects were required to free recall as many of the items as possible.

Results

The mean number of words and years recalled by the savant and control groups in each of the conditions are displayed below in Table 4.5. The means would suggest that whereas the two groups appear comparable in terms of their recall of words, the savants were better able to recall the year items than the controls. Individual subjects' scores are presented in Appendix A.

Table 4.5 ***The mean number of items recalled by savants and controls in all conditions (standard deviations in parentheses).***

	Words	20th century years	Mixed years
Savants	11.00	14.50	11.88
	(5.53)	(6.35)	(5.06)
Controls	10.13	4.63	1.75
	(5.84)	(3.46)	(1.39)

The total number of items recalled by each subject within each of the three conditions was entered into a mixed analysis of variance with one between-subjects factor of group (savants vs controls) and one within-subjects factor of condition (words vs 20th century years vs mixed years). This revealed a significant main effect of group ($F(1,14) = 9.82$, $p < .01$) and a significant main effect of condition ($F(1,14) = 9.22$, $p < .005$). However, these main effects were modified by a highly significant interaction between group and condition ($F(1,14) = 16.98$, $p < .001$). This interaction is illustrated in Figure 4.2.

Planned simple effects analysis revealed no significant difference between groups in terms of their recall of words ($F(1,14) = .09$, ns). However, the two groups differed in terms of their recall of 20th century years ($F(1,14) = 14.93$, $p < .005$) and mixed years ($F(1,14) = 29.84$, $p < .005$). Thus, as Figure 4.2 suggests, the difference between groups was confined to the recall of years and did not extend to the recall of words.

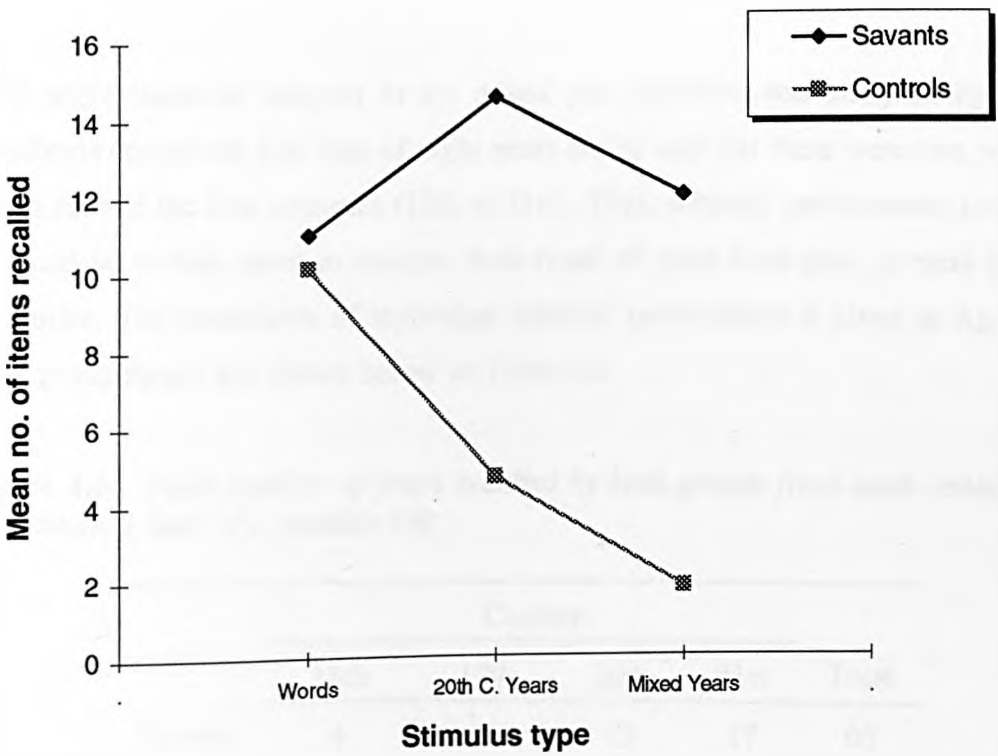

Figure 4.2. ***Mean number of words, 20th century years and mixed years recalled by savants and controls.***

A series of post-hoc t-tests were performed on the differences within groups. In view of the number of possible comparisons, a conservative significance level of p = .005 was adopted. For the savant group, none of the comparisons between conditions reached significance: words vs 20th century years ($t(7) = 2.54$, ns); words vs mixed years ($t(7) = .76$, ns); 20th century years vs mixed years ($t(7) = 2.84$, ns). However, for the control group the difference between words and 20th century years was significant ($t(7) = 4.08$, p = .005) and the difference between words and mixed years was also significant ($t(7) = 4.65$, $p < .005$). The difference between 20th century and mixed years did not reach significance ($t(7) = 3.54$, ns).

The performance of subjects in the mixed year condition was analyzed further. This condition comprised four lists of eight years and in each list there were two years taken from each of the four centuries (18th to 21st). Thus, subjects' performance in Condition 3 could be broken down to analyze their recall of years from past, present and future centuries. The breakdown of individual subjects' performance is given in Appendix A. The group means are shown below in Table 4.6.

Table 4.6 ***Total number of years recalled by both groups from each century within Condition 3 (out of a possible 64)***

	Century				
	18th	19th	20th	21st	Total
Savants	4	21	53	17	95
Controls	3	5	3	3	14

The total number of items recalled by each subject from each of the four centuries (18th to 21st) were examined using linear contrast analysis. This showed that, for the savants, 20th century years were significantly better recalled than the other three century years combined ($F(1,7) = 38.90$, $p < .001$). However, for the controls, 20th century years were no better recalled than items from other centuries ($F(1,7) = .05$, ns).

Finally, a Mann-Whitney U Test was performed on the difference between scores obtained by both groups for the 18th century years, within Condition 3. A non-parametric test was selected due to the non-normality of the distribution of scores for these distant years. This revealed no significant difference between the two groups ($U = 28$, $n = 16$, ns).

Discussion

In line with the experimental predictions, savants recalled significantly more calendrical items from LTM when compared to the control group. Individual years, whether taken from the present century or from past and future centuries, were inherently more memorable for the savants. Indeed, this difference is really quite marked, with the savants recalling, on average, over three times as many items from the 20th century and over six times as many items from the mixed year condition than the control group. Importantly, however, there was no difference between the two groups in their recall of words. Thus, the LTM advantage of the savant group does not extend to material unrelated to the area of the skill and appears to be calendar-specific. This pattern of results is consistent with that concerning expertise in the normal population, and is also in line with O'Connor and Hermelin's (1990) research with savant mnemonists. Importantly, the lack of a difference between groups in terms of their recall of word items suggests that savant *general* LTM function is comparable with that of IQ-matched controls. In turn, this would suggest that the factors which predispose such individuals to become calendar calculators do not include generally superior encoding, storage and retrieval processes.

So what are the implications of the present findings for the representation of savant calendar knowledge? Such high levels of recall for year items relative to controls, suggests that the savants do indeed have access to an extensive knowledge base concerning the calendar. Even though the savant is unable to perform the process of calculation on the single years, nevertheless, these items must lend themselves to a form of elaborated processing. In effect, individual years are more *meaningful* to the savant as they can be related to a substantial amount of existing knowledge. All of the date calculators in the present sample have a strong interest in calendar information relating to events, such as when they went on various day trips, the dates on which all of the clients joined their day centre. Not only is this source of knowledge available to them, importantly, they can calendar calculate over a range of these years, therefore possessing extensive knowledge regarding the day-date pairings within these individual years. It is thus somewhat unsurprising that such a rich database of calendar knowledge would promote the recall of year items, even in the absence of the calculation process.

Furthermore, it would follow that savant knowledge relating both to events and to the calculation of dates, would favour the recall of 20th century years. All of the events of personal significance to the savant would have occurred within their own lifetime, or at least within the present century. Also, the 20th century represents the period of the calendar which falls within the calculation spans of all the savants. This proposed memorial advantage for 20th century years was supported by an analysis of the items recalled by the savants within the mixed year condition; more years were recalled from the 20th century than from the other centuries. This pattern of performance contrasted with that of the control group within the mixed condition. Recall was not enhanced for years from the present century. It is relevant to note that while the calculation ranges of *all* of the savants cover the present century, the spans of some of the group extend into the 19th and 21st centuries (e.g. subjects J.P., G.C. and D.K.). Thus, as Table 4.6 shows, the proportion of items recalled from the 18th to 21st century would appear to map onto the calculation range of the group. In other words, when presented with a range of different years, the pattern of recall appears to reflect the dates they can calculate.

This was investigated further by an analysis of the difference between groups in terms of their recall of 18th century years. As H.P. is the only savant who can calculate across these years, in effect this represented an investigation of calendar-related memory, largely independent of calculation span. As there was no difference between groups, this suggests that savants do not necessarily have a better memory in general for calendar-based information. Rather, their superiority appears to be confined to years within which they can calendar calculate. This, in turn, has implications for the acquisition of calendar knowledge. Although, the inclusion of the word condition in the present experiment ruled out any generalised LTM differences between groups, the possibility remained that these individuals *became* savants because they were better able to retain numerically-based/date-related information over time, relative to individuals of comparable IQ. The lack of a difference between groups for the 18th century years does not support this proposal.

A further important point, relating to the acquisition process, has emerged from the present experiment. Specifically, as a knowledge base expands and develops, it becomes easier to acquire additional information relating to that area. Thus, as an individual develops an interest in the calendar and begins to learn about day-date pairings, any new information pertaining to day-date pairings will be efficiently processed in relation to their increasing calendar knowledge. *This* would be the advantage that the savant has over other individuals when exposed to calendar information in an everyday setting. His/her existing knowledge would allow the effective uptake of further examples of date information, which in turn may form the basis of the date calculation process. In this way, elaborative processing may be an important aspect of savant calendar ability and is perhaps central to the acquisition of calendar knowledge.

Two final points should be noted relating to the current findings. The first concerns the fact that, although the controls did not recall more 20th century years than other years in the mixed year condition, the difference between their recall of items from the 20th century condition (Condition 2) when compared to Condition 3 approached significance. This may be explained by the additional memory load involved in Condition 3, which comprised items varying not only in terms of their decade and precise year, but also in terms of their century. In contrast, Condition 2 involved a comparatively reduced memory load, in the form of a series of years taken from the same century.

The final point concerns the *extent* of calendar knowledge representation in both groups. In the control group, words were found to be significantly more memorable than years. This suggests that whereas words may be extensively represented in LTM, information relating to years is not. In contrast, the fact that savant recall levels were comparable between words and years suggests that date information may be as extensively represented in LTM as knowledge relating to words.

In conclusion, the present experiment has succeeded in isolating a savant memory advantage in relation to IQ matched controls. Savant LTM superiority is confined only to years which fall within their calculation spans. Although, it may be somewhat obvious that calendar calculators find years more memorable than non-calculating controls, this difference had never been shown experimentally. Furthermore, this finding not only establishes the existence of a savant calendar-specific knowledge base, it also necessitates the investigation of the organization which exists within this knowledge store. This research forms the basis of Experiments 4 to 7. However, given that the current experiment has indicated the key role played by calculation ability in the recall of date information, the following experiment attempts to investigate this further.

Experiment 3: The Effect of the Calculation Process on the Savants' Memory for Dates

Introduction

The previous two experiments, investigating short- and long-term recall, have revealed that the savants do indeed show a memory superiority over controls. Importantly, not only is this superiority confined to the calendar, it would appear to be specific to dates that fall within their calculation spans. Thus, dates for which they can calculate enjoy a privileged status in terms of their LTM representation. As suggested in Chapter 2, the savants' knowledge of dates may be conceptualised as a *network* of representation, with information corresponding to one date or to a feature of the calendar which is linked with many other related dates. Such a richly interconnected knowledge base would account for the savants' high level of recall of dates within their span, relative to that of controls. Importantly, it would follow that the process of calculation makes actual use of these connections between date information stored in LTM. In other words, it is the knowledge of how one date relates to another date which plays a role in calculation. One way of testing this is to compare the subject's ability to remember dates following the process of calculation when compared to an equivalent study task. Presumably, if the process of date calculation activates links within the knowledge base and makes use of these interconnections, this would result in an enhanced ability to remember the calculated date when compared to an equivalent studied date.

Such a procedure, of comparing the memorability of dates following contrasting calculation and study conditions, is in many ways analogous to the literature regarding the "generation effect", as outlined in Chapter 2. Researchers such as Slamecka and Graf (1978) have demonstrated that subjects are better able to retain words which they have generated themselves, (e.g. in response to the semantically related cue *fast-s_ _ _*), when compared to externally provided words which they are required to simply read (e.g. in the form *fast-slow*). Importantly, such findings are interpreted in terms of the increased elaboration resulting from the generation process. That is, in order to generate the word, the subject activates connections within the network which subsequently provide multiple access routes to the concept to be retrieved. Evidence that the generation effect depends on a highly structured knowledge system comes from two sources. First, Nairne, Pusen and Widner (1985) obtained an effect of generation over study *only* for medium and high frequency words and not for low frequency and non-words. According to the authors, this could be interpreted in terms of the greater number of associative links between higher frequency words and other entries within the lexicon. That is, generating information which is not part of an elaborate interrelated network apparently results in a very limited or no generation effect. The second relevant line of support comes from Reardon, Durso, Foley and McGahan (1987) who explored the generation effect with a group of individuals judged to have an expert level of knowledge of psychology. Their performance was compared with that of subjects whose knowledge of psychology was minimal. Both groups were also given equivalent generate and read tasks in an area (sports trivia) about which they were judged to have a comparable level of knowledge. The authors obtained a generation effect but only for the experts and only in their area of expertise. The authors concluded that the generation effect arises from the utilization of a richly interconnected knowledge base, which in turn facilitates the process of elaboration thereby promoting the memorability of the generated items.

In summary, the present experiment examined the memory of the savants for dates which they had previously calculated, compared with dates they had earlier studied. In line with the relevant literature on the generation effect, it was predicted that the savants would be better able to retain calculated rather than studied dates. In turn, this would suggest the involvement of elaborated knowledge relating to dates within their calculation spans.

Method

Before outlining the procedure used within the present experiment, it is necessary to note two points relating to the methodology. First, memory was tested using recognition rather than recall. This was consistent with the literature which shows that the generation effect is more reliably elicited under conditions which utilize recognition as the test of memory (Serra and Nairne, 1993). Second, and perhaps most importantly, recognition is often regarded as a more exhaustive test of memory than recall (Shanks and St John, 1994). As the present experiment was perceived to involve an increased memory load relative to Experiment 2 (in the form of a longer list of items and the presentation of actual dates rather than individual years), recognition was used in order to make the task less difficult for the subjects. The second point relating to methodology concerns the fact that the subjects were not informed they were to be given a test of memory. In other words, they were presented with a surprise recognition test. This follows from findings suggesting that the generation effect is enhanced under conditions of incidental memorisation (Watkins and Sechler, 1988). Thus, to reiterate the present experiment utilized design features regarded as optimal in eliciting the effect of generation over study.

Subjects. As the present experiment involved the process of calendar calculation, this precluded the use of a non-calculating control group. Thus, only the savant group was tested. Eight savant calculators participated; H.P., G.C., R.D., J.B., J.P., D.K., P.M. and P.E. whose details are given in Chapter 3. Subjects P.M and P.E. were not involved in Experiments 1 and 2 as they were recruited to the research at a later stage. M.W. who took part in Experiments 1 and 2 was not available for testing. A decision was made not to test subject A.T. as his previous performance indicated that he experienced marked difficulty with tests requiring long-term retention. This was reflected in his inability to recall any of the items from the three conditions in Experiment 2. Although A.T.'s pattern of performance was mirrored by that of a control subject, which to a degree justified his inclusion in a between-groups comparison, the present experiment explored *within-group* patterns of performance based on memory. Thus, A.T.'s predicted inability to cope with such a formal test of memory would not have contributed to the interpretation of differences between the calculation and study conditions.

The mean verbal IQ of the group, as measured on the Peabody Picture Vocabulary Test was 65.6 (*SD* 12.91) and the mean non-verbal IQ of the group, obtained from the Ravens Progressive Matrices Test, was 77.9 (*SD* 23.00).

Materials. The experiment involved two conditions; the first of which required subjects to simply read/study the dates and the second which required the calculation of dates.

Study condition. Subjects were presented with a list of 18 dates to study/read. Each date comprised not only the year and month but also the corresponding weekday. In order to construct this list, three sets of six dates were selected to fall on one of three days; Monday, Thursday and Sunday. The recognition phase of the experiment required subjects to identify the Monday dates presented within this list. Thus, the Thursday and Sunday dates served as "filler" items. Within each of these three subgroups, the dates were selected to span an equivalent year range. For example, the Monday dates fell from 1919 to 1984, the Thursday dates ranged from 1923 to 1987 and the Sunday dates spanned 1918 to 1982. The 18 dates were then combined in a randomized order to form the list presented to subjects for study. This is illustrated below in Table 4.7.

Table 4.7 ***List of dates presented to savants in study condition.***

Monday 7th January 1980
Thursday 28th May 1936
Sunday 14th March 1982
Thursday 2nd September 1971
Monday 22nd December 1919
Sunday 29th April 1979
Thursday 1st December 1977
Monday 16th March 1925
Sunday 30th August 1953
Thursday 5th July 1956
Sunday 23rd June 1918
Monday 27th August 1984
Thursday 13th December 1923
Monday 11th June 1962
Sunday 21st September 1941
Monday 4th October 1948
Thursday 12th February 1987
Sunday 26th November 1939

Within the recognition phase of this condition, a list of 10 dates was presented to the subjects. This list contained five of the original dates which fell on a Monday within the previous study list. The remaining items were "distractor" dates, which also fell on a Monday. These distractors were taken from years which fell two years into the past or future from the target years. In other words, the distractors were from a comparable year range. The recognition list is presented below in Table 4.8. Asterisks, which were omitted from the version presented to subjects, have been added in order to indicate the target dates. The distracter and target dates were placed in a randomized order within the list.

Table 4.8 ***Recognition list presented to subjects in study condition.***

Monday 16th March 1925 **
Monday 19th September 1927
Monday 3rd July 1978
Monday 4th October 1948 **
Monday 6th May 1946
Monday 7th January 1980 **
Monday 11th June 1962 **
Monday 25th April 1960
Monday 17th February 1986
Monday 27th August 1984 **

Calculation condition. As in the above condition, a list of 18 dates was presented. However, this list did not contain the respective weekdays of the dates. Again, the list was constructed using three groups of items falling on different weekdays; Monday, Tuesday and Friday. As in the study condition, this task required the Monday dates to be recognised in the subsequent test of memory. Thus, the Tuesday and Friday dates served as "filler" items. These three subgroups of dates were selected to span an equivalent year range. For example, the Monday dates spanned from 1918 to 1983 which was comparable with that used in the study condition. The Tuesday dates ranged from 1922 to 1990 and the Friday dates spanned 1919 to 1981. These dates were placed in a random order to form the list presented to subjects for calculation. This is shown below in Table 4.9, although the respective weekdays which are shown in parentheses were omitted from the list presented to subjects.

Table 4.9 ***List of dates presented for calculation.***

8th August 1919 (Friday)
7th September 1964 (Monday)
14th March 1922 (Tuesday)
23rd December 1918 (Monday)
3rd November 1981 (Tuesday)
27th June 1975 (Friday)
16th April 1979 (Monday)
5th January 1940 (Friday)
20th August 1968 (Tuesday)
10th July 1950 (Monday)
7th February 1941 (Friday)
8th June 1937 (Tuesday)
17th April 1981 (Friday)
24th January 1927 (Monday)
2nd October 1990 (Tuesday)
30th March 1956 (Friday)
17th February 1953 (Tuesday)
1st August 1983 (Monday)

The recognition test for the calculate condition, comprised 10 dates, all of which fell on a Monday. Five of these dates were taken from the original list presented for calculation. The remaining five dates were distractor Monday's, taken from an equivalent year range as the target Mondays. The order of targets and distractors was randomised within the list which is illustrated below in Table 4.10. The asterisks, which are used below to indicate that targets, were omitted from the recognition list presented to subjects.

Table 4.10 *List of dates presented for recognition in calculation condition.*

24th January 1927 **
11th August 1952
7th September 1964 **
16th April 1979 **
25th May 1925
10th July 1950 **
1st June 1981
29th October 1962
1st August 1983 **
4th February 1985

All lists in both conditions were presented to subjects on sheets of A4 card, printed in double line spacing and in Times Roman 20pt sized font. An additional piece of A3 card was used which contained a small window cut into the card, large enough to reveal only one date at a time within the list.

Procedure. The order of presentation of conditions was alternated between savants. In addition, the two conditions were administered in separate testing sessions.

Study condition. Subjects were told that they were to be shown a list of dates and that the experimenter wanted to examine whether they could read the dates. It was stressed that they should look at the items very carefully and think about what they were reading. It was also stressed that they would not need to calculate the dates as the weekdays would be included in the list. In this way, the test was disguised as a measure of reading ability, with emphasis also placed on the subject studying the date carefully.

The A3 cardboard window was used to reveal only one of the dates at a time. This represented an attempt to concentrate the savants' attention on each of the individual items. Each date was displayed for a period of five seconds during which the savant was required to read the date out loud. When all 18 dates had been displayed in isolation, the cardboard window was removed and the whole list was available to study for an additional 15 seconds. Following the removal of the list, the subjects were congratulated on their ability to read the dates. The experimenter then waited five minutes before presenting the recognition list. During this interval, no further tests were given and the experimenter tended to talk generally with the subject. Following the five minute interval, subjects were presented with the surprise recognition list. They were told that the list contained some of the Monday dates which they had read on the previous list. It was stressed that not all of the dates on the new list would have been seen previously, only some of them. However, the subjects were not told how many dates they should identify out of the 10 items on the recognition list. Subjects were required to identify the familiar dates in any manner they chose, e.g. pointing or reading the date aloud.

Calculation condition. Subjects were informed that they were to be given a test of calendar calculation. There would be 18 dates which they should try and calculate as accurately as possible. They were told not to worry about how long it took them. Rather, they should concentrate on achieving the correct answer. After each of the dates, they would not be told whether they were right or wrong; they would be informed at the end of the list. As in the study condition, dates were displayed individually within the A3 cardboard window, which was moved down to the next date immediately after a weekday had been generated for the previous date. At the end of the list, the subjects were congratulated on their calendar skills. Unlike the study condition, the full list was not presented for additional inspection time. A five minute interval followed the removal of the list, during which the experimenter attempted to engage the subject in conversation. Again, no intermediary task was presented during the interval between calculation and recognition tests. After the interval, the list containing 10 Mondays was placed in front of the subjects. They were informed that some, but not all, of the items would be dates they had previously calculated. As in the study condition, the savants were not told how many of these dates they were expected to identify. Subjects were encouraged to identify the previously calculated dates in any manner they chose. For example, one savant insisted on using his own pen to tick off the familiar items.

Results

All subjects were able to read and calculate the full set of items presented. The number of Monday dates correctly identified from the two recognition lists were evaluated to take account of false positive responses. This applied to two subjects, in the study condition only. Both J.B. and R.D. recognized five items, of which only four had been shown previously. The false positive response was then subtracted from the number of correctly identified items to give a score of 3. Table 4.11 below shows the individual scores obtained by the savants, together with the means and standard deviations of scores obtained under both conditions. Clearly, the means indicate that recognition was easier for the savants following the calculate rather than study condition. Indeed, the savants performed at ceiling within the calculation condition.

Table 4.11 ***Number of dates recognised following study and calculation tasks (out of a total of 5).***

Subject	Study Condition	Calculation Condition
H.P.	4	5
G.C.	3	5
R.D.	3	5
J.B.	3	5
J.P.	2	5
D.K.	3	5
P.M.	2	5
P.E.	3	5
Mean	2.88	5.00
SD	0.64	0.00

Due to the non-normality of the distribution of scores, a non-parametric test was selected to test the difference between group performance in the two conditions. The number of items correctly recalled by each subject, in both conditions, was analyzed using the Wilcoxon Matched-Pairs, Signed-ranks Test. This revealed a significant difference between conditions ($Z = 2.52$, $n = 8$, $p < .05$), which confirmed the ease with which subjects recognised the calculated, when compared with the studied dates.

Discussion

The results show that a difference was obtained between conditions in the direction predicted. Significantly more dates were recalled following the calculate when compared with the study condition. In line with the reasoning proposed earlier, it can be suggested that the process of calculation does indeed involve the use of an elaborate, richly interconnected knowledge base. Whereas the activation resulting from reading an item may be concentrated largely on the specific representation(s) for that date, the calculation process makes additional use of the interconnections *between* date representations. In turn, this activation of relational links facilitates subsequent memory by providing an increased number of access and retrieval routes to the previously presented date. Thus, the savant appears to utilize the connections between dates stored in LTM as part of the calendar calculation process.

However, an alternative interpretation of the current findings should be considered; the generation effect may have been obtained due to the increased mental effort involved in the date calculation process. For example, calculation may utilize additional attentional resources. Although this suggestion cannot be addressed directly within the current experimental design, it is important to consider the evidence regarding the generation effect in the normal population using words rather than dates. Importantly, these studies have shown that engaging in an effortful process to generate an item does not necessarily give rise to the effect of generation over study. As mentioned previously, Nairne et al. (1985) did not obtain an effect when subjects were required to generate low frequency and nonwords. Reardon et al. (1987) did not obtain the effect for their subjects outside of the individuals' area of expertise. If the generation effect was simply attributable to an increase in the cognitive resources required for the generation process, then the effect would be evident on *all* tasks which required generation. However, the effect appears to be limited to tasks which utilize an elaborately structured knowledge base.

It is also important to note that several features of the current experimental design were introduced to favour performance in the study when compared to the calculation condition. First, each date in the study condition was presented for five seconds. As the savants could calculate most of the dates in under five seconds, the study items therefore received a greater amount of time for inspection. Second, an additional 15 second study period of the whole list was provided which was not given in the calculation condition. Also, Slamecka and Graf (1978) noted a further point which may favour the recall of the studied dates. This relates to the fact that in the read condition, the full response is accessible the moment the stimuli are seen which would give more time for processing the item. In the calculate condition, the full response, i.e. the answer, is only available at the end of the exposure time to the item. Finally, it is possible that some of the brighter individuals may have anticipated a test of memory following the study list, as it was more difficult to disguise the purpose of this condition. It was presumed that because the savants are often given tests of calculation, then an ulterior purpose would not have been so readily anticipated in the calculate condition. The fact that the two conditions were given in separate sessions was intended to reduce any expectation that they were to be given a subsequent memory task. To reiterate, several of the current experimental design features were introduced to favour performance in the study condition. In view of this, the outstanding performance of the savants in the calculate condition appears all the more marked. Indeed, the savants achieved maximal performance in this second task which would indicate that the experimenter's concern, regarding the difficulty of the experiment, was somewhat misplaced.

To conclude, the present experiment has extended the findings of the previous two studies. Although savants do not possess superior general short- and long-term memories in relation to IQ-matched controls, through exposure to the calendar, they have developed an elaborately structured knowledge base which underlies their ability to calculate. Moreover, the calculation process appears to utilize the relational structure of dates stored in LTM. It thus becomes important to explore the nature of the organization within this knowledge base, i.e. *how* are these dates related; what is the structure of calendar-specific knowledge? This forms the subject of investigation in the following four experiments.

CHAPTER 5

THE ORGANIZATION OF CALENDAR KNOWLEDGE

Overview of Experiments 4 to 8

Based on the findings of the previous experiments, it is suggested that the savants possess an elaborately structured talent-related knowledge base which underlies their ability to calculate dates. It is important to now explore the specific organization and structure which characterises their LTM for date information.

Studies by Hermelin and O'Connor (1986), Young and Nettelbeck (1994) and Ho, Tsang and Ho (1991) have shown that savant date calculators utilize calendar rules and regularities as part of the calculation process (see Chapter 2). For example, the savants make use of the 28 yearly repetition within the calendar to aid their calculations. This suggests that savant date knowledge may be organized to reflect these calendar regularities. From the subject descriptions in Chapter 3, it is clear that the savants also have an impressive memory for the dates of specific events. Thus, savant calendar knowledge may also reflect the relationships between significant events falling on specific dates, e.g. Easter Sunday.

The organization of calendar knowledge was explored in the following experiments by presenting the savants with lists of dates for recall. In the experimental lists, dates were linked according to features associated with the calendar, e.g. the 28 year rule, the occurrence of Easter Sunday. Recall of these lists was compared to control lists of dates which were not related according to these specific calendar features. Importantly, a facilitation in the recall of related date information would suggest that these lists reflected the organization of calendar knowledge, i.e. they were mapping the organization of LTM.

As was noted in Chapter 1, equivalent research has been conducted with other savant abilities and also with experts in the normal population. For example, the superior recall of tonal when compared to atonal music is taken as evidence that savant musical knowledge reflects the rule-governed structure of tonal music (e.g. Sloboda et al., 1985). Similarly, the better memory of chess experts for meaningful board positions when compared to random arrangements is taken to suggest that chess knowledge comprises the LTM representation of real game configurations (e.g. Chase and Simon, 1973). Thus, the comparable approach adopted in the following experiments, which involved manipulating the relationships between dates within a list to assess the effect on the savants' levels of recall, may prove an informative means by which to explore calendar knowledge structure.

However, given that most of the subjects in the present sample have a diagnosis of autism it is important to consider the work of Hermelin and O'Connor (1970), Frith (1970a; 1970b) and Tager-Flusberg (1991) in relation to the following experimental design. Importantly, these studies have shown that individuals with autism have difficulty in extracting patterns of organization from lists of items to be recalled. This research can be divided into those studies which demonstrated that autistic subjects failed to utilise list organization based on semantic or *pre-existing* links in LTM and list structure for which there would be no pre-existing associations in LTM. For example, Hermelin and O'Connor (1970) showed that whilst the recall of normal and mentally handicapped control subjects was facilitated by presenting words within meaningful sentences rather than random word strings, the autistic children did not derive the equivalent memorial advantage from words presented in this redundant format. Similarly, Tager-Flusberg (1991) found that the recall of autistic subjects was not enhanced by presenting a list of semantically related words (animal names) when compared with semantically unrelated words. In contrast, the recall levels of normal and mentally handicapped controls were superior for the related word list. Importantly, however, Tager-Flusberg went on to show that the performance of the autistic group was not attributable to an encoding deficit; the autistic subjects were able to use semantic cues to facilitate word retrieval. This suggests that these word items are stored in a semantically related format in LTM, but these pre-existing links are not activated in order to facilitate retrieval[3].

Frith's (1970a; 1970b) work examined the ability of autistic children to extract structure from stimuli for which there would be no pre-existing links in LTM; the structure was purely inherent to the input. For example, subjects were presented with simplified binary sequences of words, constructed using two devices; repetition and alternation. Different

[3] Tager-Flusberg's (1991) findings have recently been replicated in a study by Bowler, Gardiner and Matthews (in prep) involving adults with Asperger's Syndrome.

patterns of binary sequences were created by using either of the two devices or by mixing them together, e.g. "horse-spoon-spoon-horse-horse", with word sequences varying in terms of their redundancy. For example, a more redundant sequence would be one involving only alternations when compared with a sequence involving both repetitions and alternations. An analysis of correct responses revealed that the autistic children, in contrast to normal and mentally handicapped controls, failed to take advantage of the redundancy in sequences in order to facilitate recall. Furthermore, an analysis of errors revealed that the autistic subjects would often fail to extract the predominant feature of the sequence (i.e. either repetition or alternation) and tended to apply the repetition rule whether this was the dominant rule or not. This provides further evidence of the autistic individual's failure to extract structure and organization to facilitate memory performance.

As the calendar represents an outstanding area of function for the savant, it is predicted that recall *will* be facilitated for dates linked according to features of the calendar. Thus, within the confines of the calendar, the savants will not demonstrate the pattern of recall performance characteristic of individuals with autism. Specifically, from the evidence indicating the savants' use of calendar rules and regularities, it was predicted that their LTM representation for date will be organized to reflect the principles of calendar *structure*. As a point of interest, the final experiment in the thesis represents almost a "control study". The savants were presented with lists of words, involving semantically related and structurally related items together with the appropriate control lists. If the savants *were* to demonstrate a facilitation in recall performance for related dates, this final study would illustrate the domain specificity of such recall performance. These remaining five experiments will all be described within the present chapter, beginning with an investigation of the recall of dates falling on the same day.

Experiment 4: Recall and the Organization of Dates: Same day vs Different Day Dates.

Introduction

The present study represents the first attempt to explore the effect of organization on the recall of date items. Levels of retention for lists of related dates will be compared to unrelated control lists. Importantly, the key relationship shared between dates in the experimental condition concerns the day of the week on which the dates fall.

The day of the week of a date is perhaps the most basic unit of calendar structure. In effect, the day-date correspondance is the "building block" of the calendar. Regularities within a given year arise from the fact that every eighth date will fall on the same weekday. By utilizing this regularity, knowledge of the day of the week for just one date in a specific month, can in turn produce the corresponding weekday for other dates within the same month. For example, knowledge that the 1st May 1995 was a Monday, allows the 8th, 15th, 22nd and 29th of May to be generated as Mondays. Adopting the same calendrical pattern, together with a knowledge of weekday order, the 2nd May 1995 was a Tuesday and thus the 9th, 16th, 23rd and 30th were also Tuesdays. Furthermore, this proposed relationship between dates falling on the same day may extend beyond month units. To know the number of days in each month, or more precisely the last date of each month, means that the "seven day regularity" can be applied across different months. For example, the 30th June 1995 was a Friday and armed with the knowledge that there is no 31st June, then the 1st of July becomes a Saturday, the 8th July a Saturday and so on.

It is thus easy to appreciate how regularities in the calendar, in this case relating specifically to days of the week, may serve to structure calendar knowledge. As dates falling on the same weekday share a special relationship and form a significant regularity within the calendar, then these individual dates may be represented in a similar relational format in LTM. Thus, savant date knowledge would reflect the patterning of dates which fall on the same day, at least within restricted ranges of the calendar. In order to test this, recall performance was examined for lists of dates falling on the same weekday compared to lists of dates falling on different days of the week within a given year. As the lists of same day dates are suggested to reflect the structure of calendar knowledge, these related lists were predicted to be better recalled than the unrelated, different day lists.

It is assumed that the associative relationship shared between same weekday dates would extend across the span of one calendar year, i.e. dates falling on a Monday in February 1990 and on a Monday in November 1990 would be linked because they form part of the same extended pattern. Of course, this regularity continues beyond individual years. However, in terms of the LTM representation of calendar information, it is suggested that dates within the same year will share the strongest associative links. Thus, dates which are temporally and structurally proximate will be more extensively interconnected than individual dates falling in different years. Therefore, in order to maximise any obtained effects of calendar organization, dates were chosen to fall in the same year within each list.

Of further interest to the following study is the savants' ability to consciously process the organization within lists. As an indication of this, the subjects will be questioned directly about any perceived relationship between the items. For example, will they be able to provide a verbal indication that all of the experimental list items fall on the same day? Importantly, how would this explicit processing of the relationship between dates relate to their level of recall for these items?

There are, of course, obvious difficulties associated with adopting this questioning approach. We know that calendar calculators are notoriously bad at providing details of their calculation method. When asked about their knowledge of the calendar only the two most able calculators could provide fragmentary information regarding date rules and regularities (Hermelin and O'Connor, 1986). Furthermore, with low verbal IQ's and a diagnosed communication disorder, most of the subjects would be expected to experience genuine difficulties in verbal expression. However, the approach utilized in the following studies, which involves questioning the subjects directly about the experimental stimuli, is more focussed, using specific examples of visually presented, familiar dates. This should provide a structured framework for eliciting verbal responses which in turn may yield interesting observations regarding the savants' awareness of date relationships.

In summary, the present experiment investigated the recall of date lists organized according to the day of the week on which they fall. Recall was predicted to be enhanced for dates which all share the same weekday when compared to lists of dates which do not share this principle of calendar regularity. In addition, to accompany the study of recall performance as a measure of knowledge structure, attempts were made to explore the subjects' ability to report the relationships between dates.

Method

Subjects. Eight savant calendrical calculators participated in the present study. Specifically they were G.C., H.P., J.P., R.D., J.B., D.K., P.E. and P.M. The mean verbal IQ of the group, as measured on the Peabody Picture Vocabulary Test was 65.6 (*SD* 12.9) and the mean non-verbal IQ of the group, obtained from the Ravens Progressive Matrices Test, was 77.9 (*SD* 23.0). Additional subject details are given in Chapter 3.

The following experiment did not involve a control group. Experiment 2, which investigated the long-term recall of individual year items, illustrated the difficulty experienced by an IQ and diagnosis matched control group in recalling calendar information. Most of the group were struggling to recall more that one individual year from a list of eight. Thus, the memory load required in the following study was judged to be too demanding for the controls. More importantly, the study represents an attempt to explore *within group* differences: specifically, the memorability of certain dates when compared to other dates and the conclusions which can be drawn regarding the *talent-specific* knowledge system. These predicted differences in the levels of recall could only arise from the ability to calendar calculate, thus precluding the use of a non-calculating control group.

Materials. Four lists of eight dates were used. These are shown in Table 5.1, below. Each list comprised dates taken from a different year. The years 1988, 1989, 1991 and 1992 were chosen to represent fairly recent and familiar years.

Experimental lists. List 1 (1988) and List 3 (1991) formed the experimental lists. As is shown in Table 5.1, all of the dates in List 1 fell on a Monday in 1988 and in List 3, all of the dates fell on a Thursday in 1991. It should also be noted that although Table 5.1 indicates the day of the week of the dates, the lists presented to subjects did *not* include this information. Within these lists, the dates were chosen to fall in different months and to span the whole year. In addition, the items were chosen to represent the range of dates within a month, i.e. from the 1st to the 30th/31st. In effect, this kept the memory load to capacity so that dates were not concentrated within particular months or particular date ranges.

Control lists. List 2 and List 4 acted as control lists, containing dates which fell on different days of the week. These are also illustrated in Table 5.1. List 2 containing dates from 1989 acted as a specific control for items in List 1 due to the close proximity of the years. List 4 with dates from 1992 acted as a control for items in List 3. As dates from more recent years tend to be more speedily calculated (O'Connor and Hermelin, 1984), both control lists were selected from more recent years than the experimental lists.

Table 5.1. *Same day and different day lists presented to subjects.*

List 1: 1988 (Leap)	List 2: 1989
15th February 1988 (Monday)	11th July 1989 (Tuesday)
7th November 1988 (Monday)	4th March 1989 (Saturday)
24 October 1988 (Monday)	20th December 1989 (Wednesday)
18th July 1988 (Monday)	13th April 1989 (Thursday)
1st August 1988 (Monday)	29th October 1989 (Sunday)
4th January 1988 (Monday)	24th February 1989 (Friday)
9th May 1988 (Monday)	19th June 1989 (Monday)
12th September 1988 (Monday)	6th September 1989 (Wednesday)

List 3: 1991	List 4: 1992 (Leap)
10th October 1991 (Thursday)	8th May 1992 (Friday)
27th June 1991 (Thursday)	19th October 1992 (Monday)
7th March 1991 (Thursday)	26th January 1992 (Sunday)
25th April 1991 (Thursday)	11th November 1992 (Wednesday)
5th December 1991 (Thursday)	4th July 1992 (Saturday)
30th May 1991 (Thursday)	31st December 1992 (Thursday)
19th September 1991 (Thursday)	21st April 1992 (Tuesday)
14th February 1991 (Thursday)	24th February 1992 (Monday)

As a further point, experimental List 1 comprised dates which all fell in a leap year (1988). In order to equate the two conditions on this variable, control list 4 was selected from another leap year (1992).

Each individual list was printed in Times Roman font, 20pt, on a seperate piece of card. The lists appeared in the format shown in Table 5.1 but with the corresponding days omitted from the presentation list. An additional piece of A4 card was used which contained a small window cut into the card, large enough to reveal only one date at a time within the list.

Procedure. The order of presentation of the lists was derived by using the ABBA/BAAB counterbalancing design. Assigning an "A" to the experimental lists and a "B" to the control lists, eight different combinations of list presentation were generated. Therefore, each savant was presented with a different sequence of lists but the presentation order of experimental and control lists remained counterbalanced. The precise order of list presentation for each subject is shown in Appendix B.

Before the lists were presented, the subjects were told they were to be shown a list of dates which would also be read to them. They were instructed to try and remember the dates as they would subsequently be asked to recall as many as they could from the list. Importantly, subjects were asked not to calculate the dates as the experimenter already knew the day of the week on which they fell.

Each date within the list was displayed individually to the subject for five seconds. This was achieved by using the cardboard window which was moved down the list, revealing one date at a time. The date was also read aloud by the experimenter. Therefore, presentation was both visual and auditory. Through a combined use of the window and reading out the dates, it was hoped to focus the savants' attention as much as possible on each of the items. In most cases the subjects would choose to read aloud the date displayed although no explicit instructions were given to do so.

Following the five second presentation of each individual date the cardboard window was removed and the whole list was displayed for 10 seconds. This constituted an attempt to encourage as much relational processing across items as possible. During this 10 second study period the subjects were encouraged to look very carefully at the dates.

This was followed by a one minute interval in which the subjects were actively engaged in verbal interchange with the experimenter. Topics covered would include other activities known to be of interest to the subject and conversation points stimulated by the immediate environment. Calendar and date related topics were not discussed.

After the one minute interval the subjects were requested to free recall the previously presented dates. Subjects were informed they could take as long as they needed to remember the dates and the dates could be given in any order they chose. When appropriate the experimenter probed for the recall of further items. This took the form of "That's very good, you have done well to remember those dates. There were also some other dates on the list. Could you tell me what they were...?". Care was taken to adopt this approach across all the lists. When the subject could clearly not recall any more items, they were congratulated on doing so well.

Verbal reports. Following the presentation of all four lists, the subjects were asked questions such as "what can you tell me about those lists of dates?" and "did you notice anything special about any of the lists?". If the subjects were unable at this stage to identify the relationship, the four lists were then placed in a randomised layout in front of the subjects and similar questions were asked again.

Results

The total number of dates recalled by the subjects for all four lists is shown in Table 5.2, below, together with means and standard deviations. It should be noted that, for the sake of clarity, the lists are not presented in the order 1 to 4, within Table 5.2. Rather, the lists are ordered to indicate the recall scores of date falling on the same day in a leap year (List 1) followed by dates falling on different days in a leap year (List 4) and dates on the same day in a non-leap year (List 3) followed by the different day dates in a non-leap year (List 2). The mean number of dates recalled for each of the four lists are also shown in Figure 5.1, below.

Table 5.2. ***Number of dates recalled from same day and different day lists (out of a total of 8).***

Subject	Same day (leap) List 1	Different day (leap) List 4	Same day (non-leap) List 3	Different day (non-leap) List 2
H.P.	6	4	5	3
G.C.	8	6	7	6
R.D.	5	4	6	4
J.B.	3	2	3	2
J.P.	6	6	7	4
D.K.	7	4	6	5
P.M.	7	2	5	1
P.E.	7	5	6	5
Mean	6.13	4.13	5.63	3.75
SD	1.56	1.55	1.30	1.67

The total number of dates recalled by each of the subjects from all four lists was entered into a repeated measures ANOVA with two within-group factors; day of the week (same day dates vs different day dates) and year type (leap years vs non-leap years).

The analyses revealed a significant main effect of day of the week ($F(1,7) = 25.58$, $p < .01$). Same day, related dates were significantly better recalled than the different day, unrelated lists (with means of 5.88 and 3.94 respectively for the two conditions). There was a near significant main effect of year type ($F(1,7) = 3.94$, $p = .087$), with a trend towards leap years being better recalled than non-leaps and no significant interaction between the two variables ($F(1,7) = .05$, ns).

The verbal reports given by the subjects are included in the Discussion section, below.

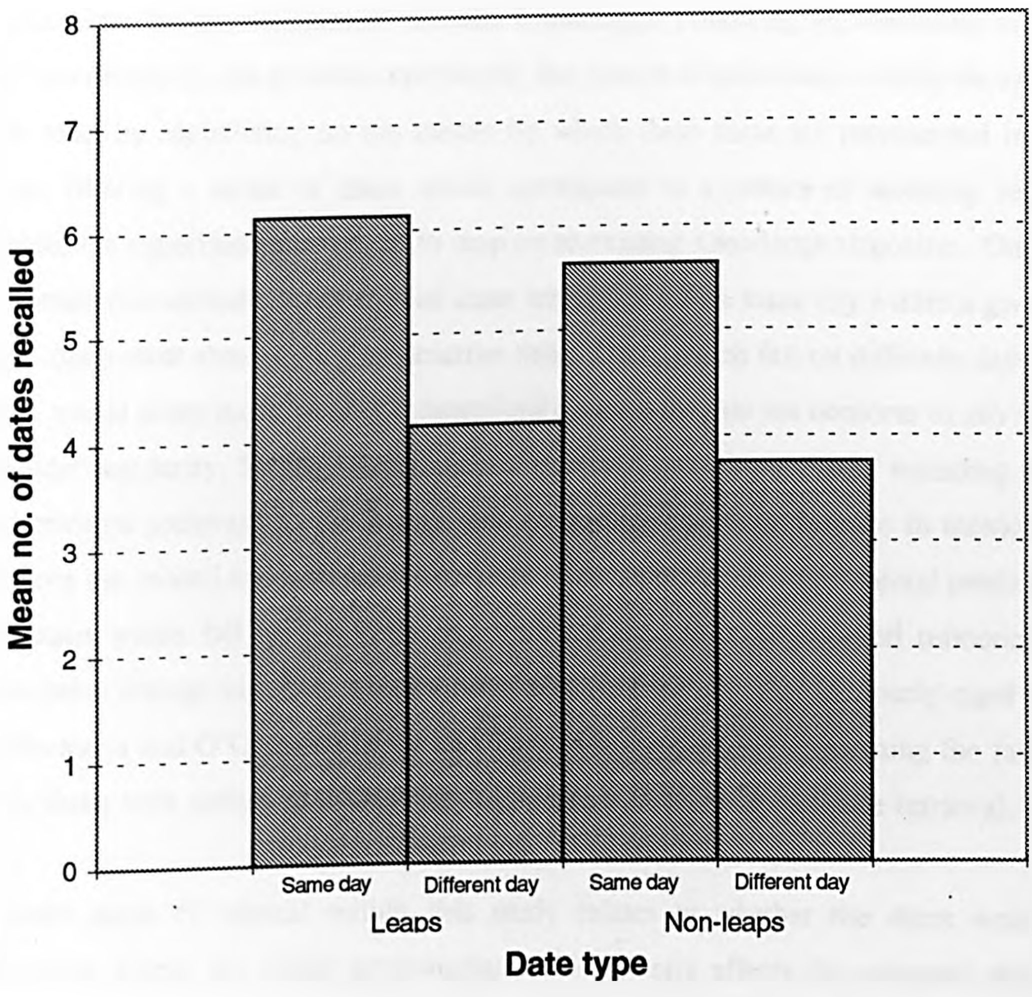

Figure 5.1. ***Mean number of dates recalled from the same day and different day lists.***

Discussion

As the results clearly show, the level of recall was superior for the related date lists. As the two conditions were equated on all other relevant factors with the only source of variance between lists being the day of the week on which they fell, then the resulting difference in memorability can only be due to this specific organization relating to the weekday. No other list feature differentiated between the two conditions. This in turn has implications for the structure of calendar knowledge. Following the reasoning offered in the introduction to the present experiment, the pattern of relatedness within the same day lists must be capitalising on the means by which these dates are represented in LTM. Thus, offering a series of dates which correspond to a pattern of weekday repetition enables the experimental material to map on to existing knowledge structures. Due to the important calendrical relationship of dates which fall on the same day within a given year these dates must share strong associative links. Dates which fall on different days of the week would share much weaker connections because they do not conform to any specific calendar regularity. Strong interconnectivity would provide increased encoding options and retrieval pathways to the items, thus accounting for the difference in memorability between the related and unrelated date lists. This supports the experimental prediction in that dates which fall on the same day within a list are better recalled reflecting their associative linkage in LTM. These results also contrast with the previously cited studies of Hermelin and O'Connor (1970) and Tager-Flusberg (1991) concerning the failure of individuals with autism to utilize list organization in order to facilitate retrieval.

Another point of interest within this study relates to whether the dates were fully calculated during the initial presentation. This directly affects the subjects' ability to describe the relationship within lists; the pattern of organization can only be extracted explicitly if the dates are calculated. Although instructions were given not to calculate, each date was presented for at least five seconds which would normally be a sufficient length of time for the subjects to generate the appropriate weekday for such recent years. Interestingly, during the presentation of the experimental stimuli in the study phase, not one of the savants spontaneously vocalised the day of the week for any of the items.

However, it is still a strong possibility that dates were calculated (either automatically or deliberately) but the product was not verbalized. Evidence that at least two of the group had calculated the dates was revealed by subsequent questioning. Following the recall phase of the experiment, after being asked if he had "noticed anything special about the lists", H.P. (verbal IQ of 80) proceeded to answer that one of the lists "was all Mondays", another "was all Thursdays" and the others were all "different days". Subject G.C. (with a verbal IQ of 79) gave a very similar answer. The remaining six subjects were unable to answer the experimenter's probes about the relationship between dates. The four lists were then laid out in front of the six subjects individually and the experimenter continued to probe for the recognition of the list relationships. Two of the subjects (R.D. and J.B.) continued to respond negatively.

The remaining four individuals (J.P., P.E., D.K. and P.M.) proceeded to calculate each of the dates, stating aloud the correct day of the week. Subsequent answers to the probes therefore gave some indication of the same day compared to different day list relationship. Although the evidence is inconclusive, this appeared to be the first time these four subjects had consciously (or at least deliberately) calculated the items. At the very least, it was the first time they had produced the verbal output of the process. Thus, it would seem that, together with the subjects R.D. and J.B., these six individuals had displayed a clear facilitation in recall levels without having explicitly processed the pattern of relatedness within lists.

This is a very important point and should be clarifed in a number of ways. First, it is fully accepted that a procedure which requires mentally handicapped subjects to provide a verbal report is problematic. It is therefore unsurprising that the two subjects who were able to report the relationship between dates were the two calculators with the highest verbal IQ's. This information should therefore be treated with an appropriate degree of caution. Nevertheless, all of the calculators involved in the present study are able to produce an explicit, verbalisable output as a component of their skill, i.e. they will tell you the day of the week. Furthermore, all of the subjects willingly volunteer and enquire about date information in a non-experimental context, e.g. asking about birthdays, informing the experimenter of the dates of her past visits. So, whilst obtaining verbal data from the savants is not an ideal approach, nevertheless, it was judged to be appropriate.

A second point relates to recent work on the implicit/explicit knowledge distinction. As was noted in Chapter 2, authors such as Shanks and St John (1994) warn against equating knowledge which cannot be verbalised with implicit knowledge. That is, simply because a subject cannot report acquired information does not indicate conclusively that this knowledge is unconscious. Such knowledge which cannot be verbalised may be revealed on other tests, e.g. prediction tests, and as such is transferable and therefore explicit. This is a strict view, not necessarily adhered to by other studies in which the lack of verbal report is taken as a measure of unconscious learning (e.g. Lewicki, Czyzewska and Hoffman, 1987). Nevertheless, it is a pertinent point given the IQ levels of the present subjects and serves to reinforce the caution with which the results are interpreted.

The performance of subjects H.P. and G.C., who were able to report the organization within lists and were therefore assumed to have calculated the dates, merits further discussion. Interestingly, although G.C. achieved the highest level of recall in the group, H.P.'s performance did not surpass that of at least four other subjects. Thus, the ability to verbalise the list relationship did not necessarily lead to enhanced performance. This is of specific interest in view of the results from Experiment 3, demonstrating the increased memorability of calculated dates compared to studied dates. We know that H.P. had calculated the items during the initial presentation of the dates. The comparable recall performance of the other subjects therefore suggests that they were doing more than simply studying the dates. It may be suggested that the presentation of dates in the format used in this study automatically triggered the underlying knowledge representations which correspond to the dates and which subserve calculation. These same knowledge representations and interconnections were activated whether or not the output of the process was consciously formulated. This may not have occurred for items in the study condition of Experiment 3, because the days were displayed as part of the date items.

The important point, however, is that there was differential activation/differential processing *between lists* rather than between subjects. Whether the subject engaged in studying or calculating the dates, either consciously or unconsciously, we can assume that the same processing approach governed performance across all four lists. However, over and above this, all eight subjects recalled more items from the related compared to the unrelated lists. This is the key point relating to the experimental hypothesis, which suggests that the calendar-specific knowledge is structured to reflect the significant relationship between dates sharing the same weekday within a year.

Of additional interest is the fact that the savants did not produce any intrusion errors. The subjects generated only the presented dates and appeared not to guess. Had such intrusion errors occurred, it would have been useful to examine whether they conformed to the list relationships, e.g. whether errors on List 1 were also Mondays. This would have suggested that the subject had extracted the pattern of organization even though they were unable to articulate it. In addition, the calculators did not produce partially remembered dates. Nor did they confuse the date and months between seperate items by combining the date portion of one item with the month of another. This suggests that when the savants are presented with a single date, it is encoded, stored and retrieved as a whole unit rather than being processed as individual segments e.g. 1st / August / 1988.

As a final point concerning performance in this experiment, the results revealed a near significant main effect of leap years, with a trend towards leap year dates being better recalled than non-leaps. It was noted in Chapter 2 that Young and Nettelbeck's (1994) three subjects failed to make use of monthly structure to facilitate calculation in leap years. The present results, therefore, appear somewhat at odds with Young and Nettelbeck's findings. The eight savants were all shown to be able to utilize calendar-based structure within a list of leap year dates in order to faciliate recall. The memorability of leap years compared to non-leap years will be the specific subject of investigation within a following experiment.

Experiments 5a and 5b: The Memorability of Dates Falling at 28 year Intervals.

Experiment 5A

Introduction

We are all familiar with the fact that there are seven days in a week and that the calendar operates on this seven day cycle. Our everyday lives are structured according to this facet of the calendar. However, the "28 year regularity" may not seem quite so familiar. The Gregorian calendar contains a 28 yearly internal repetition, thus years which are 28 years apart are structurally identical. Only through considerable experience and knowledge of extended periods of the calendar would such a feature become apparent.

Savant calculators studied by Young and Nettelbeck (1994), Hermelin and O'Connor (1986) and Ho, Tsang and Ho (1991) have all been shown to utilize the 28 yearly rule. Thus, it can be suggested that calendar knowledge will be structured to reflect the relationship between dates falling at 28 yearly intervals. In order to test this, a list of dates sharing the same date and month was presented for recall, with each subsequent date falling 28 years later eg. 1st July, 1914, 1st July 1942, 1st July 1970, 1st July 1998. The recall of this list was compared to a control list of dates which was also composed of the same date and month but at regular intervals of 23 years. Years which are 23 years apart are not structurally identical. So, although in this case, dates in the control list share a pattern of relatedness and fall at regular yearly intervals, these intervals are of no calendrical significance. It was hypothesized that recall would be superior for items from the experimental list in which the dates conform to a specific pattern of organization within the calendar, in comparison to the control dates which do not fall at calendrically significant intervals.

Method

Subjects. Eight savants participated in the present study. These were the same subjects who took part in Experiment 4.

Materials. Two lists of eight dates were used. These are shown in Table 5.3, below. List 1 comprised the experimental dates which fall at an interval of 28 years. In order to keep the range of dates within the spans of all of the savant group, specifically within the 20th century, the eight dates were divided into two groups of four. Within each group of four dates, the date and month portion of each item remained the same with the only variation being between the individual years. By retaining the same date and month, it was hoped to emphasize the differences between years. List 2 shows the dates, falling at 23 yearly intervals, which formed the control condition. Again the eight dates were divided into two groups of four, in order to restrict the items to the 20th century. In both lists the dates were presented in chronological order within the groups of four, thus preserving the yearly sequence.

Table 5.3. ***Lists of dates used as stimuli in Experiment 5a***

List 1: 28 Year Dates	List 2: 23 Year Dates
1st July 1914	22nd April 1916
1st July 1942	22nd April 1939
1st July 1970	22nd April 1962
1st July 1998	22nd April 1985
14th May 1911	6th June 1921
14th May 1939	6th June 1944
14th May 1967	6th June 1967
14th May 1995	6th June 1990

The dates were presented in Times Roman font, 20 Pt size. An extra space was introduced between items four and five of each list in order to emphasize the two groups of four.

As in Experiment 4, the procedure involved the use of a cardboard A4 sheet with a "window", which allowed one date at a time to be revealed.

Procedure. Subjects were informed that they were to be shown a list of eight dates which they should try and remember. The experimenter would first of all show them each date and also read out the date. Subjects were advised to concentrate and look very carefully at the items. They would then be allowed to look at the whole list for eight seconds before it was removed. After a short interval they would be asked to remember as many dates as possible from the list. As in Experiment 4, it was stressed that this was a test of memory, not of calculation. As the experimenter already knew the days of the week for all of the dates, the subjects were asked to concentrate on remembering the dates rather than calculating them.

The order of presentation of the two lists was alternated between subjects. Each date was displayed individually for three seconds by the experimenter moving down the cardboard window. As in Experiment 4, each date was also read aloud by the experimenter. Again, the subjects would often choose to read aloud the date. Following the individual presentation of each item, the cardboard window was removed and the whole list was presented for an eight second study period. It should be noted that the current experimental procedure reduces the exposure time of the stimuli when compared to Experiment 4. This aspect of the procedure was modified in an attempt to prevent the calculation of the dates.

After removal of the list of items, the subject was encouraged to engage in a verbal interchange with the experimenter for a period of one minute. Topics covered were unrelated to the calendar. Following this filled interval, subjects were requested to recall as many of the previously presented dates as possible, in any order.

Verbal reports. Immediately after the subjects had recalled the dates, they were questioned about the relationships between the items. For example, they were asked "What did you notice about all of the dates in the first list..?" and "Were the two lists different in any way?". The two lists were then placed in front of the subject and the questions were repeated.

Results

The total number of dates recalled by each subject is displayed in Table 5.4 below, together with the means and standard deviations for each list. A related *t*-test performed on these scores revealed a significant difference between lists ($t(1,7) = 6.06$, $p=.001$), with the experimental, 28 year dates being better recalled than the control, 23 year list.

Table 5.4. ***Number of dates recalled from the experimental and control lists (out of total score of 8)***

	Number of dates recalled	
Subjects	Experimental (28 year dates)	Control (23 year) dates
H.P.	8	6
G.C.	8	6
R.D.	5	2
J.B.	4	2
J.P.	6	5
D.K.	8	7
P.M.	7	3
P.E.	8	6
Mean	6.75	4.62
SD	1.58	2.00

Order of recall Of further interest is the order in which the dates were recalled: specifically, whether the exact yearly intervals were retained. In order to examine this, a scoring system was devised in which subjects received a score of '1' for 3 dates, from each group of four, which were recalled in order and a score of '2' if all of the four dates were recalled in order. Thus, the preservation of order was scored separately for the two groups of four dates in each list. Of course, the yearly intervals within each group of four dates could still be preserved if the subject recalled the items in reverse order of original presentation. Therefore, the analysis of recall order also included reversed sequences, e.g. 1st July 1998, 1st July 1970, 1st July 1942, 1st July 1914.

Within this scoring system, the maximum score is '4' for each list. This would indicate that all eight items were recalled in an order which reflected the original 28 or 23 year sequence. A score of '3' would indicate that within the list, one entire group of four dates together with three dates from the other group were recalled in order. A score of '0' suggests that the dates were recalled in a randomized order. Table 5.5 below shows the results of applying this scoring procedure to the recall order of each subject's responses.

Table 5.5. ***Order of recall for experimental and control dates.***

	Experimental (28 year) dates		Control (23 year) dates	
Subjects	1st July dates	14th May dates	22nd April dates	6th June dates
H.P.	2	2	0	0
G.C.	2	2	0	0
R.D.	0	1	0	0
J.B.	0	0	0	0
J.P.	1	0	0	0
D.K.	2	2	1	2
P.M.	1	2	0	0
P.E.	2	2	1	0
Total	10	11	2	2

As can be seen from Table 5.5, all of the subjects obtained higher scores for the experimental list. Each subjects' scores for the two groups of four in each list were totalled to give one experimental and one control list score. Due to the non-normality of the distributions of scores, a Wilcoxon Signed-Ranks Test was used to compare subjects' scores for the two lists. This revealed a significant difference between the two conditions

($W = 0$, $p < .01$). Thus, there was a tendency to preserve the calendrically significant interval of 28 years when recalling the experimental dates. In contrast, the control dates were recalled in a more randomized order.

Finally, it is interesting to note that the preserved order of recall did not always correspond to the temporal order of date presentation. P.E. and R.D. recalled items from the second block of four experimental dates before the first group of four and in the control list, G.C. recalled the June dates before the April dates. Furthermore, within the groups of four, subjects G.C. and J.P. recalled four experimental dates in reverse order, with D.K. recalling four control dates in reverse order.

Discussion

The present study has succeeded in revealing a difference in memorability between the two date lists. Dates linked according to the 28 year rule were significantly better recalled than the items which fell at 23 year intervals; a repetition which is of no calendrical signficance. Furthermore, an analysis of the order in which the two sets of items were retrieved revealed a difference between conditions. There was a significant tendency to recall the experimental items in an order which reflected the original presentation. Specifically, the experimental dates were often retrieved in an order which preserved the successive 28 year intervals between items. Even though the second portion of the list was sometimes recalled before the first group of four dates and occasionally the order of the dates within each group of four was reversed, nevertheless the sequence of dates was preserved. This was not the case for the control items.

It is important to note, however, that the analysis of recall *order* is highly dependent on the *number* of items recalled. As fewer dates were retrieved in the control condition then order is of course less likely to be preserved. For this very reason, the performance of subjects R.D. and J.B. in the control condition should perhaps be disregarded. As these subjects recalled only two control items, then their order of response cannot be scored with the adopted system. Nevertheless, for subjects H.P. and G.C. who both recalled six out of eight items in the control condition, these items were retrieved in a randomized order. Although this reduces the discussion to a very small number of subjects, the contrast between their performance in the experimental and control conditions is quite marked and should therefore be noted.

This point concerning recall order may in fact prove as informative about calendar knowledge structure as the actual difference in retention levels between the two conditions. If, as it is suggested, savant LTM representation of date information reflects the 28 year repetition, then the retrieval of a specific date should automatically activate the same associated date 28 years earlier and 28 years later. By presenting the same date at 28 yearly intervals, the experimental list would have capitalized on this facet of knowledge structure. Therefore, it is precisely because the items were recalled in order, that levels of retention were higher. Items may be recalled in a "chain of association"; a process of sequential activation. Thus, it is the *order* of recall that predicts the *number* of experimental dates retrieved. As with subject J.B., when the experimental items are not recalled in order, fewer dates tend to be recalled. Importantly, in the control condition, due to the fact that an interval of 23 years does not form part of calendar organization, the recall of one date will not automatically trigger the recall of another date 23 years earlier or later. This may explain the finding that even when retention levels are relatively high, for example six out of eight control items recalled, these tend to be retrieved in a randomized order.

However, if as it is suggested, one experimental date will automatically activate another related 28 year date, why did some of the subjects fail to perform at ceiling in the experimental condition? One possible explanation is that associated 28 year dates may be activated, but the level of activation may not be sufficient to cause the item to be retrieved. This would fit with the concept of spreading activation through a network of related concepts (Collins and Loftus, 1975). This interpretation does, however, remain speculative. In addition, the three subjects whose recall levels were the lowest in the experimental condition were also the subjects with the lowest verbal IQ's. Thus, levels of intelligence may also operate to constrain memory performance.

As in Experiment 4, the verbal reports provided by subjects proved interesting and informative. In this experiment, during the study phase of the procedure, subject P.M. announced spontaneously that the experimental list items were "every 28 years" and the control dates were "every 23 years". In general, P.M. demonstrates an outstanding facility to calculate the difference in years between two particular dates as reported in Chapter 3. A similar facility had been noted for J.B. on previous occasions, however in the present study she did not offer any information regarding the intervals between dates. H.P. was also able to report accurately on the relationship between dates in both conditions but only after prompting from the experimenter. The only other subject who offered any information prior to the re-presentation of the date lists was G.C. who gave the days of the week for three dates from each list. Thus, subjects H.P. and G.C. had again extracted features from the stimuli lists which they could verbalize. The remaining subjects gave no response at this stage. When re-presented with the two lists for inspection, G.C. was able to note that in one of the lists the dates fell 28 years apart and in the other they were 23 years apart. The remaining five subjects proceeded to calculate the individual dates. This was in line with their performance in Experiment 4. Thus, their answers subsequently referred to the day of the week of the respective dates and did not relate specifically to the 28 yearly interval.

As in Experiment 4 which investigated same day dates, the evidence is mixed regarding the subjects' explicit processing of list relationships. It is worth noting that H.P. is an outstanding numerical calculator and G.C. is also arithmetically able. Numerical ability, together with comparatively high verbal IQ's may explain these subjects' ability to explicitly process and verbalize the links between dates. The important point, however, is that a differential performance between conditions for *all* of the group was observed, regardless of the ability to verbalize patterns of relatedness.

P.M.'s performance deserves further comment. Although he was able to verbalize the relationship between the dates in both lists, this did not appear to facilitate his performance in the control condition. He recalled just three of the items from a total of eight. Thus, he did not appear to utilize his knowledge that the dates fell at 23 yearly intervals to generate the candidate items. Importantly, from previous work with the experimenter (reported in Chapter 3) he is known to be able to calculate the interval in years between two dates. The crucial point here is that P.M.'s performance in the control condition offers another example of the dissociation between memory performance and verbalizable knowledge. His performance is in complete contrast to that observed for several of the subjects in both the previous and current experiment, when recall appeared to be facilitated in the absence of explicit, verbalizable knowledge of the experimental relationship. In the control list, P.M. was able to articulate the relationship between items but this did not facilitate his performance.

The explanation of such opposing patterns of dissociation between recall and verbal report must lie in the structure of calendar knowledge. Importantly, the recall of items will only be facilitated if the relationship between dates maps the structure of date knowledge. This is the key point which is proposed to determine performance in the experimental list. The ability to explicitly process the relationship may thus be quite independent of memory performance. For the control condition, however, calendar knowledge is not suggested to be organized according to a 23 year regularity. Thus, this relationship between dates does not map onto the structure of date knowledge. Consequently, even if the subject can extract the "rule", as in P.M.'s case, this may also be quite independent of memory performance. Specifically, this may be the case due to the relatively low IQ's of the present subjects. It could be argued that performance in either condition may not depend entirely on retrieval from LTM. If the relationship between dates is extracted, the subject needs only to retrieve the first date from each group of four and then proceed to apply the rule (e.g. add 23 years) to generate all of the items. We can suggest that P.M. who had extracted the relationship was unable to then apply the rule. This may well have been a function of his level of intelligence. In conclusion therefore, whether or not the subject can report the relationship between dates may be independent of memory performance, as the faciliation in recall is predicted to result from nonconscious facets of knowledge organization.

It is also interesting to note the presence/absence of intrusion errors at this stage. As in Experiment 4, subjects did not produce incorrect answers for the experimental condition. They either recalled the correct date or not at all. Interestingly, two subjects did make errors in the control condition. J.B. suggested the "6th January 1971" and R.D. gave the "22nd April 1971". Both of these date do not conform to a 23 year regularity which suggests that the relationship between the control dates had not been extracted. The subjects who were unable to identify the 28 year pattern across dates were not ultimately informed of the relationship between items. This was due to the planned presentation of additional date lists exploring the 28 year rule.

A discussion of the present findings would not be complete without making one final point. The current study failed to control for one very important variable: the day of the week on which the dates fell. The dates chosen to form the experimental condition, because they do fall 28 years apart and thus come from structurally identical years, will of course fall on the same day. Any dates chosen from yearly intervals which are of no calendarical signficance, such as 23 years in the control condition, do not share this feature and will therefore only fall on the same day "by chance". So, in the present case, the variable which is intended to be manipulated between lists i.e. yearly cycles/repetitions, at the same time may have operated to confound the design by determining the day of the week on which the dates fall. In view of the results from the previous experiment, we know that the day of the week on which a list of dates fall can be a very important factor in determining recall performance.

To illustrate the problem, the respective days of the week of the dates within Lists 1 and 2 of the present study are shown below in Table 5.6.

Table 5.6. ***Lists of dates used as stimuli in Experiment 5a.***

List 1: 28 Year Dates	List 2: 23 Year Dates
1st July 1914 (Wed)	22nd April 1916 (Sat)
1st July 1942 (Wed)	22nd April 1939 (Sat)
1st July 1970 (Wed)	22nd April 1962 (Sun)
1st July 1998 (Wed)	22nd April 1985 (Mon)
14th May 1911 (Sun)	6th June 1921 (Mon)
14th May 1939 (Sun)	6th June 1944 (Tues)
14th May 1967 (Sun)	6th June 1967 (Tues)
14th May 1995 (Sun)	6th June 1990 (Wed)

While it can be seen that there is some variation between days in List 1 and there are repetitions of days in List 2, thus indicating that this is not a complete replication of Experiment 4, nevertheless, there is a difference between lists in terms of the day of the week on which they fall.

The decision to compare the recall of these two lists should, however, be defended. The exposure time of the individual dates in this study was reduced from the previous experiment, in order to prevent calculation. Indeed, support comes from subject G.C.'s verbal report indicating that he had tried to calculate the dates but did not have sufficient time. In addition, dates from the early half of the 20th century were included in the present lists. As O'Connor and Hermelin (1984) showed, the more distant the date from the present year, the longer the date will take to calculate. This was also the case for the calculation speeds obtained from the present group of subjects (reported in Chapter 3). Therefore, in addition to reducing the exposure time of each date, the items were also from more distant years which typically take longer to calculate. Calculation of the whole list of dates was thus presumed to be impossible. However, in order to strengthen the experimental design, further lists of dates were presented. These dates were directly comparable in terms of the day of the week on which they fell.

Experiment 5B

Introduction

In order to clarify the situation and determine that enhanced levels of recall in the experimental condition are due to the *sequence* of dates, rather than the weekday on which they fell, three further lists were presented for recall. These are shown in Table 5.7, below together with the respective weekdays.

Table 5.7. ***Lists of experimental and control dates***

List 3: 28 Year Dates	List 4: 17 Year Dates
6th August 1913 (Wed)	17th February 1929 (Sun)
6th August 1941 (Wed)	17th February 1946 (Sun)
6th August 1969 (Wed)	17th February 1963 (Sun)
6th August 1997 (Wed)	17th February 1980 (Sun)
27th October 1906 (Sat)	12th January 1945 (Fri)
27th October 1934 (Sat)	12th January 1962 (Fri)
27th October 1962 (Sat)	12th January 1979 (Fri)
27th October 1990 (Sat)	12th January 1996 (Fri)

List 5: 11 Year Dates
8th January 1948 (Thurs)
8th January 1959 (Thurs)
8th January 1970 (Thurs)
8th January 1981 (Thurs)
20th September 1955 (Tues)
20th September 1966 (Tues)
20th September 1977 (Tues)
20th September 1988 (Tues)

List 3 comprised dates which fell at 28 yearly intervals. This represented the experimental list. The two remaining lists were control lists, comprising dates falling at 17 year and 11 year intervals. These specific control dates were chosen at these intervals because they all fall on the same day, within each group of four. That these dates do all fall on the same day is more of a "coincidence" rather than a true calendar regularity. Unlike the experimental list years, the control years are not structurally identical within each list. Nevertheless, by selecting these particular dates, the study controls for the weekday of each item. As performance in Experiment 5a was suggested to be due to the yearly intervals between dates rather than their respective weekdays, it was predicted that recall would again be superior for the 28 year list when compared to the 17 and 11 year control dates.

Method

Subjects. Seven subjects were presented with the following lists. These were H.P., G.C., J.B., R.D., D.K., P.M. and J.P., whose details are provided in Chapter 3.

Materials. The three lists, printed in Times Roman 20pt size, were presented for recall. These were displayed individually in the format shown above in Table 5.7, with the respective weekdays omitted from the lists. The procedure once again involved the use of a cardboard window to display each date individually.

Procedure. The order of presentation of the lists was randomized across subjects. The procedure was identical to that used in Experiment 5a. Dates were displayed individually for three seconds, followed by an eight second study period. Subjects were then required to free recall the dates after a one minute filled interval. As in the previous experiment, subjects were questioned about their knowledge of the relationships between dates following this experiment.

Results

The total number of dates recalled by each subject from the three lists, together with the means and standard deviations are given below in Table 5.8. The means are also displayed in Figure 5.2.

Table 5.8. ***Number of dates recalled in the experimental and control lists from Experiment 5b (out of a maximum score of 8).***

Subjects	Number of dates recalled: 28 year dates (experimental)	17 year dates (control)	11 year dates (control)
H.P.	8	5	5
G.C.	8	5	6
R.D.	4	2	2
J.B.	3	3	1
J.P.	5	4	3
D.K.	8	6	6
P.M.	8	4	5
Mean	6.29	4.14	4.00
SD	2.22	1.35	2.00

The number of dates recalled by the subjects for each of the lists was entered into a one way ANOVA with one within group factor of yearly interval (28 years vs 17 years vs 11 years). This revealed a highly significant main effect ($F(2,21) = 21.58$, $p=.001$). It was predicted that the 28 year list would be better recalled than the two control lists. Linear contrast analysis, which compared the 28 year list with the two control lists combined, supported this prediction ($F(1,6) = 46.5$, $p<.001$). Thus, the results are in line with those obtained in Experiment 5a. It should also be noted that there was no significant difference between the 17 year and 11 year control lists ($F(1,6) = 0.125$, n.s.).

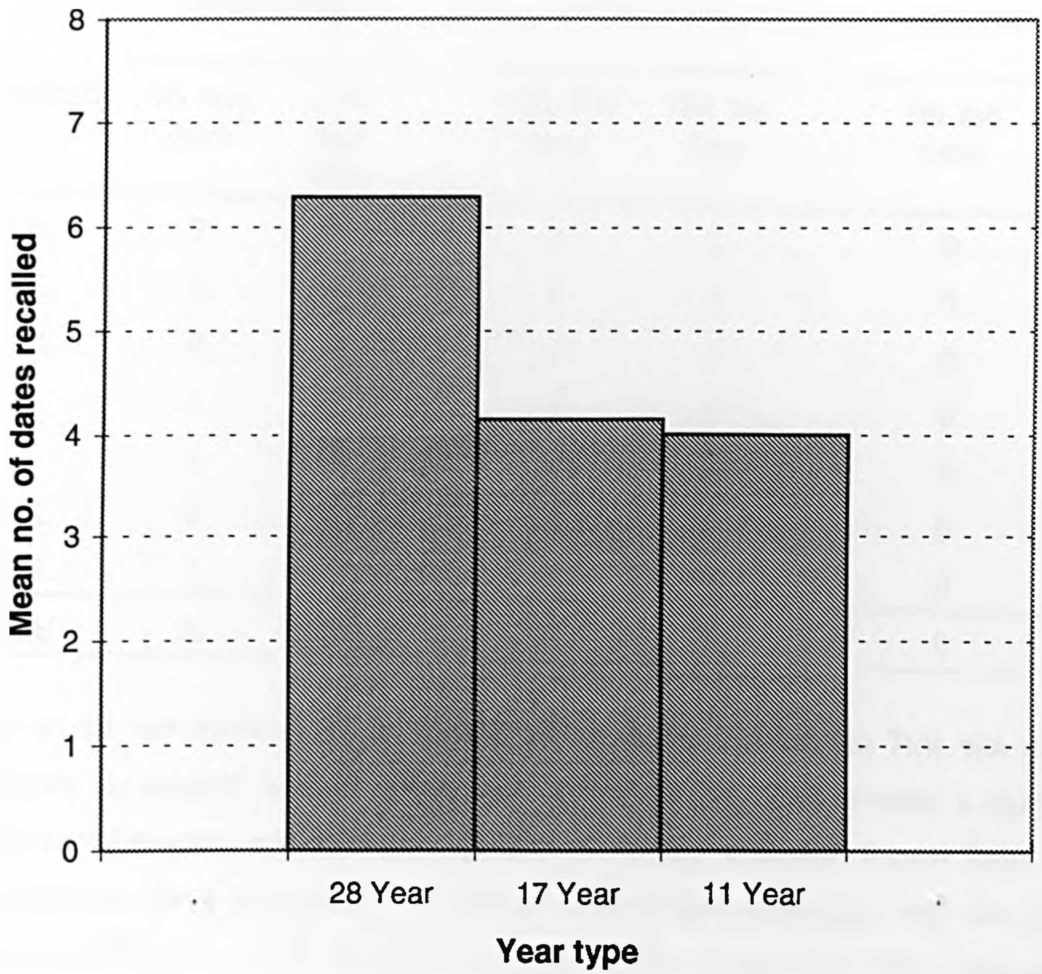

Figure 5.2. ***Mean number of dates recalled from the 28, 17 and 11 year lists.***

Order of recall. The scoring system used in Experiment 5a was applied to the order of recall of the present date lists. A score of '2' was taken to indicate that all of the dates within a group of four were recalled in order. A score of '1' was given when the order of three of the dates within a group was preserved. Subjects scores are shown below in Table 5.9.

Table 5.9. ***Order of recall for Lists 3, 4 and 5.***

	28 year dates		17 year dates		11 year dates	
Subjects	6th Aug dates	27th Oct dates	17th Feb dates	12th Jan dates	8th Jan dates	20th Sept dates
H.P.	2	2	0	0	0	2
G.C.	2	2	0	0	0	2
R.D.	0	2	0	0	0	0
J.B.	1	0	0	0	0	0
J.P.	1	0	0	0	0	1
D.K.	2	2	1	1	0	2
P.M.	2	2	0	0	0	2
Total	10	10	1	1	0	9

Due to the non-normality of the distribution of scores, a Friedman Test was used to compare the subjects' total scores for each of the three lists. This revealed a significant difference between conditions ($Xr^2 = 10.5$, $p < .005$). Wilcoxon Signed Rank Tests revealed that the experimental list scores were significantly higher than both the 17 year list dates ($W = 0$, $p < .05$) and the 11 year dates ($W = 0$, $p < .05$). Thus, the subjects again displayed an increased tendency to recall the 28 year experimental dates in order when compared to the control lists.

Discussion

The results confirm that recall is superior for dates which map onto previously experienced patterns within the calendar when compared to control lists. Importantly, this is shown to be the case even when the respective weekdays of the dates are controlled for. The experimental results thus validate those obtained in Experiment 5a. Also, as in the previous experiment, there was a tendency to recall the experimental dates in an order which preserved the 28 yearly sequence. This supports the suggestion that the retrieval of one date may automatically activate the same date 28 years earlier and later. It is interesting to note, however, that the order of recall was often preserved for the second set of dates within the 11 year control list, i.e. 20th September, 1955; 1966; 1977; 1988. Rather than reflecting the structure of calendar knowledge, this pattern of performance is suggested to be due to the numerical distinctiveness of this yearly sequence. In particular, the repetition of the last two digits forming the specific year within the decade, e.g. 1955, 1966, may have enhanced the memorability of these items.

Subjects P.M., G.C. and H.P. all spontaneously noted the yearly intervals between dates for all three lists. As in the previous experiment, the remaining subjects did not refer to the yearly intervals between items and following the re-presentation of the lists, proceeded to calculate the dates. However, as in Experiment 5a, a differential pattern of performance was observed between the experimental and combined control lists for *all* of the subjects, regardless of their ability to state the relationships between dates. This again suggests the relative independence of verbal report from the operation of non-conscious facets of calendar knowledge structure, which serve to facilitate the recall of experimental items in comparison to control dates.

The least remarkable performance of the present study was that of J.B.. When her recall levels for the two control lists are examined separately, it can be noted that she recalled as many 17 year dates as 28 year dates. It is worth mentioning that J.B. was presented with the 17 year list first and the 28 year dates last. Furthermore, in the 17 year list, unlike the 28 year or 11 year lists, J.B. had noted real life events for the three dates she eventually recalled. For example, 12th January 1979 was in the same year as her father died and in 1962 she had moved to a particular residential home. It is possible that the process of relating these events to the specific dates had resulted in a more elaborated encoding of the items, thus increasing their memorability.

One final point for discussion relates to the calendrical structure of the years used in the present study. Although both experimental and control lists were selected to fall on the same weekday within each group of four dates, only the experimental dates shared exactly the same yearly structure. Within each group of four dates for the 11 year and 17 year control lists, dates were extracted from different structural configurations. For example, in List 4, the 8th January 1959, 8th January 1970 and 8th January 1981 were all extracted from the same yearly configuration. However, the first date, 8th January 1948 was taken from a leap year which began on the same day as the other dates but was structurally dissimilar from the 1st March onwards. Therefore, by choosing a date for this group of four, which fell before the 29th February, all of the items would fall on the same day yet they were not extracted from the same yearly structure.

Interestingly, the fact that the experimental, structurally identical years were better recalled than the control lists may accommodate Young and Nettelbeck's (1994) suggestion that savant date calculation is based on the rote memorisation of the 14 different calendar templates. These templates relate to the 14 possible yearly configurations of the calendar. From Young and Nettelbeck's suggestion, it would follow that each 28 year date within a set of four, would activate the same memory representation corresponding to the specific yearly template. The control condition would have required the activation of different calendar templates stored in memory.

Irrespective of the precise theoretical interpretation adopted, the present experiment has succeeded in revealing an enhanced memorability for dates organized according to a structural regularity spanning years of the calendar. Savant long-term representation of date information therefore appears to reflect the important calendrical relationship between dates which fall at 28 yearly intervals.

Experiment 6: The Significance of Leap Years

Introduction

The previous three experiments have been successful in revealing differences in the memorability of dates according to aspects of calendar structure. Specifically, the weekday of a series of dates and the yearly intervals between dates in a list have been shown to influence the recall of date items. A further aspect of calendar structure which may also affect the memorability of dates relates to the calendar configuration of a given year; specifically whether the year is a leap year.

We do not have to possess the skills of a savant calendar calculator to be familiar with the concept of leap years. The inclusion of an extra date every four years, in the form of the 29th February, is common knowledge. However, the identification of precisely which years are leap years represents a more difficult feat. Such a task may be possible if a benchmark date system is used, such as "The Los Angeles Olympic Games were in 1984, which was a leap year". Previous and following leap years could then be generated by calculating four yearly intervals.

The rapid speed of savant calculation for dates taken from leap years suggests that these individuals are unlikely to use such a laboured, consciously formulated approach. Rather, the process of identifying years as containing a February 29th may be an automatic or nonconscious process.

Without question, savant calendar knowledge *must* reflect the fact that certain years are structurally different; they contain a February 29th. Otherwise the savants would be unable to calculate across these specific years with any degree of accuracy. It remains to be established, however, whether these years are represented in a relational format in LTM. In view of the previous findings indicating the associative nature of savant calendar knowledge, it is suggested that leap years, which represent structurally anomalous years falling at such regular intervals, will be linked associatively in savant LTM. In order to test this, recall was examined for a list of leap years compared to "non-leap" years, with the specific prediction that the leap year items would be better recalled.

The results of Experiment 4 are relevant. When comparing the recall of lists of dates falling on the same day and different days, the analysis had also revealed a near significant main effect of leap year. There was a trend for lists of dates taken from leap years to be better recalled than those from non-leap years. Experiment 4 had specifically investigated recall levels relating to calendar structure *within* a given year. Due to the distinctive yearly configurations of leap years when compared to non-leap years, the pattern and strength of connections between dates falling in such years may be especially marked. This would account for the increased memorability of dates from leap years. Rather than a further comparison between dates extracted from individual years, the current experiment aimed to contrast the recall levels of the year items themselves. An investigation of the memorability of a list of years e.g. *1986, 1962, 1950*, rather than specific dates, also precludes any process of calculation. The presentation of single year items should activate memory representations corresponding to those years, but unlike the experimental stimuli of the previous three experiments, would not present the opportunity for actual date calculation.

In summary, the representation of leap years in savant LTM was explored in the present study. Specifically it was predicted that leap years would be better recalled than lists of years which do not have a 29th February.

Method

Pilot Study. Before outlining the main experiment exploring the recall of leap years, details will be given of a relevant pilot study. This study represented a preliminary attempt to explore differential levels of recall for related and unrelated calendar information. The experimental stimuli, in the form of two lists of eight years, were presented following Experiment 2. The experimental procedure of this pilot study was identical to that used in Experiment 2. This involved the individual years being read out by the experimenter at the rate of one every three seconds. The year items were not visually presented. Following a filled interval of one minute, the subjects were required to free recall the years from the list. The two lists of years used in this pilot study are shown below in Table 5.10.

Table 5.10. ***Lists of items presented in pilot study.***

List 1: Leap years	List 2: Control years
1960	1978
1944	1917
1976	1953
1988	1966
1952	1991
1936	1930
1992	1942
1912	1989

List 1 comprised leap years and List 2 contained "non-leap" years. The order of list presentation was alternated between subjects. Six of the savants (H.P., G.C., R.D., J.B., J.P. and D.K.) were presented with these two lists of years and their individual recall scores are shown below in Table 5.11.

Table 5.11. ***Subjects' recall scores for Lists 1 and 2 (out of a total of eight items)***

Subject	Number of years recalled: List 1 (leap years)	List 2 (non-leaps)
H.P.	6	4
G.C.	5	3
R.D.	5	3
J.B.	4	2
J.P.	5	4
D.K.	6	3
Mean	5.17	3.17
SD	0.75	0.75

As can be seen in Table 5.11, the mean number of years recalled from List 1 (leaps) was 5.17 out of a total of eight and the mean number of years recalled from List 2 was 3.17. Using a related *t*-test the difference in recall scores was shown to be significant ($t(5) = 7.75$, $p = .001$). Thus, the leap years were better recalled than the control, non-leap years.

The control list had contained an equal number of both even and odd-numbered years. Interestingly, there appeared to be a tendency to recall the even non-leaps, such as 1942, 1978, when compared to the odd-numbered control years. In fact, out of a total of 19 control years recalled by all of the subjects, 13 of these were even-numbered years. However, this pattern of performance in the control condition may well have been a spurious finding.

The presentation of further lists of years was planned. This was in an attempt to replicate the finding of increased memorability of leap years over non-leaps and to further explore recall levels for odd and evenly-numbered years. These lists form the stimuli used in Experiment 6 reported below. In this study, odd and evenly numbered non-leaps were presented as separate lists. The experimental procedure was also changed in line with that used in Experiments 4, 5a and 5b. Thus, the presentation of items was visual in addition to auditory and the subjects were also given a 10 second period in which to further study the items. As the number of years recalled by each subject was expected to increase using this adapted procedure, the number of items in each list was adjusted from eight to 10 years.

Method

Subjects. Eight savant calendrical calculators participated in the present experiment. These were H.P., G.C., R.D., J.B., J.P., D.K., P.M. and P.E. whose subject details can be found in Chapter 3.

Materials. Three lists of years were presented for recall. These are shown below in Table 5.12. For the experimental presentation, the lists were displayed in Times Roman 20pt size, in double line spacing.

Table 5.12. ***Lists of years presented for recall in Experiment 6.***

List 3: Leap years	**List 4: Even non-leaps**	**List 5: Odd non-leaps**
1964	1970	1977
1948	1954	1943
1932	1926	1961
1996	1974	1989
1972	1994	1925
1916	1962	1951
1956	1986	1993
1980	1938	1967
1968	1910	1985
1924	1982	1969

List 3 comprised leap years, List 4 contained even numbered non-leaps and List 5 contained odd-numbered non-leaps. All of the years were taken from the 20th century in order to ensure that they fell within the calculation spans of the eight savants. Within each list, years were taken from different decades in order to span the 20th century. The order of years in each list was randomized so that the items did not fall in chronological order. None of the leap years or control years used as items in the pilot study were included in the present experiment.

The experimental procedure involved the use of a "window" cut into an A4 cardboard sheet. The size of the window ensured that only one of the years was revealed at a time.

Procedure. The subjects were informed that they were to be shown a list of years, rather than dates, taken from the 20th century. They would be shown each of the years separately and the experimenter would also read out the years for them. They would then see all of the years together in a list. A one minute conversation would follow the removal of the list. They would then be asked to remember as many of the years as possible, in any order. Again, it was stressed that this was a test of memory. The subjects were encouraged to concentrate and think carefully about each of the years so that they would be able to remember them later.

The order of presentation of the three lists was randomized across subjects. Using the cardboard window, each of the years was displayed individually for a period of three seconds. The experimenter also read out the year, which would often be accompanied by the subject choosing to read the year aloud. The A4 cardboard window was then removed and the whole list was available for a 10 second study period. After removal of the list, the experimenter engaged the subject in a verbal interchange for one minute. Topics discussed did not relate specifically to the calendar. Subjects were then requested to recall years from the list in any order they chose.

Verbal reports. Immediately after the presentation of all three lists, subjects were questioned about the experimental and control stimuli. Probes included "Did you notice anything special/different about the lists of years?" and "What can you tell me about those lists..?" The lists were then placed in front of the subject for further visual inspection and the earlier questions were repeated.

Results

Table 5.13 below shows the number of items recalled by the subjects from each of the three lists, together with the means and standard deviations. The means are also displayed in Figure 5.3, overleaf.

Table 5.13. ***Recall scores for Lists 3, 4 and 5 (out of a total of 10 items)***

	Number of years recalled		
Subject	List 3 (leap years)	List 4 (even non-leaps)	List 5 (odd non-leaps)
H.P.	8	5	6
G.C.	9	8	7
R.D.	4	3	3
J.B.	8	5	4
J.P.	7	6	6
D.K.	8	10	7
P.M.	10	8	7
P.E.	8	8	6
Mean	7.75	6.63	5.75
SD	1.75	2.26	1.49

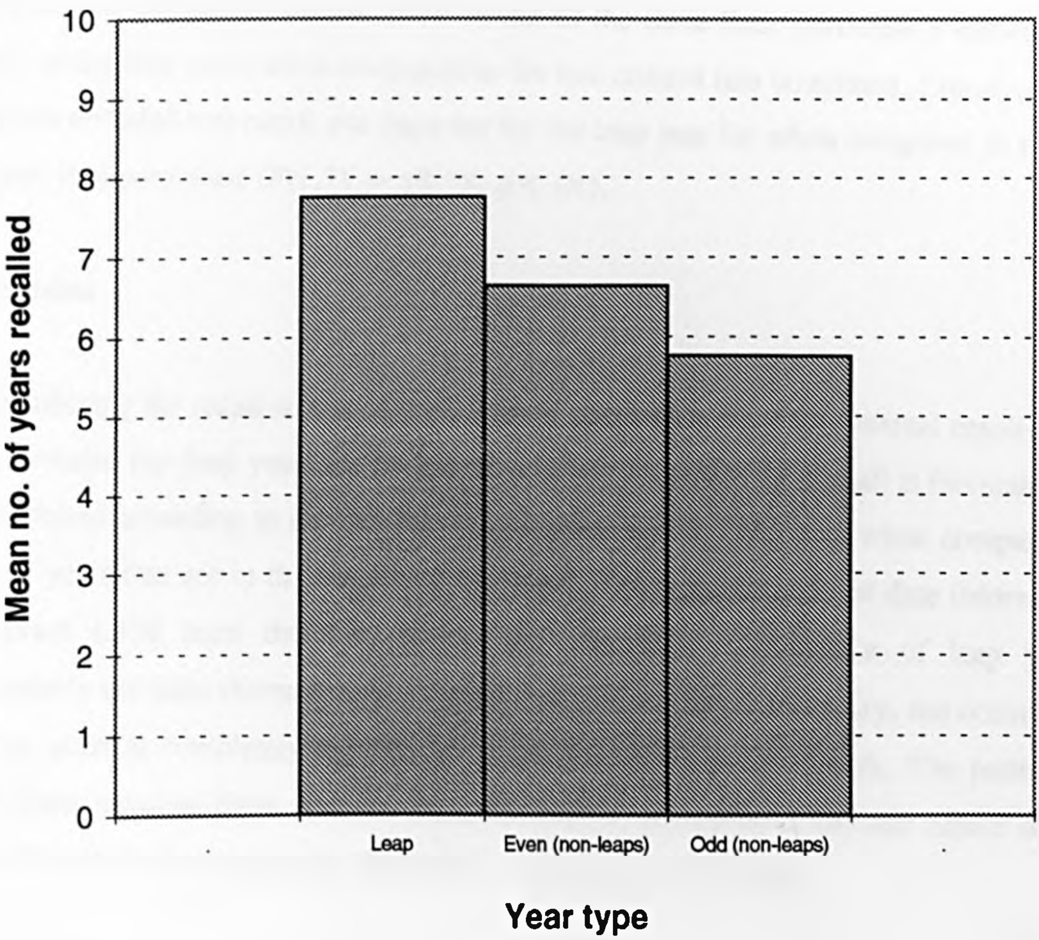

Figure 5.3. ***Mean number of leap years, even non-leaps and odd non-leap years recalled.***

These scores were entered into a one-way ANOVA with one within-group factor of year type (leap vs even non-leap vs odd non-leap). This revealed a significant main effect ($F(2,14) = 8.95$, $p < .01$). A series of post-hoc *t*-tests were performed on the recall scores for each of the lists. The only pairwise comparison which reached significance was the difference between the leap year list and the odd numbered years ($t(7) = 5.29$, $p = .001$). Both the difference between leap years and even numbered years ($t(7) = 1.94$, ns) and between the two control lists ($t(7) = 1.99$, ns) failed to reach significance. Further analysis was performed on the recall levels of the three lists, particularly between the recall of the leap years when compared to the two control lists combined. Linear contrast analysis revealed that recall was superior for the leap year list when compared to the two control lists combined ($F(1,7) = 12.76$, $p<.01$).

Discussion

By combining the recall scores of both control conditions, the experimental results have thus revealed that leap years are comparatively more memorable. Recall is facilitated for years linked according to the fact that they contain a 29th February, when compared to lists of years that are in the same way unrelated. The representation of date information in savant LTM must therefore reflect the calendrical significance of leap years, particularly the links shared between these years. Within the 20th century, the occurrence of leap years is completely regular, at constant intervals of four years. The pattern of relatedness between these years is therefore highly structured; a specific aspect of the calendar which also appears to characterise savant date knowledge.

Although the experimental prediction was supported concerning the superior recall of leaps compared to non-leap years, this was achieved by combining the means of the two separate control lists. When the recall of the individual lists was compared, the results were not quite so clearcut. Although there was a highly significant difference between the leap years and odd numbered non-leaps, the number of years recalled from the even non-leap list did not differ significantly from either of the other two lists. Importantly, if the difference in recall levels between the two control lists *had* been significant, then this would have been attributable to a simple odd/even distinction. This would have suggested that even numbered years are easier to recall than odd years. However, precisely because there was *not* a significant difference between the even and odd control lists, then the observed difference between leaps and odd controls must be attributable to a factor over and above that of odd/evenness. There must be a further knowledge-based distinction which accounts for the superior memorability of leap years. The only difference between these leap years and odd control years, other than the odd/even distinction, relates to the structure and calendar configuration of the years. Leap years have a February 29th, odd numbered years *never* have a February 29th. Thus, the experimental items were much more distinctive in terms of their memorability.

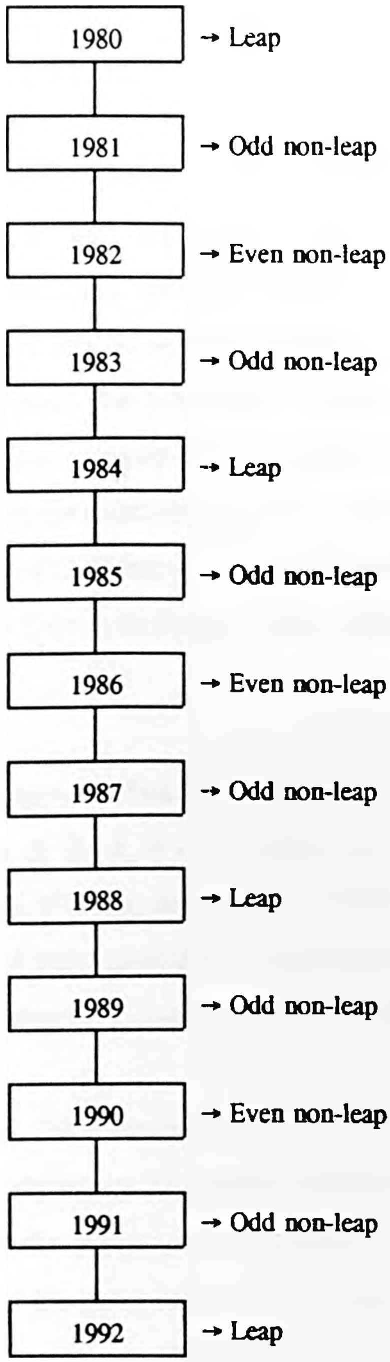

Figure 5.4. ***Mapping the sequence of leaps, even and odd non-leaps onto the calendar.***

The failure to find a difference between leap years and even numbered non-leaps is more difficult to interpret. The crucial point to make is that there are as many evenly numbered non-leaps as there are leap years. Every alternate even numbered year is a leap and thus, every intervening even year is a non-leap. Figure 5.4 represents an attempt to display this diagrammatically. For this reason, even numbered years which do *not* have a February 29th may be as memorially distinct as those years which *do* have a February 29th.

Perhaps the best way to conceptualise the findings from the present experiment is to envisage the recall scores for the three lists as points on a continuum of memorability/distinctiveness. Odd numbered years occupy the lowest point on this continuum; leap years never fall in an odd numbered year. Also, in comparison to the two even numbered conditions, the odd years fall every other year in the calendar and are thus more numerous and consequently less distinctive. Even numbered non-leaps occupy a middle position on the continuum. They are less frequent than the odd years and *as* frequent as the leap years. However, they do not show a calendrically distinctive structure by containing 29 days in February. Thus, they are structurally equivalent to the odd numbered years.

Nevertheless, it can be suggested that by their quality of "evenness" they appear "leap-like" i.e. by ending in a *0, 2, 4, 6* or *8* they share a superficial, but not structural, resemblance to a leap year. Finally, leap years can be regarded as occupying the highest point on the continuum of memorability. They are highly distinctive years which share a characteristic calendar structure and which fall at predictable yearly intervals.

Odd/Even Sorting Task. This interpretation of the present experimental findings rests heavily on the subjects' ability to distinguish between odd and even numbers. Indeed, subject H.P. volunteered the information that two of the lists were "even" and that List 5 was "all odd". None of the other subjects used these terms. Subject G.C. was able to state that Lists 3 and 4 were "in two's" and that List 5 "was not in two's", which indicated an understanding of the essential difference between odd and even numbers.

In order to explore levels of understanding with the other six individuals, a simple sorting task was presented at the beginning of the following testing session. The even non-leap list and the odd non-leap list were placed in front of the subject. The left-right positioning of the two lists was alternated between subjects. Six year items were printed on individual pieces of paper (7cm by 4cm), in Times Roman font, 20 point size. These six years were: 1990, 1946, 1958, 1963, 1979 and 1931. The first three years are even numbered non-leaps and the last three are odd-numbered non-leaps. These items were novel stimuli and had not been included in either the pilot study or Experiment 6. The individual items were placed in a jumbled order in front of the subject, at a distance from Lists 4 and 5. The subjects were then asked to place the individual years together with either of the two lists, according to "which list it goes best with/the list it matches". Instructions were given to look very carefully at the years and to "think about the numbers that you see". Subjects P.E., R.D. and D.K. had no difficulty with this and were able to sort the years correctly. Although a little slower, both P.M. and J.P. were also able to complete the task successfully. When presented with the individual years, the final subject, J.B. proceeded first of all to state the difference in years from the present year for each of the items. She then gave an example of a real life event which had occurred during the four most recent years. For example, she gave details of a holiday taken in 1958. Eventually, J.B. was able to sort 1958 and 1990 with the even list and 1931 and 1963 with the odd list. However, items 1946 and 1979 were sorted erroneously. Thus, in total, five of the six subjects performed successfully on this task and were able to sort according to whether the year was odd or even.

1970	1977
1954	1943
1926	1961
1974	1989
1994	1925
1962	1951
1986	1993
1938	1967
1910	1985
1982	1969

1931

1958 1979 1990

1963 1946

Figure 5.5. ***Example of the layout of the sorting task materials***

It is worth noting that correct performance on this sorting test could not have been achieved by matching the years in terms of their structural similarity. Within both lists, years were taken from a range of the 14 different calendar templates. Thus, many of the years within each list were structurally dissimilar. In fact, the degree of similarity in yearly structure was as comparable *between* lists as within lists. Moreover, each of the six target years was selected to correspond to a specific calendar template shared by just one of the years in each list. For example, the target year 1990 shares exactly the same yearly structure as 1962 from the even list and 1951 from the odd list. It would thus be impossible for the subject to sort this item according to its structural configuration because 1990 matches years from both lists. This point serves to reinforce the conclusion that subjects must have sorted according to a numerical feature of the year items; specifically, the odd/even distinction.

The fact that five of the subjects did perform successfully on the sorting task is open to conflicting theoretical interpretations. Shanks and St John (1994) regard the effective completion of such a task as an index of *conscious* knowledge. That is, even though the subjects were unable to verbally describe the difference between odd and even years, nevertheless the fact that they were able to utilize their knowledge within the constraints of the sorting task, indicates that the processes underlying such a odd/even decision were open to conscious inspection. Other researchers disagree. Lindsay and Gorayska (1994), for example, argue that successful performance on such a forced choice task, in the absence of verbal report, simply establishes the presence of information. It does not establish that the subject is conscious of this information. Thus, there appears to be a lack of theoretical agreement concerning the implicit/explicit nature of such task performance. However, within the context of the present experiment, seven of the eight savants demonstrated the ability to distinguish between odd and even numbers. Importantly, this supports the suggestion of a continuum of memorability from even leap years to even non-leaps through to odd non-leap years.

As a final point concerning the odd/even distinction, a number of explanations can be offered to account for J.B.'s failure to sort the target years appropriately. First, she may have failed to understand the task requirements. Second, she may have sorted the years according to an idiosyncratic criterion, possibly relating to the real life events she attached to several of the year items. Third, she may have sorted randomly due to a genuine inability to distinguish the concept of odd/even. The fourth possible explanation for her performance is consistent with Shanks and St John's (1994) view. Her knowledge concerning the odd/evenness of a date may be truly implicit; it can operate to effect levels of recall but does not transfer to alternative tasks measuring the same knowledge concept. Unfortunately, this remains at the level of conjecture.

Verbal reports. Additional information, in the form of subjects' verbal reports, again proved revealing with regard to the processing of list relationships. None of the group spontaneously noted that List 3 comprised leap years. However, when the experimenter subsequently probed for this information, H.P. and D.K. were able to identify List 3 items as leap years. H.P. also continued to inform the experimenter that List 3 years "can be divided by four" with List 4 items "divided by two". D.K. pointed to List 3 and said "these are all leap years" and, pointing specifically to List 4, said "these are not". His report did not appear to refer to List 5.

The three lists were then placed in front of the subjects and, following further inspection of the items, J.P. and P.E. noted the List 3 relationship, using the term "leap years". As the remaining subjects, J.B., R.D., G.C. and P.M., failed to offer any suggestions, they were then informed of the pattern of relatedness within List 3 compared to the other lists. G.C. commented "ah, jump years" and J.B. noted "yes, every four years". R.D. and P.M. made no further comments.

In terms of relating verbal reports to actual memory performance, it would appear that for most of the group, recall was facilitated in the absence of the formulation of the list relationship. For subject J.P., the relationship was not verbally formulated until the lists were presented at the end of the experiment. Subjects J.B., R.D., G.C. and P.M. failed to report the relationship at all. Yet their recall scores indicate the increased memorability of leaps compared to non-leaps. Interestingly, D.K. was able to state the leap year relationship without having to study the lists, yet he recalled more items from List 4, the even non-leaps than from List 3. Perhaps D.K.'s performance can be regarded as an extreme example of the memorial distinctiveness of even-numbered years *without* a February 29th. Subject P.E.'s performance in which an equal number of leaps and even non-leaps were recalled, could also be interpreted in the same way.

A final point regarding verbal reports concerns H.P.'s performance. Even though he was able to accurately report the leap year relationship, and to provide further details concerning the arithmetical properties of the years, his recall performance did not surpass that of several of the other subjects. Again, as in Experiment 4 which investigated same day dates, this may represent another facet of the dissociation between verbal report and recall performance. Importantly, however, the *pattern* of H.P.'s memory performance reflects that of most of the other subjects.

In line with Experiment 4, subjects did not produce any intrusion errors. The savants only recalled items that had previously been presented and did not appear to guess when attempting to recall the years. Consequently, the information gained from verbal reports, relating to the processing of list relationships, was not supplemented by an analysis of incorrect guesses.

In summary, the present experiment has succeeded in demonstrating the enhanced memorability of leap years when compared to non-leaps. This supports the findings of the pilot study reported in the present chapter and also the findings of Experiment 4. Importantly, even when the process of calculation cannot be performed on the items to be recalled, as in the present study, savant memory performance continues to reflect the important structural relationships between calendrical features. The organization of savant calendar memory can therefore be suggested to extend beyond specific dates within a year (Experiment 4) and dates spanning across related years (Experiments 5a and 5b) through to connections between the year items themselves. This would be in line with the concept of hierarchical organization, i.e. savant date knowledge is characterised by links between dates in the same year, links between dates in different years, links between years. This offers an interesting conceptualisation of the knowledge base which underlies savant date calculation.

Experiment 7: Memory and Easter Sunday

Introduction

The previous three experiments were designed to examine recall levels in relation to *structural* features of the calendar. Having explored three of these structural regularities, the present experiment will focus on a contrasting source of calendar knowledge; Easter Sunday.

The subjects who participated in the present study have all previously demonstrated their familiarity with the dates of Easter Sunday within the 20th century. For example, they were able to answer questions such as "On what date did Easter Sunday fall in 1982?". This therefore represented a source of knowledge relating to the calendar which was shared by all the members of the group. Importantly, however, this knowledge does not relate to the structure of the calendar.

In order to illustrate this, we need to be familiar with the factors that determine the occurrence of Easter. In 325 AD the church fathers of the First Council of Nicaea decreed that Easter would fall on the first Sunday following the 14th day of the Paschal, or Easter, moon. The Paschal moon was specified as the first moon whose 14th day came on or after March 21st. Since the moon's month is 29.53059 days long - the time it takes the moon to go through its phases - and since the Earth's month is 30 or 31 days long (with 28 or 29 days in February) the lunar and earth calendars are rarely in phase. This results in Easter occurring on any date between March 22nd and April 25th. Hamblin's (1966) description of Easter as being "calendrically illogical" seems rather fitting.

In order, therefore, to be able to calculate the occurrence of Easter, it is necessary to be familiar with the phases of the moon. A knowledge of the present Gregorian calendar alone, would not permit the individual to predict the date of Easter.

For the purposes of the current study, the relative *independence* of Easter from Gregorian calendar structure is a vital point to make. For this very reason, Easter differs from knowledge concerning leap years, the 28 year regularity and the weekday of specific dates which all derive from calendar structure. Of key interest is whether this difference will be reflected in contrasting patterns of recall performance for the Easter dates when compared to the results of Experiments 4 to 6.

The theoretical rationale for predicting a differential pattern of recall performance between the present and previous experiments was as follows. On the basis of the previous three experiments, savant date knowledge is suggested to be organized according to the structure of the calendar. This is supported by the facilitation in recall for dates linked according to calendar regularities. These lists are thus suggested to map onto the organization of savant date knowledge. Easter dates are not determined by structural rules or regularities. Therefore, lists of Easter Sundays would not map the organization of the knowledge domain suggested to underlie date calculation.

Following from this theoretical interpretation, it may be suggested that the presentation of a list of experimental dates, related by the fact that they are all Easter Sundays, may *fail* to facilitate levels of recall when compared to a list of control dates. However, rather than simply predict the null hypothesis for the present study, i.e. no difference in recall between Easter and control dates, the experimental procedure was extended to include an additional list of dates. This was intended to explore the implicit/explicit processing of list relationships.

Specifically, a second list of experimental stimuli, in the form of another series of Easter Sundays, was presented for recall. However, for the first time in this series of experiments, subjects were informed of the list relationship before they were required to recall the dates. With the stimuli adopted in Experiments 4 to 6, the links between the dates in the experimental lists may have been activated automatically in savant LTM. In the present study, however, as Easter dates are not determined by the structure of the calendar, the links between the experimental items may not be activated automatically. Therefore, recall may only be facilitated if the links between the Easter dates are activated explicitly.

Thus, within the same experimental design, not only was the recall of a related list of dates compared to an unrelated control list, recall levels were also contrasted for two lists of experimental dates. In one list the pattern of relatedness remained unformulated for the subject, in the other list the relationship was made explicit.

In summary, the pattern of recall performance in the present study was predicted to contrast with that observed in Experiments 4 to 6. As Easter Sunday is independent of calendar structure, and calendar structure is suggested to characterise the organization of savant date knowledge, levels of recall were predicted to be comparable between the experimental dates and the control dates. However, recall was hypothesized to be facilitated for a second list of Easter Sundays for which the list organization was made explicit.

Method

Subjects. Eight savant calendrical calculators participated in the present experiment. These were H.P., G.C., R.D., J.B., J.P., D.K., P.M. and P.E., whose subject details can be found in Chapter 3.

Materials. Three lists of eight dates were used. These are displayed in Table 5.14, below.

Table 5.14. ***Lists 1, 2 and 3 used as stimuli in Experiment 7.***

List 1 Easter Sunday	**List 2** Control Sundays	**List 3** Easter Sunday/explicit
1st April 1956	15th October 1933	27th March 1932
29th March 1970	28th October 1990	3rd April 1988
22nd April 1973	16th September 1984	31st March 1991
28th March 1948	6th September 1987	7th April 1985
5th April 1931	5th October 1958	26th March 1978
19th April 1992	22nd September 1974	25th March 1951
30th March 1986	23rd October 1977	11th April 1971
26th March 1989	25th September 1949	21st April 1946

List 1 and List 3 comprised dates taken from the months March and April, spanning the years from 1931 to 1992. The dates in both of these lists were Easter Sundays. Control List 2 comprised dates taken from September and October, which span the years 1933 to 1990. Rather than select the control dates from the same months as the experimental lists, these particular control months were chosen to minimise the overlap between lists. September and October can be regarded as structurally equivalent to March and April; they are calendrically adjacent 30 and 31 day months. A further important point concerning the control list is that all of the dates fell on a Sunday. Thus, the present experimental design controlled for the weekday of the dates.

Although the three lists spanned an equivalent range of the calendar, several of the dates within each list were taken from the same decade. Specifically, two dates from the 1970's and two dates from the 1980's were used to form each list. Together with one date from the 1990's, these items were deliberately chosen to fall within the lifetime experience of the individual subjects. For the same reason, future dates were not included as items in the current study. This was in an attempt to increase the familiarity of the items and thus promote the chance of recognition of the dates as being Easter Sundays. Of course, this emphasis on more recent years is consistent across all three lists.

The order of dates within each list was randomized so that the items were not presented in chronological order. This resulted in a number of repetitions of dates taken from the same month. For example, in List 1 the 19th *April* 1992 follows the 5th *April* 1931. This effect of monthly repetitions is balanced across lists.

Lists 1 to 3 were printed on individual A4 sheets, in Times Roman font, 20pt size in double line spacing.

A cardboard sheet, in which a "window" was cut, was used to display each of the dates individually.

Procedure. Subjects were told that they were to be shown *two* lists of eight dates, all of which fell on a Sunday. Details of the procedure were given, i.e. that the dates would also be read out to them, they could then look at the whole list, and after a one minute interval, they would be asked to remember as many of the dates as possible. It was stressed that the subjects should "think carefully about the dates". This may help them to remember the items.

The order of presentation of Lists 1 and 2 was alternated between subjects. Lists 1 and 2 were always presented before List 3. Using the cardboard window, each date was displayed for a five second period. The experimenter also read out the date, often accompanied by the subject themselves. Following the individual presentation of the dates, the cardboard window was removed and the whole list was available to study for 10 seconds. The list was then removed and the experimenter attempted to engage the subject in a verbal interchange for a period of one minute. This was in order to displace any verbal rehearsal of items by the subjects. Topics covered during the one minute interval did not refer to Easter or to other calendar-related issues. Finally, the subjects were required to free recall as many of the previously presented dates as possible.

Verbal reports. Following the presentation of Lists 1 and 2, the experimenter questioned the subjects regarding their processing of the list relationships. For example, they were asked "What did you notice about those lists?" and "Were they different in any way? Was there anything special about one of the lists?".

Presentation of List 3. Unlike the previous four experiments, these questions were not repeated using the actual lists as prompts. Rather than re-presenting the lists for further inspection, the subjects were informed of the list relationship. This took the form of:

"All of the dates you have just seen fell on a Sunday. However, one of the lists was special. Do you remember the dates from March and April that were in the first/second list? These were important dates because they all fell on Easter Sunday. Now I am going to show you a new list of dates. Again, these are special dates because they are also Easter Sundays. I am going to ask you to remember as many of these dates from March and April as you can. Now try and concentrate and remember these Easter Sundays...".

It can be noted from these instructions that the link between the dates in List 3 was emphasized several times. It should also be noted from the subject instructions given at the beginning of the experiment that List 3 was a "surprise" list. Subjects were originally informed they were to be shown only two lists.

The experimental procedure for this final series of dates was identical to that used for Lists 1 and 2.

Results

The total number of dates recalled by the subjects for each of the three lists is shown below in Table 5.15, together with the means and standard deviations. The mean recall scores for each of the lists are also shown in Figure 5.6, below. Recall scores were entered into a one-way ANOVA with one within group factor of list type (List 1/Easter vs List 2/Control vs List 3/Easter). This revealed a significant main effect of list ($F(2,14) = 19.74$, $p < .001$).

Table 5.15. *Recall scores for Lists 1, 2 and 3 (out of 8).*

	Number of dates recalled		
Subject	List 1 Easter	List 2 Control dates	List 3 Easter (explicit)
H.P.	7	4	7
G.C.	6	6	8
R.D.	3	3	4
J.B.	5	4	7
J.P.	3	4	5
D.K.	5	6	8
P.M.	5	5	8
P.E.	4	3	7
Mean	4.75	4.38	6.75
SD	1.39	1.19	1.49

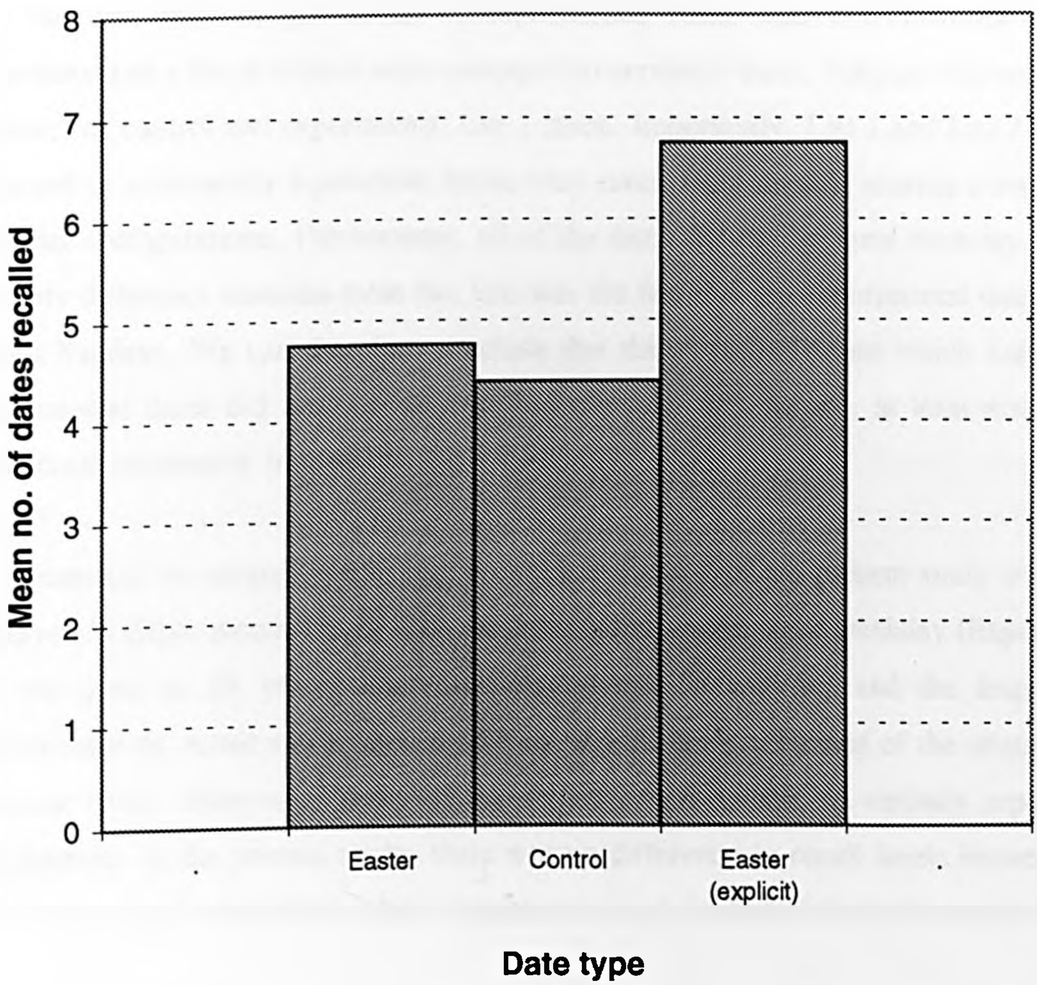

Figure 5.6. ***Mean number of dates recalled from Easter (implicit), control and Easter (explicit) lists.***

Post hoc analyses on the differences between the individual lists revealed a non-significant difference between List 1 and List 2 ($t(7) = .80$, ns). However, the difference between List 1 (Easter) and List 3 (Easter/Explicit) was highly significant ($t(7) = 5.29$, $p = .001$) as was the difference in recall performance between the control List 2 and Easter List 3 ($t(7) = 6.33$, $p < .001$).

Discussion

For the first time in this series of experiments, recall was not enhanced by the presentation of a list of related when compared to unrelated dates. Subjects retained equal numbers of control and experimental List 1 items. Importantly, List 1 and List 2 can be regarded as structurally equivalent. Items were taken from months sharing comparable calendar configurations. Furthermore, all of the dates fell on the same weekday. Thus, the only difference between these two lists was the fact that the experimental dates were Easter Sundays. We can therefore conclude that this specific feature which linked the experimental dates did not operate to effect memory performance, at least within the procedural constraints imposed on Lists 1 and 2.

It is important to contrast performance for Lists 1 and 2 of the present study with that observed in Experiments 4 to 6. With the dates falling on the same weekday (Experiment 4), the dates at 28 yearly intervals (Experiments 5a and 5b) and the leap years (Experiment 6), recall was enhanced *without* subjects being informed of the relationship between dates. Moreover, many of the subjects were unable to verbally report the relationship. In the present study, there was no difference in recall levels between the experimental and control lists when subjects were not informed of the link between items.

This dissociation in performance between the present and previous experiments must be related to the role of calendar structure. It has been stressed that the patterns of list relatedness used in the previous experiments represented structural regularities within the calendar. Savant date knowledge is suggested to be organized according to these regularities, therefore these experimental lists mapped the organization of savant knowledge. Easter is not determined by calendar structure, its occurrence is irregular, even calendrically illogical. Thus, the network of related date information, stored in LTM, which is suggested to underlie savant date calculation, would not reflect the links between Easter Sundays as an intrinsic feature of the relational structure.

We know, however, that Easter dates *are* represented in savant LTM. The present group of eight savants can provide the dates of Easter Sunday for a wide range of years in the 20th century. Yet, the present study has shown that links between these dates do not appear to be activated if the relationship between items remains unformulated for the subject. Two contrasting interpretations can be made from this. First, the Easter Sunday memory representations may not be linked in savant LTM; they are stored as isolated, single representations. Alternatively, information relating to Easter Sunday may be interconnected in LTM but these links need to be activated explicitly. The presentation, alone, of Easter dates does not serve to automatically trigger relational processing.

The recall scores for List 3 support this second interpretation. Significantly more dates were recalled when the link between items was verbalized for the subject. It can therefore be assumed that informing the subject of the list relationship served to externally and deliberately activate the links between these Easter dates in LTM. Thus, it would appear that Easter dates *are* related within the savant knowledge base. However, the memory processes which operate on these calendar-related items are unlike those associated with the long-term representations of structural features of the calendar. The implications of differential patterns of recall performance for the representation of savant calendar knowledge will be discussed further in the following chapter. Specifically, an attempt will be made to integrate the findings of this series of experiments into a conceptualisation of different sources of talent-related knowledge.

A number of points should be made regarding the experimental procedure of the current study. The exposure time of the individual date items was increased in the present design, when compared to Experiments 5a and 5b. Controlling for the weekday of the dates in the current procedure ensured that the calculation of the items was not a factor predicted to effect memory performance. Whether the dates were calculated or not, all three lists shared the same structural relationship relating to weekday. Moreover, the subjects were told that all of the dates would be Sundays *before* the lists were presented. Making explicit the *structural* relationship between dates should have had the effect of freeing cognitive resources to focus on the additional relationship between items in List 1. The evidence would, however, suggest that the process of linking the Easter dates, at either a conscious or unconscious level, did not occur for the items in List 1.

Another methodological point concerns the selection of September and October as control months. Ideally, List 2 should have comprised Sundays from the months of March and April which were not Easter Sundays. There was a concern, however, that the degree of repetition involved by presenting three lists in close succession, which all comprised dates from the same months, may have proved confusing, particularly for the less able subjects. Choosing dates from September and October therefore offered a variability in items extracted from different months without affecting the essential structural similarity between lists. Furthermore, there is no evidence, either within previous research or within the present thesis, to suggest that dates taken from particular months are more memorable when compared to equivalent dates taken from other months. This would seem to be supported by the fact that savants are not suggested to use a "benchmark date" system when performing calculations (Hill, 1975).

Furthermore, it could be argued that the selection of months in which Easter *never* occurs, would have provided an enhanced contrast when compared to the Easter dates, i.e. they may have served to reinforce the distinctiveness of the experimental items. September and October do not contain an equivalent calendar-related event which is variable. March and April are particularly significant because they *do* contain such an event; the date of which varies from year to year. Therefore, the fact that there was not a difference in recall performance between List 1 and List 2 was all the more marked and informative.

As with the previous studies, subjects' verbal reports were interesting to note. Following the presentation of Lists 1 and 2, the savants were questioned about the features of the dates they had noticed. H.P. was the only subject to note the experimental relationship, pointing to the appropriate lists and stating "these are all Easter Sundays, these are not".

Importantly, H.P. was the only subject to recall an equivalent number of dates from both List 1 and List 3. Thus, his level of recall was not enhanced by the relationship between items being made explicit for the final list, as he had already recognized the experimental relationship when presented with the List 1 items. Consistent with this is the fact that H.P. obtained the highest recall score in the group for List 1.

The remaining seven subjects, when questioned about the features of the first two lists, all stated that these dates were Sundays. Although they had previously been told this fact by the experimenter, their ability to provide this information in the form of a verbal report is notable. This supports assumptions made in Experiment 4, regarding the subject's ability to state the weekday of the dates as the correct list relationship. It can be argued that, in the present experiment, this may simply have been a repetition of the experimenter's original statement relating to the day of the week of the dates. However, this does indicate that the subjects were able to verbalize this repetition appropriately.

That at least some of the subjects are capable of adequate levels of verbal report was also indicated in the case of D.K.'s assertion following the presentation of List 3. After recalling as many dates as possible from this list, he informed the experimenter that "24th March 1991 is wrong. It is not Easter Sunday". Although this date is not shown in List 3, it was originally included in the final series of dates. D.K. had indeed spotted a mistake in the construction of the date lists. Fortunately, he was the first subject to be presented with the stimuli for this experiment. This item was subsequently replaced with the "31st March 1991", which was presented to the remaining seven subjects. It appeared that the reference tables from which these Easter stimuli were taken contained an error. The remaining dates used in this final study were cross-checked against another source and found to all be correct. However, D.K.'s clever observation illustrated his ability to use language skills to communicate information about the date stimuli.

Supplying the subjects with the pattern of relatedness for List 3 meant, of course, that this link between items was fully available for conscious inspection. Evidence that some of the subjects may have utilized this information in order to generate further possible dates can be found in an examination of the intrusion errors. Subjects G.C., P.M. and

J.P. all suggested dates which did not form part of the final list. However, these dates were all consistent with the list relationship; they were all Easter Sundays. G.C. informed the experimenter that "you could have said April 15th 1990 and April 19th 1987", P.M. suggested "11th April 1993" and J.P. gave "April 3rd 1994" as an answer. Importantly, each of these errors occurred at the very end of the series of dates correctly recalled by the subjects. In both G.C. and P.M.'s case, all eight Easter dates were correctly recalled, yet both subjects proceeded to give incorrect additional dates. In J.P.'s case, the intrusion error occurred after he had correctly recalled five dates from the list. In situations such as this, when subjects are obviously generating possible items in accordance with a "rule", there is the question of whether such guessing inflates the recall scores. As was noted, however, the errors occurred at the end of the subjects' attempts to recall the list, which suggests that the savants resorted to an educated guess when genuine recall levels were exhausted.

The ability to generate incorrect answers in accordance with the list relationship, as observed for List 3 in the present study, is in contrast to that observed in the previous Experiments 4 to 6. Not once did the subjects use the pattern of list relatedness in order to suggest possible dates. This was the case even when the subject was able to verbally report the list relationship. One possible reason for this may relate to the fact that the subjects were told about the List 3/Easter relationship *before* the dates were presented. For the previous studies, the relationship between dates, if it was consciously formulated at all, may have only been realised *after* the items were recalled or during the re-presentation of the lists. It is true to say that relying on subsequent verbal reports does not make entirely clear the exact stage at which the relationship was consciously realised. However, the point being made is that the generation of intrusion errors, consistent with the Easter relationship, represents a further dissociation in performance between the present and the previous experiments; a dissociation which may relate to the implicit/explicit processing of information. A further interpretation of this pattern of findings will form part of the theoretical framework offered in the following chapter.

One question raised by the present study relates to the acquisition of knowledge concerning these Easter dates. How do the savants know the dates of Easter over such a wide range of years? The fact that subjects can generate Easter Sundays which occurred before their lifetime indicates that the knowledge does not simply derive from personal experience. Rather, information must be acquired from another source. An insight into the acquisition process of Easter dates can be gained through noting the fragmentary reports of two of the subjects. When questioned, H.P. informed the experimenter that he knew about Easter because of "his book", which was an old almanac. G.C. reported that his knowledge came from "old diaries". From the experimenter's experience, it was noted that the dates of Easter are often included in many perpetual calendars which display each of the 14 calendar templates together with a list of the respective years which correspond to these templates. The vital point to make is that because Easter is not determined by calendar structure, the dates *must* be acquired from an external source. The subject has to be informed when Easter will fall, rather than use his own knowledge of calendar structure to predict the date. This is an important point, the implications of which will be addressed in the following chapter.

As a final point of discussion, a parallel can be drawn between the results of the present study and those of Hermelin and O'Connor (1970) and Tager-Flusberg (1991), reviewed in Chapter 6. These studies investigated the recall of semantically related words by individuals with autism. As many of the present subjects are diagnosed as autistic, these previous investigations are highly relevant to the present series of experiments. In the Hermelin and O'Connor (1970) and Tager-Flusberg (1991) studies, there was no difference in the recall of semantically related and unrelated word lists by the individuals with autism. This contrasted with the performance of normal and mentally handicapped control subjects who retained more related when compared to unrelated words. In the present study, there was no difference in the recall of related Easter dates when compared to unrelated control dates. Evidence from the autistic subjects within the 1970 and 1991 studies, suggested that words *are* stored in a related form in LTM. For example, the autistic individuals could retrieve the appropriate target word using a semantically related cue. However, the important difference when compared to the controls, was that the presentation of related words did not appear to automatically activate the links between these items in LTM. The same interpretation has been offered for this final experiment in the thesis. The links between Easter dates *are* present in LTM, but do not appear to be activated automatically in order to facilitate recall.

Thus, to conclude, in the previous experiments investigating structural regularities, the recall performance of the savants was enhanced by list relatedness; a finding inconsistent with the previous memory investigations of individuals with autism. However, in the final experiment the subjects' performance was more characteristic of their diagnosis, indicating a lack of sensitivity to list organization. Such a dissociation in memory performance between different types of talent-related stimuli has proved insightful. It allows an increased understanding of the underlying mechanisms of the talent and the specificity of the skill; in other words, we move closer to understanding what is "special" or "different" about a module of savant talent. Furthermore, by integrating the findings from savant research with the general literature on autistic cognitive performance, it allows us to further understand the frequent link between autism and special ability.

The following experiment completes the present investigation of savant memory performance. Specifically, this study is concerned with the recall of related and unrelated *word* lists.

Experiment 8: The Recall of Structurally and Semantically Related Words.

Introduction

The previous four experiments have shown that savant recall is facilitated only for dates which are linked according to calendar *structure*. Dates which are related according to a non-structural feature of the calendar, specifically the occurrence of Easter Sunday, were no better recalled that a list of control Sundays. Importantly, the savants' recall performance for the structurally related dates appears to contrast not only with their recall of Easter items, but also with the general findings concerning the memory performance of individuals with autism (e.g. Hermelin and O'Connor, 1970).

The following experiment represented an exploration of the domain specificity of such recall performance. Specifically, the experiment aimed to investigate whether the savants would be able to extract structural regularities from a list of non-calendrical words in order to facilitate memory. The facilitation of recall for structurally related when compared to unrelated words would suggest that the pattern of performance found in Experiments 4 to 6 is not modular. Savants are equally able to extract structural relationships from both calendar related and non-calendrical stimuli. However, the lack of a difference between the recall of structurally related and unrelated words would suggest that the memory performance obtained in Experiments 4 to 6 is unique and specific to the calendar.

As a further point of interest, semantically related and unrelated word lists were presented for recall. These lists formed a test of the savants' ability to extract a non-structural relationship from non-calendrical words. If the recall of the savants *was* facilitated by a structural relationship between words, the semantically associated list would provide an indication of the specificity or generality of such a finding. For example, a difference in recall for the structurally related words but not the semantically related words would suggest that savants can only extract *structural* relationships from stimuli. On the other hand, a difference in recall for *both* sets of related items would suggest that savants can extract any relationship between words in order to facilitate recall. The inclusion of semantically related and unrelated word lists would also illustrate whether the recall performance of the savants is comparable with that found in other studies involving individuals of the same diagnosis but presumably without savant abilities (e.g. Tager-Flusberg, 1991).

Experiment 8a: The Recall of Structurally Related and Unrelated Words.

Method

The recall of structurally related words was tested by presenting subjects with "sentence-like" but meaningless word strings. Within the related lists, words were selected to conform to the rules of syntax. However, the words were deliberately chosen so that no underlying meaning could be derived from the word strings as a whole. In this way, the word strings were judged to correspond to Chomsky's (1965) phrase "green ideas sleep furiously", which is meaningless in content but is grammatically structured.

Subjects. Seven subjects participated in the final experiment. These were H.P., G.C., J.P., J.B., D.K., P.M. and P.E. whose subject details are given in Chapter 3. Attempts were made to test R.D. but he refused to cooperate with the experimenter.

Materials. Four strings of four words were constructed to form sentences which did not violate syntactical/grammatical rules, but were essentially lacking in semantic content. These are shown below in Table 5.16. The four sentences were matched as closely as possible for word frequency (taken from Thorndike and Lorge, 1968). Sentences (1) and (2) were taken to form List A, sentences (3) and (4) comprised List B. Thus, each list comprised eight words.

Table 5.16. ***Stimuli presented in Lists A and B forming the structurally related condition.***

List A					
	(1)	fat	chairs	walk	sadly
	(2)	naughty	cars	eat	quickly
List B					
	(3)	happy	teeth	kick	loudly
	(4)	busy	apples	sing	safely

The structurally unrelated condition was created by randomising the order of the words within each of the individual sentences which are shown above. These jumbled word strings are shown below in Table 5.17. Word strings (5) and (6) were taken to form List C and word strings (7) and (8) formed List D.

Table 5.17. ***Simuli presented in Lists C and D forming the structurally unrelated condition.***

List C					
	(5)	walk	fat	sadly	chairs
	(6)	cars	quickly	naughty	eat
List D					
	(7)	teeth	loudly	happy	kick
	(8)	sing	busy	safely	apples

Subjects were presented with either List A together with List D, or List B together with List C. In this way, subjects received all four word strings, two in the structurally related format and two in the jumbled format. The combination of lists (i.e. either A and D or B and C) was counterbalanced across subjects, as was the order in which the lists were presented (i.e. four subjects received the structurally related strings first, three subjects received the jumbled word strings first). The eight words which comprise each list were printed in Times Roman 20pt size, on A4 paper, landscape format. An example of the format in which the words were presented is shown below in Figure 5.7.

fat	chairs	walk	sadly
naughty	cars	eat	quickly

Figure 5.7. *Format of presentation of List A.*

Procedure. Subjects were informed that they were to be shown eight words, four words at a time, which they should look at very carefully. They would be required to read the words out loud and the experimenter would also read the words for them. After one minute they would be asked to remember as many of the words as they could, in any order.

The A4 piece of paper showing the respective list was placed in front of the subject and all of the words were covered with another piece of A4. The subjects were reminded that they should concentrate on trying to remember as many of the words as possible. The A4 cover was moved down to reveal the first word string which the subject was required to read aloud. The experimenter repeated the whole of the word string after the subject had read all four words. After the items from the top word string had been read, the A4 cover was placed over these items to reveal only the bottom four words. Again the subject was required to read the items aloud, with the experimenter repeating back the whole of the word string. Each word string was displayed to the subject for a total of 10 seconds. After a one minute filled interval, in which the subject was encouraged to talk with the experimenter, he/she was requested to recall as many of the previously presented items as possible. With subject P.M., who was unable to read the words, the items were read aloud by the experimenter (in addition to being visually presented) with P.M. repeating back the whole of the word string.

Results

With the exception of P.M., all subjects were able to read the words. Some of the less able savants were subsequently asked about the meaning of the lower frequency words, such as *safely*. All of these subjects were able to provide some indication that they understood the meaning of the words. This vocabulary/comprehension check was conducted after the subjects had completed both the related and unrelated conditions.

The number of words recalled by the seven subjects from both the structurally related and unrelated lists are shown below in Table 5.18, together with the group means and standard deviations. A related *t*-test, performed on the difference between recall scores for the two lists, was not significant ($t(6) = 1.00$, ns). Thus, the presentation of words related according to syntactic structure did not appear to facilitate recall when compared to words which were structurally unrelated. A discussion of these findings will be given following the results of Experiment 8b.

Table 5.18. ***Number of words recalled by subjects in structurally related and unrelated word lists (out of a total of eight)***

Subject	Structurally related list	Structurally unrelated list
H.P.	3	3
G.C.	4	4
J.B.	5	5
J.P.	2	2
D.K.	6	6
P.M.	3	3
P.E.	6	5
Mean	4.14	4.00
SD	1.57	1.41

Experiment 8b: The Recall of Semantically Related and Unrelated Words.

Method

Subjects. The same subjects who participated in Experiment 8a took part in the present experiment.

Materials. Subjects were presented with two lists. In the first list, the words represented items of food and were therefore all taken from the same semantic category. In the second list, words were taken from different conceptual categories, i.e. they were semantically unrelated. The words from each list were individually matched in terms of their word frequencies (taken from Thorndike and Lorge, 1968). The two lists are shown below in Table 5.19.

The lists were printed on separate sheets of A4, portrait format, in Times Roman 20pt size. Another sheet of A4 card was used which contained a "window" large enough to reveal only one word at a time.

Table 5.19. ***Lists of semantically related and unrelated words presented for recall.***

Semantically related words (experimental list)	Semantically unrelated words (control list)
carrot	toothbrush
bread	desk
cake	knife
butter	door
jam	taxi
banana	sock
onion	leaf
potato	fence
sugar	summer
cheese	pencil

Procedure. The subjects were informed that they were to be given a test of memory. They would be shown a list of 10 words which they should read aloud and try to remember. After they had been shown each of the words separately they would be allowed to inspect the whole of the list. After a one minute interval they would be asked to remember as many of the words as possible.

The experimenter placed the list in front of the subject and preceded to move down the A4 "window" to reveal each of the words. Each item was shown for a period of three seconds. After the subject had read the word aloud the experimenter would also repeat the word. Following the removal of the cardboard window, the subject was encouraged to study the whole list for a further 10 seconds. After a one minute filled interval, the subject was required to recall as many of the words as possible, in any order.

Results

The total number of words recalled by the subjects from each list is shown below in Table 5.20, together with the means and standard deviations. A related t-test was performed on these scores and revealed that the difference in recall between lists was not signficant ($t(6) = .26$, ns). Thus, the fact that the words in the experimental list were related according to their conceptual category did not serve to facilitate recall.

Table 5.20. ***Number of words recalled by subjects from the semantically related and unrelated word lists (out of a total of 10).***

Subject	Semantically related list	Semantically unrelated list
H.P.	3	5
G.C.	4	6
J.B.	6	5
J.P.	7	6
D.K.	7	6
P.M.	4	5
P.E.	7	6
Mean	5.43	5.57
SD	1.72	0.54

Discussion of Experiments 8a and 8b.

The results indicate that the recall levels of the savants were not facilitated by either structural or semantic relationships between word items. In contrast to the results of Experiments 4 to 6 in which recall was facilitated for lists of structurally related dates, a comparable pattern of performance was *not* obtained for the recall of non-calendrical words. This would therefore suggest that the facilitation in recall performance obtained in the earlier experiments is domain-specific; it is confined to the calendar. The findings concerning the recall of semantically related and unrelated lists are consistent with those of previous studies involving individuals with autism (e.g. Hermelin and O'Connor, 1970; Tager-Flusberg, 1991).

Although the present findings provide strong evidence of the modular nature of savant recall ability, through having found no difference in the savants' recall of related and unrelated words, it could be suggested that with a larger group of subjects significant differences may have been obtained. However, an inspection of the individual subjects' scores does not support such a suggestion. In addition, all of the individuals involved in the present study make use of grammatical/syntactical rules to structure their utterances (however limited). In this way, the present finding that savant recall levels are not facilitated by structural/grammatical links between words appears all the more marked. Their knowledge of the structure and regularities in the calendar must represent a truly outstanding and unique area of function.

CHAPTER SIX

DISCUSSION AND OVERVIEW OF FINDINGS

The preceding studies have investigated various aspects of memory performance in a group of savant calendar calculators. Although all of the studies of savant date calculation reported in the literature implicate memory as a crucial component of the skill, none of these studies have ever focused on memory performance as distinct from calculation ability. To this purpose, the studies reported in the thesis were concerned with an investigation of memory only, independent of actual calendar calculation. The first study was concerned with a comparison between the savant group and verbal IQ and diagnosis matched controls in terms of their digit and word span performance. Results showed no difference between the groups in either condition. Thus, short-term recall, as measured on these tests, does not appear to be a component of savant date calculation ability. The second study investigated long-term memory for both general items (words) and talent-specific items (years). The savants were significantly better than controls with the years but did not differ from controls for the recall of non-calendar related items. This result indicates that the savants were able to relate the year items to their existing knowledge of the calendar, i.e. the years were encoded in an elaborated form. The third experiment confirmed that underlying the ability to calendar calculate is an extensively organized knowledge base. This investigation showed that dates which were calculated prior to a recognition test were better retained than dates which were previously studied. This enhanced retention is interpreted in terms of the calculation process having activated links between date representations stored in LTM. The following three experiments were all concerned with the savants' recall of lists of dates linked according to the rules and regularities of the calendar. These lists of dates and years were better recalled than date lists which were *not* related according to such structural features. This pattern of LTM performance suggests that the savants' knowledge of dates is organized according to the structure which governs the Gregorian calendar. A further experiment was concerned with the savants' recall of lists of event-related dates (Easter Sunday). In this instance, recall was not facilitated for the Easter list. However, when the nature of the relationship between dates was made explicit by the experimenter, such facilitation did occur. The final study illustrated the domain specificity of memory performance relating to calendar structure. The savants' recall was not facilitated for words linked according to grammatical structure. Also, as with the Easter dates which are not structure-based, semantically related words were no better remembered than a control list of verbal items.

Before discussing the results further, it should be acknowledged that the experiments were carried out on a small group of subjects only. This, however, is inevitable in view of the rarity of the savant. Indeed, the present investigation involved as large a sample of savant date calculators as has ever been directly studied. Nevertheless, because of the small number of subjects involved, the results should be regarded with some caution, particulary when the null hypothesis is sustained. It should also be noted that throughout the studies an attempt was made to interpret the findings, not only at the group level, but also in terms of the performance of individuals. This is especially important given the apparent heterogeneity of the present group, particularly with regard to their calculation speeds and spans, age of acquisition of calendar ability, IQ and arithmetical ability.

The present series of memory experiments has led to the conclusion that savant date calculation ability is subserved by an extensively interconnected knowledge base. In this respect, savant date calculators are comparable with savant musicians, artists, numerical calculators and mnemonists. As was stressed in the Introduction to the thesis, these savant talents also depend on structured representations in LTM. For example, savant musical knowledge reflects the rule-governed structure of tonal music. In addition, savant date calculators appear comparable with experts in the normal population, whose skills are also subserved by extensively organized knowledge bases. Importantly, as with the savant calculators, the superior memory performance of the experts is confined to their area of outstanding skill. In this way, the present findings concerning savant calendar calculators are consistent with the research on other savant abilities and also on areas of isolated skill in individuals of at least average intelligence.

The Organization of Calendar Knowledge: Two Sources of Talent Related Knowledge.

It should be pointed out before continuing with the discussion, that in this and the following sections, the term *knowledge* is used to refer to organized representations which are stored in LTM. In keeping with this definition, perhaps the most important findings in the present study concern the organization and structure of savant calendar knowledge. Specifically, the dissociation between recall performance obtained in Experiments 4 to

7 is particularly informative. These findings are taken as evidence to suggest two different sources of calendar related knowledge. In Experiments 4, 5 and 6, which examined the recall of dates falling on the same weekday, at 28 year intervals and leap years, there was a facilitation in recall *without* the relationship between dates being made explicit. In Experiment 7, in which the dates were Easter Sundays, there was no such facilitation in recall. Memory was enhanced only when the pattern of relatedness was verbally formulated for the savant. Importantly, the same day dates, 28 year dates and leap years all relate to calendar *structure*. Easter Sunday, on the other hand, has nothing to do with Gregorian calendar structure. There is no regularity in the occurrence of Easter. It can turn up as early as March 22nd or as late as 25th April and is in fact described as being "calendrically illogical" (Hamblin, 1966). The key point here is that knowledge of calendar structure, or the actual process of calculation, would never allow the savant to be able to predict when Easter will be. The same point can be made for birthdays. Knowledge of calendar structure would not allow the savant to predict the *date* of someone's birthday. Knowledge of birthdays is like the knowledge of Easter Sunday. They are externally imposed, non-structural items of information, which map onto the calendar but are not inherent to calendar structure; they are not calendrically determined. *Moreover, because they are externally imposed, arbitrary items of information, they can only be explicitly acquired.* The savant will only know when someone's birthday is because they have been told or they have read about it.

Therefore, this series of recall tests may have succeeded in tapping two different sources of savant knowledge, both of which relate to the calendar. The first can be labelled as *structural* knowledge, the second as *non-structural* or *event-related* knowledge. Figure 6.1, below, depicts this distinction diagrammatically. The characteristics associated with the two knowledge stores will now be described in more detail.

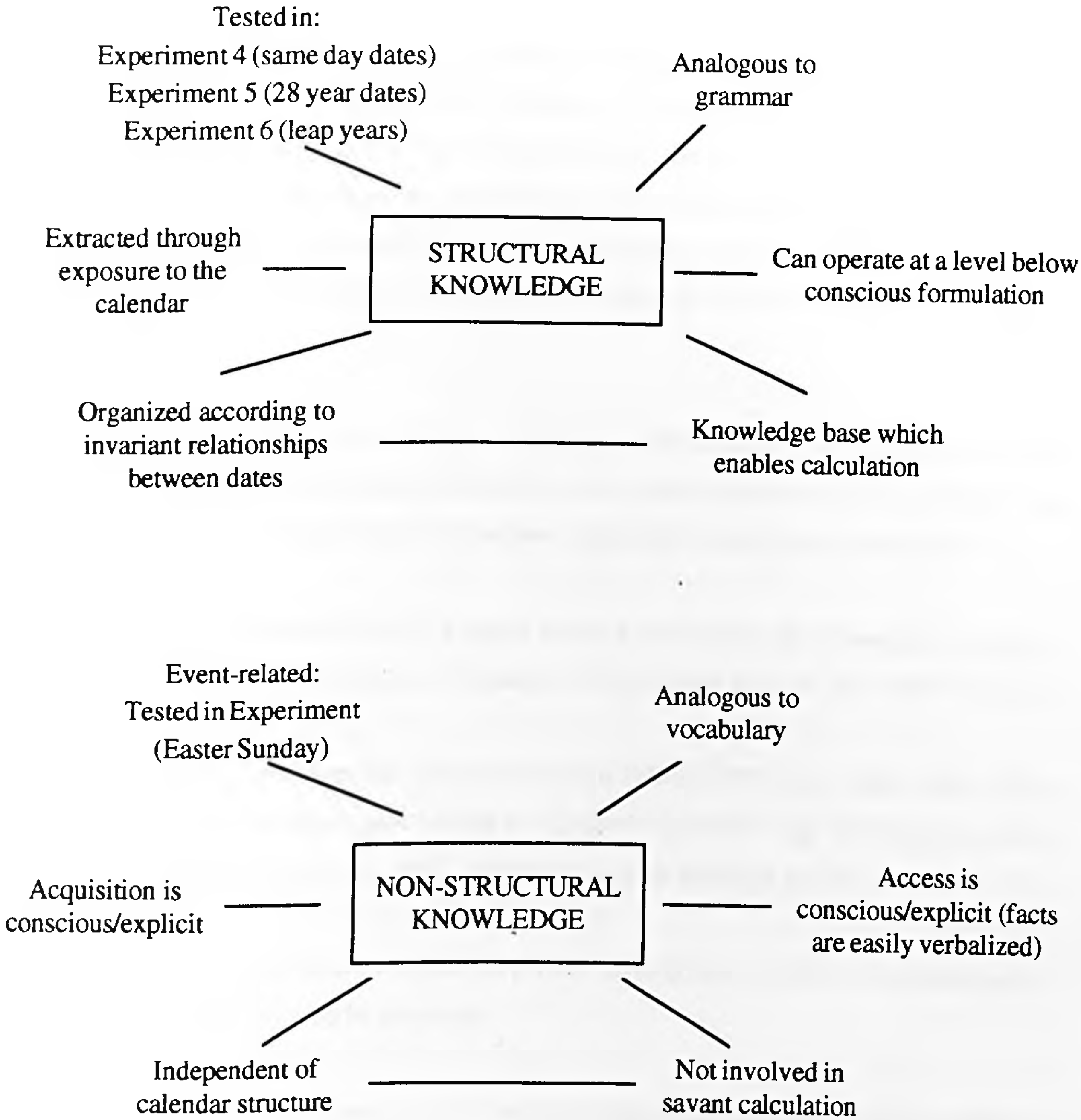

Figure 6.1. ***Two sources of calendar related knowledge.***

1) Structural knowledge.

As proposed in Chapter 2 and supported by the present investigation, savant calendar knowledge may be conceptualised within an associationist/network view of LTM organization. Dates are linked to other dates; the activation of representation(s) corresponding to one date may in turn activate other dates related according to features of the calendar. Specifically, *structural knowledge* corresponds to the invariant relationships between dates; it reflects the patterning and structure of the Gregorian calendar.

Format of structural knowledge. Structural knowledge of the calendar may be characterised by relationships between dates on several different levels. Specifically, the following relationships between dates were explored by the present investigation:

- links between dates in a month and in a year which fall on the same weekday, e.g. 1st July 1996 was a Monday, 8th, 16th and 25th of July 1996 were also Mondays.
- connections between years containing a February 29th, e.g. 1984, 1988, 1992.
- links between years falling at 28 yearly intervals, e.g. 1972 has the same calendar structure as 1990, 1973 has the same structure as 1991.

Although not tested directly within the present investigation, the following relationships between dates may also be proposed:

- day-date correspondences of individual, sequential dates, e.g. 1st July 1996 was a Monday, 2nd July 1996 was a Tuesday, 3rd July 1996 was a Wednesday.
- links shared between months of the same calendar configuration, e.g. 1st July 1996 was a Monday, therefore the 1st April 1996 was a Monday.
- connections between the same date in adjacent years, e.g. 1st July 1996 was a Monday, 1st July 1997 will be a Tuesday, 1st July 1998 will be Wednesday.

In addition, the savant may possess knowledge of "micro-rules" or small recursive patterns in the calendar. For example, subject P.E. will sometimes whisper "5,6,6,11" after having calculated a date. This is presumed to refer to the fact that the same date falling at these yearly intervals will occasionally fall on the same day.

The process of calculation. On the basis of the current results it can be suggested that the activation of connections between date representations underlies the calculation process. It is the knowledge of how one date relates to another date which enables the savant to generate the weekday in response to a given date, particularly for distant dates. Perhaps for more recent dates, the dates may be encoded together with their corresponding weekday, and so can be retrieved directly from LTM. However, in order to provide the weekday for more distant dates, for which the corresponding calendar may never have been seen, the savant needs to activate the links *between* dates, thus utilizing their knowledge structure. This may be the reason why future dates and/or more distant dates typically take longer to calculate, a finding obtained in both the present thesis and by O'Connor and Hermelin (1986).

Structural knowledge and the method of calculation. From the reports of parents and the subjects themselves, it would appear that most of the savants are able to calculate beyond the range of years for which they have had access to calendars. Even subject D.K., who reports having had access to a 100 year calendar, can calculate beyond this span. Thus, the description of structured knowledge activation described above may well characterise their method. Certainly, H.P., P.E. and P.M. have remarked on the 28 year repetition of the calendar. However, subject J.P. represents a contrast with the other subjects. He reports having memorised a 200 year calendar which comprised the 14 different calendar templates together with the corresponding years. In this respect, he is similar to the three savants studied by Young and Nettelbeck (1994). J.P.'s date calculation method must therefore involve the retrieval from LTM of the calendar template which corresponds to the year of the target date. It is possible that he may then "read off" the correct weekday, thus using a strategy based on visual imagery. On the other hand, his representation of each template may not be as literal as retaining an exact visual image of each calendar page. Rather, all J.P. would need to know to generate the whole structure of a yearly template would be the weekday of January 1st and whether there was a February 29th. A familiarity with the internal relations within each yearly configuration would then allow the correct weekday to be generated. To reiterate, the point being made is that even when a savant's method is known to be based on the rote memorisation of a perpetual calendar, the corresponding talent-specific knowledge base would still be highly structured. This is supported by the pattern of J.P.'s recall performance in the present investigation in that he recalled more structurally related than unrelated dates[4].

Is structural knowledge implicit or explicit? The answer to this question may well be "it depends". First, whether or not the savant can consciously formulate calendar regularities may depend on their level of intelligence. Certainly, the three most intellectually able savants, H.P., G.C. and P.E., are all able to give verbal reports concerning the 28 year rule. H.P. can even give fragmentary insights into the use of the 400 year cycle over thousands of years of the calendar. Second, the conscious formulation of structural knowledge may depend on the specific regularity in question. Importantly, being able to calendar calculate involves much more than a knowledge of the 28 year rule and even the most intelligent calculators find it difficult to specify *exactly* how they perform their calculations. In other words, whilst a small number of savants may be able to verbally formulate a large-scale regularity such as the 28 year cycle, the individual mappings between dates which characterise the savants' structural knowledge of the calendar may be truly inaccessible to conscious inspection. The present findings support the fact that structural knowledge of the calendar may be largely unconscious. Levels of recall were facilitated for dates linked according to calendar structure yet most of the savants were unable to verbally state the links between dates. Interestingly, a similar finding with regard to numerical calculation was noted in Chapter 1. Colburn, the child prodigy reported by Smith (1983), was able to provide the factors of numbers up to one million, yet he was completely unable to state the rules he was using. Thus, for numbers, like dates, a conscious access to calculation rules may not be necessary for their effective use.

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[4] To further investigate J.P.'s method, it would be interesting to present him with interference tasks based on visual imagery and articulatory suppression and assess their effect on his calculation ability.

Calendar rules and regularities: the "grammar" of the calendar. The implicit nature of structural calendar knowledge may permit an analogy with our utilization of grammatical structure. Savants make use of the regularities within calendar structure in order to generate the weekday of a given date. Yet, for the most part, they are unable to verbally formulate these structural patterns. We exhibit a very similar facility in our use of grammatical rules. The process by which we utilize these rules in the production of speech and language is unconscious; we would have great difficulty in verbally formulating the principles of grammatical structure. Thus, it becomes easier to appreciate how the savants can make use of calendrical regularities, yet at the same time have no conscious insight into their method of calculation.

2) Non-structural/event-related knowledge.

Content of non-structural knowledge. This source of knowledge corresponds to *event-related* or autobiographical information. It includes the savants' extensive knowledge of other peoples' birthdays, of Easter Sunday, of their previous holidays and daytrips. Importantly, every member of the present savant group is reported to possess an outstanding memory for such information. One member of staff even reported that they did not need to consult the centre's diary to check their appointments. They simply asked P.M. Thus, it would appear that the savants possess a rich database of calendar knowledge relating to episodes, experiences and events.

The acquisition of, and access to non-structural knowledge. The acquisition of such knowledge is conscious and often deliberate. For example, knowledge may be obtained from encyclopedias and almanacs or through the constant questioning of strangers about their date of birth. Furthermore, because these individual items of event-related knowledge are consciously acquired, they can only be explicitly accessed. This follows from the findings of Experiment 7, within the present thesis. Recall was facilitated for a list of Easter Sundays *only* after the link between dates was made explicit. This suggests that information relating to events *is* organized in LTM, however, the links between representations need to be activated directly. This is also consistent with the findings of

Experiment 8 in the present thesis, and the work of Hermelin and O'Connor (1970) and Tager-Flusberg (1991). These studies show that, for individuals with autism, the links between semantically related *words* in LTM appear not to be automatically activated as part of the retrieval process. The conscious and ready access to non-structural calendar knowledge is illustrated by the ease with which savants will verbalize event-related facts. All of the subjects spontaneously volunteer information relating to the date of someone's death or marriage, or even the date of the experimenter's previous visit. Such declarative knowledge contrasts markedly with their difficulty in formulating the structural regularities of the calendar.

Event-related knowledge and the structure of the calendar. The content of event-related knowledge is essentially independent of calendar structure. Specifically, knowledge of the structure of the calendar would not allow the savant to infer or predict the date of an event. Of course, once they are informed of the *date* they can generate the *day* (through the activation of structural knowledge) but the actual *occurrence* of events remains arbitrary. Importantly, because such information is independent of calendar structure then it does not subserve savant date calculation. Knowing that someone was born on the 24th July 1968 would not allow the generation of the corresponding day. This can only be obtained through the activation of knowledge pertaining to calendar structure.

An analogy between non-structural knowledge and vocabulary. Just as structural knowledge may constitute the "grammar" of the calendar, event-related knowledge may be regarded as the "vocabulary". Essentially, the labels we attach to object and concepts are all *arbitrary*. They play no direct or fundamental role in the existence of the object. Importantly, because these labels are arbitrary they can only be explicitly acquired. We only know that a chair is called a "chair" because this is the label we are taught to associate with the object. In the same way, event-related knowledge of the calendar is arbitrary. It maps on to calendar structure but is not determined by calendar structure. However, just as the words which form our vocabulary are *meaningfully* related to the object or concept they represent, for the savant, events are also related meaningfully to the date on which they occurred. In this way, non-structural/event-related knowledge may represent the "semantics" of the calendar.

There are a number of further points which should be noted concerning the two sources of calendar related knowledge:

1) What makes a savant calendar calculator? There are many individuals with autism who display a strong interest in dates, particularly people's birthdays. However, very few of these are genuine calendrical calculators. This observation was supported by the response to the experimenter's advertisement for subjects with calendar skills (see Chapter 3). Most of the individuals mentioned in the replies showed an outstanding facility for remembering birthdays and other events but were unable to generate the corresponding weekdays for these dates. In terms of the distinction between sources of calendar knowledge, it would appear that these individuals possess the non-structural/event-related knowledge but not the structural knowledge. In other words, it is precisely this aspect of calendar knowledge, i.e. structural knowledge, which "makes" a calendar calculator and distinguishes them from all other autistic individuals with an interest in dates. It would therefore appear possible to find one source of knowledge (non-structural) without the other. However, in the savant group, all subjects possessed *both* knowledge stores. One possibility is that event-related/non-structural knowledge develops before structural knowledge which gives rise to the following question.

2) Does an interest in birthdays precede the ability to calculate dates? This question was posed to the several of the parents of the present subjects. Those who were able to remember reported that the ability to calculate emerged at about the same time as their child became especially interested in dates. This would suggest that one source of knowledge does not develop before the other. However, one possibility is that through exposure to the calendar, the savant's structural knowledge is beginning to form, i.e. links are being made between dates in LTM, at a level below conscious awareness. A simultaneous interest in dates would also provide the structural knowledge base with examples of day-date pairings which could then be assimilated and elaborated within the structural knowledge base. Thus, an early interest in dates may "feed" any developing knowledge of the relationships between dates. Further suggestions on the acquisition of calendar knowledge are offered later in the present chapter.

3) Is there a limitation on the extent of structural calendar knowledge? The calculation of distant dates is suggested to depend on the activation of links between related dates in LTM. Importantly, this process which involves the extraction of calendar regularities and structure allows the calculator to generate the appropriate weekday for dates they have never directly studied or deliberately learned. However, if their ability to calculate is not necessarily dependent on having seen the appropriate calendar, why do the savants show limited calculations spans? One possibility is that in order to extend beyond their direct experience of the calendar, they need an anchor or "outlier" date around which their structural knowledge will form. An example concerning subject D.K. may illustrate the point. He reports having seen a 100 year calendar (1900 to 2000). However, his calculation span extends into the past beyond 1900, to approximately 1870. Interestingly, D.K.'s mother reports him taking a strong interest in a table mat when he was 12 years old, which depicted a single date and weekday from 1879. Therefore, encoding this single day-date pairing within his existing calendar knowledge would allow him to formulate the appropriate structural relations between dates in the years 1879 to 1900. In this way, the spans of some savants may be limited because they have never been presented with examples of day-date pairings which would permit the reformulation and extension of their structural knowledge. Further suggestions concerning the extent of an individual's calculation range are given below.

Calculation range and IQ. It is possible that an individual's IQ may operate to constrain the size of their calculation span. Importantly, however, a direct relationship between intelligence level and size of span was not obtained for the present group of savants. Rather, the relationship between calculation range and intelligence appears to be rather more complex. To summarise the present findings; IQ as obtained on the Peabody Picture Vocabulary Test or the Ravens Progressive Matrices Test did not correlate with calculation range; performance on the Wechsler vocabulary, block design and object assembly subtests *did* correlate with size of span. One question to be asked is how might the savants' performance on the vocabulary test be associated with their ability to calculate more distant dates? Importantly, as their performance on the P.P.V.T. did not correlate, why did their Wechsler vocabulary performance do so? The differences between performance on each test cannot be explained in terms of LTM representation (as this would have been tapped by both tests). Rather the key difference between tests must lie in the subject's mode of response. The P.P.V.T. requires subjects to simply point at one of four pictures which corresponds to the words read out by the experimenter. It therefore requires no generative verbal output by the subject. The Wechsler subtest, on the other hand, requires subjects to generate and verbally formulate a definition of the word in question. Thus, it may be this precise aspect of performance which separates the two vocabulary tests and is associated with the span over which the subject can calculate. It can be suggested that both the Wechsler vocabulary test and the process of calculating dates require subjects to put into words what is stored in LTM. Both require the activation of links between stored representations, with this pattern of activation then being transformed into an overt verbal response. This may the reason for the obtained correlations between vocabulary and calculation range. The Wechsler comprehension test, on the other hand, did *not* correlate with calculation range because it is suggested to be based on pragmatic/social understanding rather than the storage of factual knowledge in LTM (Happé, 1994c). This interpretation of findings is, however, highly speculative. The correlations involving the block design and object assembly subtests will be discussed towards the end of the chapter.

Conclusion. The present series of experiments on savant calculation has succeeded in distinguishing between two sources of calendar related knowledge; structural and non-structural/ event-related knowledge. Specifically, it is the store of knowledge relating to calendar structure, activated in the absence of conscious awareness, which is suggested to underlie the ability to calendar calculate. This knowledge distinction may even be compared with that suggested by Tulving (1972), concerning semantic and episodic memory. Tulving proposed that semantic knowledge is organized factual knowledge which is not dependent on a particular time and place. This corresponds to the conceptualisation of structural calendar knowledge as defined in the present investigation. Episodic memory, on the other hand, refers to personally experienced events and autobiographical information. This would appear analogous to the store of calendar knowledge regarded as non-structural. Thus, such a division of knowledge appears useful not only in our conceptualisation of general knowledge, but also in terms of knowledge within an outstanding area of function[5]. This brings us to the next point of discussion: how modular is the calendar ability of the savant?

The Modular Nature of Savant Calendar Ability.

As was noted in Chapter 1, it is unlikely that calendar calculation constitutes a module of function in line with Fodor's (1983) definition. It would be difficult to imagine the evolutionary significance of being able to calculate dates. However, the present thesis has revealed a number of findings which relate to our conceptualisation of savant calendar ability as an area of isolated function. These findings are discussed below.

1) Savant calendar calculation and general intelligence. For the present group of savants, there was no correlation between their performance on the Ravens Progressive Matrices Test (regarded as a measure of "g") and either calculation speed or range. This would suggest that savant calendar skill is independent of *general* intelligence. This result could be interpreted within Howe's (1989; 1991) view of intelligence, i.e. date calculation constitutes an autonomous and independent mental skill (without having to allow for the concept of "g").

2) Memory performance for calendar related and unrelated items. The results of the present studies provide evidence for the modular function of the savant's memory for dates compared with non-calendrical words. Specifically, the results of Experiments 4, 5 and 6 indicate that the structural links between dates stored in LTM can be activated in order to facilitate recall. However, pre-existing links between *words* in LTM were not activated automatically during the retrieval of either structurally or semantically related word lists (Experiment 8). Importantly, this *differential* activation of LTM representations during the retrieval process, for dates compared with words, may be one factor which contributes to the elevation of calendar ability to an area of outstanding function. In other words, this is why they are calendar savants rather than "word savants".

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[5] To avoid any possible confusion, the use of these terms will be clarified further. Tulving uses the term *semantic memory* for what has here been called "structural knowledge". What is referred to as the "semantics of the calendar", in the context of the present research, corresponds to Tulving's *episodic memory*.

3) Calculation ability for numbers compared with dates. From the findings reported in the chapter on the intellectual and calculation abilities of the subjects, it is clear that most of the savants are able to judge the difference between years in the present century but are unable to perform the equivalent task with numbers. In addition, their ability to sort even numbered and odd numbered years (Experiment 6) may seem remarkable given their level of numerical competence. This may represent evidence of "modular" function along the lines of that found by Carraher, Carraher and Schliemann (1985). They demonstrated the specificity of numerical calculation ability in young Brazilian street-vendors. These individuals were adept at solving mathematical problems occurring as part of their natural working situation. However, they were unable to solve the equivalent problems when presented as formal tests, involving mathematical operations or word problems. Thus, the numerical skills of these street-vendors, like those of most of the calendar calculators, appear to be context dependent. Returning to the savants' ability to judge the difference between years and not between numbers, there are a number of points which should be noted. First, it is suggested that their LTM for dates is organized to reflect 28 year intervals. Thus, their ability to judge the intervals between years may be subserved by calendar knowledge organization. Second, the fact that they can judge yearly intervals which are of no calendrical significance suggests that actual calculation may play a role. In this way, they may be able to perform the equivalent mathematical operations within the context of the calendar but not within a purely numerical context. Third, their inability to perform the judgments with numbers may reflect a lack of motivation and willingness to attempt the task. Years are highly familiar items whereas numbers represent a more daunting prospect. It is clear that further research needs to determine the precise role played by memory and calculation in the judgment of yearly intervals.

4) The modular nature of calendrical skill in relation to individual subjects. It is important to note that for some of the savants, the calendar undoubtedly represents an unique area of function. For example, P.M., with an IQ of 58 as measured on the Ravens Matrices Test, can only read words associated with the calendar and can only perform calculations within the context of the calendar. However, for other subjects, their skill with dates appears more consistent with their abilities in other domains. H.P. represents the obvious example, demonstrating an extraordinary facility for numerical calculation.

Moreover, H.P., with an IQ of 102 on the Ravens Matrices Test, is able to combine his skills in different domains. Specifically, he appears to utilize his numerical ability to circumvent any limitations on the LTM storage of structural calendar knowledge. This gives rise to an almost infinite date calculation span. Thus, whether the calendar represents a genuinely isolated area of function may vary from subject to subject.

Conclusion. It is difficult to conclude whether the calendar represents a truly modular area of function. Evidence from the present thesis suggests that the skill may be independent of general ability level and may also be subserved by unique memory and calculation functions. However, it is probable that some of the more intellectually able savants utilize their skills in other areas, particularly their numerical skills, in order to facilitate their performance with the calendar. In this way, these findings may be seen as consistent with the views of O'Connor and Hermelin (1988) who assumed an interaction between general intelligence and intelligence-independent abilities in order to explain the savant.

The Acquisition and Development of Savant Calendar Ability.

It is important to consider how the findings of the present thesis contribute to our understanding of the acquisition of savant calendar ability. The relevance of the findings will be considered in terms of (1) the role of memory ability, (2) the role of practice and (3) the significance of a diagnosis of autism.

1) The role of memory ability.

The findings of the experiments concerned with STM for digits and words and LTM for individual years and words indicated that savants do not develop their skills with the calendar because of a superior short- or long-term memory. In relation to verbal IQ and diagnosis matched controls, their recall was superior only for calendar information within their calculation span. No group differences in recall ability were obtained for numbers, words and year items outside of their calculation ranges. Two further findings from these early experiments may also contribute to an understanding of the acquisition of calendar knowledge. The first relates to the savants' enhanced ability to retain digits in STM when compared to words. For the controls, words and digits were equally memorable. Thus, for the savant, knowledge retained over time may be more likely to favour numerically based information, including dates and years, rather than information relating solely to words. Also of interest are the reports of several parents of the present savants, who report their child having always shown a demonstrable interest in numbers, e.g. relating to bus numbers and car registration plates. Thus, their numerical content may help to explain why such individuals gravitate towards calendars in the first place. The second finding relevant to the acquisition process concerns the results of Experiment 2, which illustrated how the savants were able to encode individual year items in relation to their existing knowledge of dates, i.e. they were able to encode these years in an elaborated form. This resulted in their superior recall, relative to controls, of years within their span. From this it may be possible to suggest the following process. The savant initially becomes interested in dates (concerning birthdays and events) and is also drawn to the calendar (due to its numerical content). As the savant starts to process the relationships between dates, their knowledge of calendar structure begins to develop. In addition to date information encountered in a range of settings, each new day brings a further example of a day-date pairing. Importantly, because the savant possesses this developing store of organized calendar knowledge, any new examples can be elaborated within their knowledge base. Due to their existing knowledge, a date is meaningful and therefore memorable. Such an effective uptake of date information may also explain why intensive and deliberate practice does not appear to be an essential component of date calculation ability (O'Connor and Hermelin, 1992). The role of practice in relation to the performance of the present savant group is considered below.

2) The role of practice.

In view of Ericsson et al.'s (1993) emphasis on the role played by deliberate practice in the acquisition of ability, this would represent an important factor to consider with respect to the calendar savant. Certainly, some of the findings within the present thesis would implicate practice in the acquisition of calendar knowledge. For example:

- at least one savant, J.P., possesses a perpetual calendar and would sit and copy out pages from this calendar

- the possibility cannot be discounted that the savants for whom parental reports were not available also had access to a perpetual calendar (even though they gave verbal reports to the contrary)

- all members of the group save old calendars and diaries

- some savants did not acquire the skill until they were 17 years old, therefore having ample time for practice (in excess of the 10 years suggested by Ericsson et al.)

- a number of savants, A.T. for example, will often ask strangers for their birthdays, thus seeking out opportunities in which to practice their skill.

However, there are a number of other findings which are *not* consistent with an explanation of the skill based purely on practice. These are:

- parents of several of the savants report that they have never seen their child sit and study a calendar (or at least only for a very limited time, e.g. three days in P.E.'s case)

- the calculation spans of most of the group extend beyond the year range covered by their calendars and diaries

- with some of the more distractible members of the group, notably A.T., it is impossible to conceive of them ever having sat down and studied the calendar, particularly for a length of time sufficient to acquire a 100 year calculation span

- some members of the group were proficient calculators at the age of 6/7 years old.

An important point to make is that the savants have obviously had exposure to calendars and to date related information, otherwise how else would they acquire their knowledge? However, the key point is whether this exposure to calendar information constitutes *deliberate practice*. Restating Ericsson et al.'s (1993) definition of "deliberate practice" may be useful. It is regarded as a highly structured activity, the explicit goal of which is to improve performance; it is not inherently enjoyable; it requires optimal levels of (1) resources (tuition and materials), (2) motivation (to improve performance) and (3) sustained effort. So how does the savant's experience with the calendar align with this definition? The main point of contention, from which several others follow, concerns whether the acquisition of calendar knowledge is *deliberate*. The suggestion, based on the findings of the current thesis, is that knowledge of calendar structure can be acquired, formulated and accessed at a level below conscious awareness. In this way, the savant does not deliberately "teach" himself the calendar and is not motivated to expend huge amounts of effort solely to expand his span. However, this is not to deny the fact that the savant *is* motivated and his pursuit of date information may well be effortful. Rather, the point being made is that any motivation and effort arises out of a genuine interest in the calendar: the savant's experience with the calendar *is* inherently enjoyable. Thus, the process by which the savant is suggested to acquire calendar knowledge is not consistent with Ericsson et al.'s explanation in terms of deliberate practice. In the same way, an explanation of savant date calculation based solely on *rote* memorisation of the calendar (e.g. Hill, 1975) would seem untenable.

3) The significance of a diagnosis of autism.

Seven out of the 10 savants have a diagnosis of autism. Another savant has marked "social and communication difficulties" with the remaining two subjects showing evidence of autistic tendencies. Thus, there is a need to account for the reason why so many savant date calculators have a diagnosis of autism. The ideas of Pring et al. (1995), concerning the relationship between savant artistic talent and autism, are relevant. These authors suggest that the facility for processing local elements of a figure appears not only to characterise those individuals with autism (Frith, 1989) but also those with artistic talent. In other words, *weak central coherence* may be one facet of cognitive processing which predisposes individuals with autism to develop outstanding abilities. The findings from the present thesis offer some support for this theory. It was suggested by Shah and Frith (1993) that performance on the Wechsler block design subtest may be a marker for weak central coherence in autistic individuals. In Chapter 3, a correlation was reported between block design performance and calculation range which contrasts with the lack of a relationship between non-verbal IQ (as measured on the Ravens Progressive Matrices Test) and calculation span. Thus, weak central coherence appears to be associated with calculation ability. In many respects, this is difficult to align with the present experimental findings in which levels of recall were facilitated by relationships between dates. Weak central coherence suggests that the list would not be processed as a whole and therefore the relationship between dates would not be extracted. Furthermore, the present discussion of calendar knowledge has focused on the extraction and storage of regularities and patterns within the calendar which play a part in date calculation. An individual who processes information primarily in terms of its component parts would be at a disadvantage in extracting such structure and rules. Thus, how can we account for the role played by weak central coherence, or *segmentation ability*, in savant calendar calculation?

Weak central coherence and the ability to calculate dates. Weak central coherence is suggested to result in the enhanced tendency to process local as opposed to global features. In some situations, the ability to resist the predominance of the whole may be an advantageous form of processing. For example, autistic individuals outperform normal and mentally handicapped controls on tests which require the location of a geometric shape which is embedded within a globally meaningful picture (Shah and Frith, 1983). In certain situations, such as the block design test which is regarded as an islet of ability for individuals with autism, the component pieces which have been extracted are required to be reconstituted to form a structured whole. In this case the impetus to recombine the local parts to form a whole follows from the demands and instructions of the test. However, there may be other situations in which this process occurs spontaneously, or non-strategically. Specifically, it is suggested that *the reconstitution of individual fragments to form a structured whole may well underlie the development of a modular savant ability*. Initially, the subject displays the autistic tendency to extract isolated, fragmentary information. However, these fragments are eventually reformulated to constitute an ordered, interrelated whole. With the calendar, the initial information extracted may be fragmentary. In this way, knowledge begins to form from the processing of isolated dates. Through continuous exposure to examples of dates, gathered from various sources such as an interest in birthdays, reading books, access to diaries, these individuals are also exposed to examples of calendar regularities and repetitions. For example, taking an interest in the current weekday and date would provide exposure to weekly/seven day repetitions, i.e. every eighth date falls on the same weekday. Exposure to the examples of dates and calendar regularities would then facilitate the *recombination* of knowledge, with date information continuing to be integrated within the knowledge store. In turn, the knowledge base evolves to mirror the structure of the calendar. As the present experiments have shown, savant knowledge is organized to reflect the structural relationships between dates. This reformulation of knowledge to reflect the structure of the calendar would then give rise to the use of rules, even though the rules may never have been consciously extracted. Finally, the use of calendar structure and rules permits the knowledge base to *generalise* to new dates, for which the corresponding calendars have never been directly studied. Thus, the knowledge system is able to produce weekdays to questions concerning dates which were never explicitly processed or deliberately memorised by the savant. This proposed sequence of stages in the acquisition of calendrical ability by an individual with autism is depicted below in Figure 6.2. Importantly, this view of the development of savant calendar knowledge not only integrates the evidence concerning the information processing tendencies of individuals with autism, it is also consistent with Norris' (1990) connectionist model. Calendar savants are not suggested to extract calendar rules directly. Rather, learning is instance-based, derived from many examples of individual dates, with the knowledge base reorganizing itself to reflect the structural patterns detected within the incoming input. As Norris suggests, it may therefore be possible to build a "connectionist idiot-savant calendar calculator". Within this connectionist view of savant calendar knowledge, the "input" to the system (i.e. the date question) is processed explicitly, as is the "output" of the knowledge base (i.e. the weekday answer). However, the "calculations", specifically the activation of the mappings between dates, are inaccessible to conscious inspection.

There are a number of further points which should be noted regarding the above conceptualisation of savant knowledge. First, as reported in Chapter 3, a correlation was also obtained between the savants' performance on the Wechsler object assembly subtest and their calculation spans. The object assembly task requires subjects to combine individual pieces of a puzzle to form a globally meaningful shape (e.g. hand, elephant). In this way, the test measures the ability to reconstitute individual parts to form a whole, the process which is above suggested to underlie savant ability. Second, what constitutes a "fragment" of date information initially extracted from the calendar, may vary from subject to subject. For example, for some savants it may be a single day-date pairing. For others, such as H.P., the unit may correspond to a mini-regularity. Indeed, the size of the extracted unit of information may well relate to IQ. However, the critical point is that these individual units of date information are processed as fragments and not as parts of a whole (Frith, 1989). Finally, it may be precisely because the autistic savant does not process the calendar as a whole, that he continues to sustain an interest in date information. Most of us, when presented with a 100 year calendar for example, would be daunted by the sheer size and extent of all the numerical information and would consequently never devote the time to acquiring and learning such a vast array of items.

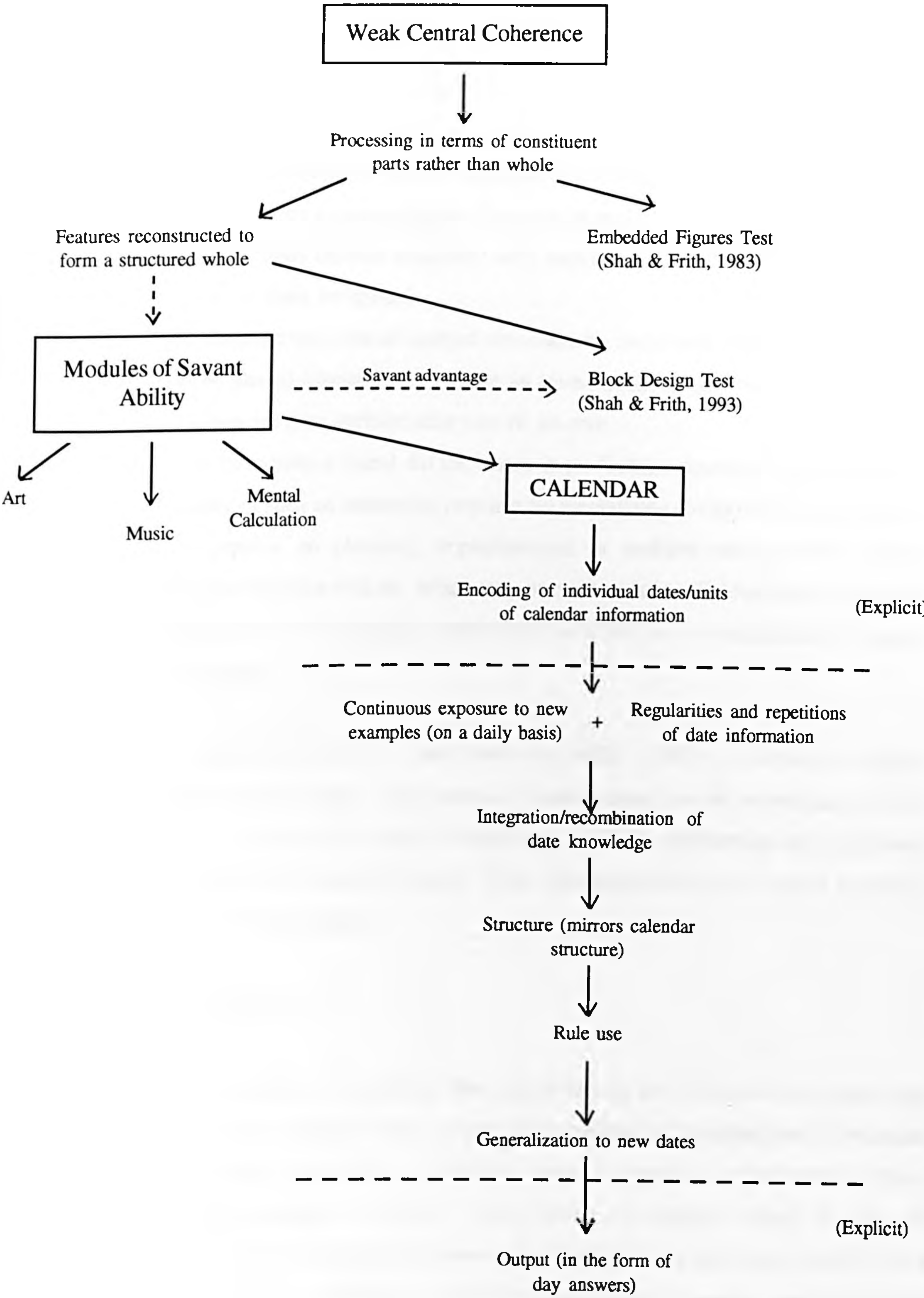

Figure 6.2. *One route to becoming an autistic savant calendrical calculator*

Why the calendar? The final point of discussion concerns the mysterious appeal of the calendar. Why are so many individuals with autism fascinated by the calendar and general information relating to dates? As has been noted, the numerical content of calendars may attract attention. A number of further suggestions are offered below:

- days and dates impose a degree of regularity and structure on an individual's life and thus readily become associated with routines, e.g. if the day is Monday, then it must be pasta for dinner.
- the calendar is a mass of internal consistencies and constant repetitions. It would thus be almost impossible to impose an idiosyncratic structure on the calendar, it possesses such an intrinsic structure of its own.
- it is essentially a literal device, there is no "hidden meaning" in the calendar. Mastery of such an instrument requires no mentalizing ability/metarepresentation.
- it requires no planning, organizational or problem-solving ability. Thus, executive function deficits, which may prevent autistic individuals from becoming "chess savants" for example, would have no effect on the acquisition of calendar knowledge.

The final suggestion concerns a point made by Miller (1989) in relation to musical savants. He notes that music, like chess and mathematics, can be viewed as a closed system, with its own internal rules and regularities. Such a system can be appreciated without reference to a broader context. This conceptualisation of a closed system is especially true of the calendar.

General Conclusions

The present investigation has revealed that underlying the skill of savant date calculation is a talent-specific knowledge base, organized according to the principles of calendar structure. Moreover, the ability to calculate dates is suggested to be based on these structured representations in LTM. The calendar is perhaps unique in that an internalization of the relationships between its individual components can give rise to a generative process, i.e. knowledge of how one date relates to another date permits the generation of the appropriate weekday. In this way, the knowledge *is* the ability. Importantly, this conceptualisation of the skill accommodates additional findings from the present investigation as well as from the existing literature. It accounts for the fact that an individual can date calculate without being able to perform basic arithmetic; savants can use calendrical rules and regularities without being consciously aware of these rules; initial acquisition of the calendar may be facilitated by a local rather than global processing strategy, thus accounting for the frequency of date calculation amongst the autistic population and finally, the non-conscious acquisition of calendar knowledge suggests that deliberate practice does not constitute a fundamental component of the skill. It would thus appear that an investigation of the memory ability underlying savant calendar calculation has greatly increased our understanding of this intriguing ability.

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Appendices

TABLE 1. Intercorrelation matrix for savants' performance on IQ measures, digit span tests, calculation speed and range.

	Wechsler Intelligence Scales Subtests (scaled scores)				IQ measures		Digit span length		
Subject	Vocab	Comp	BD	OA	P.P.V.T.	Ravens	Forwards	Backwards	Calculation Speed
Comp	-.29								
BD	.85	.07							
OA	.94***	-.13	.85**						
P.P.V.T.	.72*	.19	.86**	.80**					
Ravens	.76*	-.04	.92**	.82*	.90**				
Digit Forwards	.57	.40	.70*	.72*	.79**	.59			
Digit Backwards	.67*	.03	.42	.71*	.45	.43	.56		
Calculation Speed	.02	-.45	-.14	-.14	-.42	.03	-.64*	.07	
Calculation Range	.89**	-.23	.76*	.74*	.54	.52	.54	.41	-.07

* $p<.05$, ** $p<.01$, *** $p<.001$

APPENDIX A.

Table 1. ***Experiment 1: Subjects' verbal IQ's and chronological age (C.A.)***

Savants			Controls		
Subject	Verbal IQ	C.A.	Subject	Verbal IQ	C.A.
H.P.	80	27.5	C.E.	81	27.8
G.C.	79	29.1	P.B.	79	28.8
R.D.	64	24.7	D.B.	67	27.8
J.B.	59	45.1	C.D.	62	46.2
J.P.	44	26.2	E.C.	44	27.1
D.K.	66	34.8	P.B.	67	35.2
M.W.	76	13.3	R.E.	78	13.8
A.T.	51	29.2	S.B.	56	28.8
Mean	64.88	28.74	Mean	66.75	29.06
SD	13.19	9.00	SD	12.74	9.17

Table 2. ***Experiment 1: Subjects' digit and word spans, forwards and backwards.***

	Digits		Words	
	Forwards	Backwards	Forwards	Backwards
Savants				
H.P.	8	7	6	4
G.C.	7	3	6	3
R.D.	4	3	5	2
J.B.	6	4	4	3
J.P.	5	5	4	4
D.K.	7	3	4	2
M.W.	6	5	4	3
A.T.	4	2	4	0
Mean	5.88	4.00	4.63	2.63
SD	1.46	1.60	0.92	1.30
Controls				
C.E.	5	2	4	2
P.B.	6	6	5	5
D.B.	5	5	5	5
C.D.	3	3	3	2
E.C.	4	0	3	0
P.B.	4	0	3	0
R.E.	7	3	6	3
S.B.	6	0	5	0
Mean	5.00	2.38	4.25	2.13
SD	1.31	2.33	1.17	2.10

Table 3. ***Experiment 1: Subjects' raw scores on WISC-III arithmetic subtest (out of a total of 30).***

Savants		Controls	
Subject		Subject	
H.P.	19	C.E.	14
G.C.	16	P.B.	19
R.D.	8	D.B.	10
J.B.	10	C.D.	6
J.P.	10	E.C.	7
D.K.	8	P.B.	8
M.W.	14	R.E.	10
A.T.	1	S.B.	1
Mean	10.75	Mean	9.38
SD	(5.57)	SD	(5.40)

Table 4. *Experiment 2: List of words presented for recall.*

snow	path	king	sky
leg	dress	door	bed
fruit	salt	boat	queen
gate	hand	foot	wall
bag	girl	sun	chair
car	ring	cat	fish
wood	cloud	hair	hill
milk	box	stone	shop

Table 5. *Experiment 2: Lists of 20th century years presented for recall.*

1952	1941	1972	1911
1918	1976	1921	1938
1990	1933	1968	1926
1937	1914	1917	1953
1946	1982	1934	1947
1925	1920	1956	1989
1964	1958	1943	1970
1979	1967	1985	1961

Table 6. ***Experiment 2: Lists of mixed years presented for recall.***

1768	1843	1963	1727
1997	1912	1791	1852
1807	2086	1814	2061
1713	1732	2035	1878
2049	2048	1998	2085
1952	1785	1709	1996
2010	1891	1825	1914
1885	1994	2077	1743

Table 7. *Experiment 2: Number of items recalled by subjects in all three conditions (maximum score = 32).*

	Words	20th Century Years	Mixed Years
Savants			
H.P.	13	19	16
G.C.	16	17	15
R.D.	13	12	12
J.B.	6	17	13
J.P.	10	15	12
D.K.	16	20	12
M.W.	14	16	15
A.T.	0	0	0
Mean	11.00	14.50	11.88
SD	5.53	6.35	5.06
Controls			
C.E.	12	6	2
P.B.	15	8	4
D.B.	20	8	2
C.D.	9	5	2
E.C.	8	1	0
P.B.	9	8	3
R.E.	0	0	0
S.B.	8	1	1
Mean	10.13	4.63	1.75
SD	5.84	3.46	1.39

Table 8. ***Experiment 2: Number of years recalled from each century in mixed year condition by savant group (maximum = 8).***

Subject	Century				Total
	18th	19th	20th	21st	
H.P.	1	4	8	3	16
G.C.	0	4	7	4	15
R.D.	1	2	8	1	12
J.B.	1	2	8	2	13
J.P.	0	3	8	1	12
D.K.	1	3	6	2	12
M.W.	0	3	8	4	15
A.T.	0	0	0	0	0
Total	4	21	53	17	95

Table 9. ***Number of years recalled by control subjects from each century within mixed year condition (maximum = 8).***

	Century				
Subject	18th	19th	20th	21st	Total
C.E.	0	0	2	0	2
P.B.	0	2	0	2	4
D.B.	1	1	0	0	2
C.D.	1	1	0	0	2
E.C.	0	0	0	0	0
P.B.	1	1	0	1	3
R.E.	0	0	0	0	0
S.B.	0	0	1	0	1
Total	3	5	3	3	14

APPENDIX B.

Table 1. ***Order of list presentation in Experiment 4.***

Subject	List order	Counterbalancing design
G.C.	1 2 4 3	A B B A
H.P.	2 1 3 4	B A A B
R.D.	3 4 2 1	A B B A
J.B.	4 1 3 2	B A A B
J.P	1 4 2 3	A B B A
D.K.	2 3 1 4	B A A B
P.M.	3 2 4 1	A B B A
P.E.	4 3 1 2	B A A B