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The skills and methods of calendrical savants

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Author Notes

These studies were planned and largely conducted with Neil O'Connor who died in October 1997. We remember him with great affection. The sample of calendrical savants came from the pool built up by Neil and Professor Beate Hermelin. We thank Professor Hermelin and Dr Lisa Heavey for introducing us to two more. We thank an anonymous benefactor, the University of London Central Research Fund, and the University of London Tregaskis Bequest for financial support. We thank the savants, their families and carers for their co-operation.

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Abstract

Calendrical savants are people with considerable intellectual difficulties that have the unusual ability to name the weekdays for dates in the past and sometimes the future. Three criteria are proposed to distinguish savants whose skill depends on memorization from those who calculate: range of years, consistent deviation from the Gregorian calendar, and variation in latency with remoteness from the present. A study of 10 calendrical savants showed 5 met one or both of the criteria concerning range and deviation and 9 met the third criterion. The second study assessed their arithmetical abilities using tests of mental and written arithmetic. This broadly validated the attribution of calculation as the basis for some savants' skills. The results are discussed in relation to views that calendrical savants imply the existence of a modular mathematical intelligence or unconscious integer arithmetic.

The skills and methods of calendrical savants

Calendrical savants have the unusual ability to name the weekdays corresponding to dates despite considerable intellectual disabilities, mental illness or both. Attempts to evaluate this ability have been hampered by uncertainty over the basis of their skill. Without determining how they do it, the implications of their skills for theories of intelligence and cognition remain uncertain.

Researchers have principally considered three bases for the skill: internalization of formulae or tables, retrieval of memorized dates or calendars, and calculation in conjunction with remembered dates and calendrical regularities, such as solving the 1st January 2430 by subtracting 428 from 2430 and retrieving the weekday for 1st January 2002. Although numerous formulae and tables for determining the weekdays for dates have been published since Lewis Carroll's paper in Nature (1887), researchers have generally believed calendrical savants do not use internalized formulae (Ericsson & Faivre, 1988; Hill, 1978: Howe, 1989; O'Connor & Hermelin, 1984). They have rejected internalized formulae as a basis for savants' skills because to learn and use these formulae requires competence in reading and arithmetic beyond the savants' abilities and furthermore no savant is known to have encountered the description of such a method or been taught how to use it. Ericsson & Faivre (1988) also proposed that the ability to name years with particular calendrical features such as having the first of September on a Sunday is incompatible with mathematical methods.

Memorization of day-date combinations, ordinary or even perpetual calendars could explain the skills of some calendrical savants (Hill, 1978; Howe & Smith, 1988; Roberts, 1945: Young & Nettelbeck, 1994). When a date is presented they simply retrieve the corresponding weekday from their memory. Such memorization might result from prolonged and intensive scrutiny rather than intentional learning: several savants are known to spend a lot of time studying calendars. Although intensive study of calendars makes memorization more plausible, it is hardly conclusive: the product of studying calendars might be the development of a method for determining day-date correspondences rather than merely knowledge of particular combinations.

Some savants have provided evidence of memorizing calendars by naming the colours of the dates on calendars (Howe & Smith, 1988; Roberts, 1945) or the code numbers for years in perpetual calendars (Young & Nettelbeck, 1994). Memorization of perpetual calendars would be more economical than memorizing each year separately as it would require memorizing the seven leap year and seven nonleap year templates differing in the weekday for the first of January and memorizing the associations between years and their templates for a given range. It would not provide a basis for answering date questions from years outside this range.

Apart from their study of calendars, three other features of calendrical savants are considered to implicate retrieval of remembered day-date combinations rather than calculations involving remembered dates and calendrical regularities as the basis of the skill: speed of response, inability to explain their methods, and arithmetical incompetence. All of these are debatable.

Some calendrical savants answer date questions very quickly: the savant studied by Hill (1975) had a median latency of 3.7 seconds and the means for those studied by Young & Nettelbeck (1994) for 20th century dates were less than 10 seconds. Most of the savants (6 out of 8) studied by O'Connor & Hermelin (1984) took less than 5 seconds to answer questions about some years. Rapid responding could reflect recall but, as O'Connor & Hermelin (1984) suggest, it could also result from the skill becoming automated through being highly practised. Relevant to this is the case of a graduate student who learnt to answer date questions (Ericsson & Faivre, 1988). Originally he had tables available but after several sessions he was able to dispense with the tables and his latency continued to decrease. By the final session his latency for dates in the period from 1600 to 2000 was about 4 seconds. However, a graduate student is probably rather different from most calendrical savants in terms of intelligence; Nettelbeck (1999) questions the plausibility of the automatisation account for people with low g.

Researchers have noted that calendrical savants are rarely able to describe the processes they are using to solve date problems (Ericsson & Faivre, 1988; Howe & Smith, 1988; O'Connor, 1989). If they are unaware of steps in their problem solving, then conscious calculation seems unlikely to be involved; even young children can make valid reports of how they solve arithmetic problems (Siegler, 1987). The inability of savants to articulate their methods has been taken as evidence that they have no method other than reliance on memory. However other explanations are possible. The inability to verbalize their method may stem from general difficulties in communication, the degree of automatisation their skill has reached, or because they have acquired their procedure unconsciously (Spitz, 1995). It may even reflect an unwillingness to give away their trade secret (Roberts, 1945).

Some reports suggest calendrical savants have grave difficulties with even simple arithmetic (Hill, 1975; Horwitz, Kestenbaum, Person, & Jarvik, 1965; Roberts, 1945; Young & Nettelbeck, 1994). Roberts (1945) described a savant who was apparently limited to single digit arithmetic. Horwitz et al. (1965) claimed the twins they studied were unable to do even this. The savant studied by Hill (1975) used his fingers on all addition problems with a total greater than ten. He could only solve single digit subtraction problems if they were presented in a concrete form, e.g. "if you have three apples and you give me two, how many do you have left?". The savants studied by Young & Nettelbeck (1994) had WAIS-R Arithmetic sub-test scores of 2, 4, and 7.

Limitations in arithmetic may seem to rule out calculation as being involved in their skills. However, whether the savants' arithmetic skills are as limited as they appear is questionable. Horwitz, Deming, & Winter (1969) subsequently revised their views of one twin, claiming he could subtract multiples of 400 quickly and accurately from any given year. Indeed it was these twins that Sacks (1985) found to be swapping six-figure prime numbers with each other. Also, the savant studied by Ho, Tsang, & Ho (1991) was very successful on all arithmetic problems in the Stanford Diagnostic Mathematical Test but performed poorly on the WAIS Arithmetic sub-test. They concluded his difficulty on the latter was in understanding the story contexts for the problems. The Stanford test just required manipulations of numbers. Howe & Smith (1988) reported another kind of variability in arithmetical ability. The savant they studied could solve arithmetical problems posed in calendrical terms, e.g. " If I was born in 1841, how old would I be in 2302?", that he could not solve using more customary formats.

More convincing evidence that a particular savant's skill is just based on memorization is an inability to answer questions outside the range of the calendars studied. Charlie, one of the twins studied by Horwitz et al. (1969), performed at chance level outside the range of 1600 to 2000. Two calendrical savants studied by Young & Nettelbeck (1994) responded at chance level for dates outside 1900-2099.

Conversely, savants whose range exceeds perpetual calendars cannot be basing their answers just on memorized associations between years and templates: George, the other twin studied by Horwitz et al. (1969), answered date questions for years from 0 to 40,400. Horwitz et al. (1969) proposed that George knew that the Georgian calendar has a 400-year regularity as well as the years 1900 to 2300. He solved dates outside 1900 to 2300 by subtracting or adding multiples of 400 to find a corresponding year within that range. This method ignores the difference between the Gregorian and Julian calendars and the dropping of days when the

Gregorian calendar was adopted: Great Britain and her Dominions made the change to the Gregorian calendar in 1752 and omitted the days from 3rd to 13th September. Allowing for this, George was accurate for dates in the pre-Gregorian past (Horwitz et al., 1965). Indeed false extrapolations of calendrical regularities are another persuasive indication that the savant's skill is not just based on memorization. The savant studied by Ho et al. (1991) falsely extrapolated the 28 year regularity to derive a 700 year regularity and used this to derive 20th century dates he believed matched more remote dates. What makes this a false extrapolation is that years separated by multiples of 28 are only calendrically identical when the numbers of intervening nonleap years and leap years are exact multiples of seven. This does not obtain when the period includes century years, such as 1900 and 2100, which are not leap years. He was also unaware of the change from the Julian to the Gregorian calendar. Both these savants are credited with using a method based on knowledge of dates and calendrical regularities with some calculation, at least for more remote dates. In these cases, both the large range of years for which they can answer date questions and their consistent errors provide evidence that their method is not just a matter of retrieval from memory.

Some savants show reliable variation in their latency for answering date questions according to the month (Rosen, 1981) or year (Dorman, 1991; O'Connor & Hermelin, 1984). This has been taken to suggest involvement of some form of calculation. Rosen (1981) reported two calendrical savants who were quickest on December dates. He proposed they worked backwards from their knowledge of what day December 1st fell on in a particular year to determine the weekday for dates in other months in that year. The extra steps taken to solve date problems from other months were considered to account for the difference between latencies for December dates and those in other months. Although O'Connor & Hermelin (1984) and Dorman (1991) did not replicate the variation in latency with month, they did find that response time increased with distance in years from the present. This was more marked for future years than for past years. Such variation might result from increasing use of calculation with more remote years. These calculations would exploit calendrical regularities (Hermelin & O'Connor, 1986).

One such regularity is the one year one day rule: the same date in succeeding years falls on succeeding days unless separated by February 29th. From the fact that July 1st 2001 is a Sunday, one can by repeatedly applying this rule deduce that July 1st will fall on a Monday in 2002, a Tuesday in 2003, a Thursday in 2005 and so on. Assuming that savants are more likely to know recent day-date combinations, the increase in latency with increasing remoteness from the present might reflect the number of times the savant applies the one year one day rule to reach the target date.

Hermelin & O'Connor (1986) found some savants were faster when asked about a year 28 years in the future than when the target year was 18 years in the future. They attributed this to knowledge of the 28-year regularity and suggested that calendrical savants may switch between regularities in determining the answers for more remote dates. Such switching would tend to prevent the relationship between remoteness from the present and latency from being monotonic.

In general then, three features of the calendrical savant skill indicate a method based on calculation in conjunction with remembered dates: a range greater than that of perpetual calendars, consistent deviations from the calendar, and some variation in latency with remoteness from the present. Expt 1 establishes which calendrical savants show these features. As this method requires some mental arithmetic ability, it should be possible to find evidence of such ability in those savants who are credited with using it. Expt 2 investigates the arithmetical ability of the savants.

Experiment 1

Method

Participants. The participants were 10 calendrical savants. All but two (JB, BL) were male. Whereas eight had received a diagnosis of autism, two (JB, PM) had received no diagnosis beyond non-specific learning difficulties. Their full scale WAIS IQs, originally reported in O'Connor, Cowan, & Samella (2000), the years when their skills were first noticed and their ages at this time are presented in Table 1. Unfortunately no precise information is available for the emergence of JB's skills.

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Insert table 1 about here

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Procedure. Each savant was individually assessed over a series of sessions. For dates between 1770 and 2170, nine sets of 13 dates provided the basis for determining latencies. Questions were orally presented and savants were discouraged, if necessary, from using paper and pencil. The forms of question used were ' What day of the week was the 10th July 1968?' or ' What day of the week will be the 8th October 2024?' The sets concerned the following periods: 1772-1777, 1828-1836, 1912-1919, 1940-1947, 1968-1976, 1992-1997, 2017-2024, 2072-2080, 2157-2165. The first session comprised 20th century dates, the second session dates from the 19th and earlier part of the 21st centuries, and the third session included 18th, 22nd and the later 21st century dates. Each session took place on a different day.

To establish range for more remote future years, sets of 5 dates for each period were constructed. As well as asking the question orally, a written form of the date was presented on a sheet of paper and savants could write down intermediate steps if they wished. The fourth session presented dates from five periods: 2363-2367, 2791-2795, 3574-3578, 5191-5195 and 8374-8378. The fifth session presented dates from four periods: 12819-12823, 51275-51279, 204830-204833, and 819202-819206. The final future session featured dates from four periods: 912819- 912823, 1204830-1204834, 1819202-1819206, and 2051275-2051279.

To assess how savants would manage dates prior to the adoption of the Gregorian calendar, a set of 40 randomly generated dates between 1580 and 1752 were used. They comprised 2 dates from the 16th century, 24 from 17th, and 14 from the 18th. They were, like the remote future dates, presented both orally and in writing and writing was allowed.

Within every session the order of dates was randomized. Savants were not tested on sessions with dates beyond those they had failed to answer consistently, either by matching the Gregorian calendar or by matching a deviation from it. The criteria for consistency were five or more responses for 13 date periods and three or more consistent responses for the 5 date remote future periods. Sessions were recorded and, for the first four sessions, the intervals between the end of the question and the beginning of the response were derived.

Results

1770-2170. Two savants (JG, DM) answered as though all century years were leap years. Their responses matched the Gregorian calendar for dates in the 20th and 21st centuries but were consistently one day earlier in the 19th centuries, two days earlier in the 18th, and one day later in the 22nd. For these two savants, we only considered their responses correct if they matched this pattern.

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Insert Table 2 about here

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Table 2 shows the median correct response latencies and interquartile ranges for each savant for each period that they were above chance level. All savants performed at above chance level for the periods 1940-1947, 1968-1976, and 1992-1997 and five were above chance level for all periods in the range 1770-2170. The fastest period for each savant was typically 1968-1976 rather than the period closest to the time of testing (1992-1997). This may be because the former period was closer to the time when their skills first emerged (see Table 1). Indeed the skills of the two savants who were equally quick on both periods emerged later. To determine whether their latencies varied with years in the past, Spearman correlations were computed for each savant for dates in the recent past (1940 –1976). For those whose range extended further in the past, a second correlation was computed for all past dates in their range. Table 3 shows the results: all but BL, PE and DM were significantly slower on earlier

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dates in the recent past. Apart from JG, all the savants whose range extended further backwards were slower on more remote dates. To determine whether latency varied with year for future dates, correlations were computed using times from the periods 2017-2024 and beyond to the limit of their range for each savant. As Table 3 shows, DK, DM, and GC showed reliable increases in latency for more remote future dates but MW and HP showed no consistent trend, and JG was actually faster.

Remote future. JG was unavailable for further testing. Apart from 2363-2367, MW was above chance for all periods up to and including 8374-8378 and at chance level for more remote dates. HP has invented his own amendment to the calendar by making all years exactly divisible by 4000 not leap years. He responded consistently with his amendment up to the 12819-12823 period. DM consistently deviated for future dates as he did for the remote past. His answers exceeded chance level consistency for each period up to 204830-204833.

GC answered consistently with the Gregorian calendar for every period up to and including 2051275- 2051279.

1580-1752. The four savants differed in how they answered these questions. MW gave answers consistent with the Gregorian calendar for dates in the 16th and 17th centuries (22/26). For dates in the 18th century prior to 1740, his answer was typically the day before the Gregorian weekday (9/10). For the four later dates up to 1751, he showed no discernible pattern. HP was essentially correct in providing answers consistent with the Julian calendar on 37/40 dates. He knew when the change to the Gregorian calendar took place and what days were omitted. DM answered all 40 dates consistently in the same way as he answered other remote dates, i.e. as though all century years were leap years. GC assumed that 1700 was a leap year and did not know that days had been omitted in 1752. He answered the 18th century dates consistently with the Gregorian calendar (14/14) and for 16th and 17th century dates his answers were reliably one day later than the Gregorian weekdays (22/26).

Discussion

Three criteria were proposed to distinguish calendrical skills based on calculation from those based simply on memorization of calendars: a range exceeding that of perpetual calendars, systematic deviations from the calendar, and variation in latency with remoteness from the present. Reliable information concerning the savants' exposure to perpetual calendars is not available but it is safe to assume that none have seen ones that cover years beyond 2300. On this basis MW, HP, DM and GC all have ranges beyond perpetual calendars. They also, with the addition of JG, meet the second criterion in deviating consistently from the calendar in answering date questions. These savants would seem to have used calculations to develop their method for answering date questions. Indeed both HP and GC provided further evidence of calculation by occasionally writing down intermediate steps on remote future dates.

All the other savants, apart from BL, show variation in latency with remoteness from the present. Whether this is sufficient evidence for ruling out memorization is uncertain. The greater latencies for more remote past dates shown by JB, PM, and PE might result from these dates being less practised. Practice may result in increased strength of associations. This in turn results in reduced latencies as has been suggested for retrieval of arithmetical facts (Ashcraft, 1992; Shrager & Siegler, 1998). DK also shows variation in latency for future dates. Here differential practice is less plausible (Hermelin & O'Connor, 1986). The greater incidence of application of calendrical regularities such as the 28-year rule with more remote years might underlie the variation in latency for remote dates in the future.

So calculation is considered to contribute to the skills of some savants because of their range and deviations from the calendar (JG, MW, HP, DM, and GC) and to others by virtue of their variation in latency on future dates (DK, JG, DM, and GC). This implies they possess some arithmetical skills. These need not be very advanced: addition and subtraction of multi-digit numbers would suffice. This conflicts with previous investigations of calendrical savants that suggest severe limitations in their arithmetic (Hill, 1975; Roberts, 1945; Young & Nettelbeck, 1994). Indeed the scores of the present sample on the Arithmetic subscale of the WAIS (originally reported in O'Connor et al., 2000, reproduced in Table 4) indicate none are exceptionally proficient and several are very limited (JB, BL, PM, DK, JG, and DM). The WAIS Arithmetic test may, however, not provide a reliable guide to savant arithmetical skill: Ho et al. (1991) reported the savant they studied was markedly better at problems without story contexts than the word problems that feature in the WAIS. Also Howe & Smith (1988) described a savant who benefited from having problems set in a calendrical context. Expt 2 therefore explores the computational skills of calendrical savants using oral and written problems and includes comparison of calendrical and ordinary versions.

Experiment 2

Method

Participants. The participants were the 10 calendrical savants who took part in Expt 1.

Procedure. Each savant was individually assessed over a series of sessions.

The Graded Difficulty Arithmetic test (GDA). The aim of this test is to assess mental arithmetic. Developed by Jackson & Warrington (1986), it comprises auditorily presented multi-digit addition and subtraction problems. The test began with simple practice items (e.g. 9 + 6, 7 - 4) and continued with very easy items (e.g. 15 + 13, 19 - 7) gradually progressing to more difficult items (e.g. 244 + 129, 246 - 179). The 24 items comprised 12 additions and 12 subtractions. Correct answers had to be provided within 10 seconds for each item. Scaled scores range from 3 to 17 (Mean = 10, SD = 3).

Graded Computation and Calendrical Sums. These tests aim to establish the levels of arithmetical computation ability. The Graded Computation test (derived from Dowker, 1998) consists of sets of addition and subtraction items that identify the levels of competence in children's arithmetic. There are six levels of addition and subtraction: Level 1, single digit (e.g. 6 + 3, 8 - 4); Level 1A, single digit with carrying or borrowing (e.g. 9 + 8, 14 - 8); Level 2, two digit with no carrying or borrowing (e.g. 31 + 57, 37 - 23); Level 2A, two digit with carrying or borrowing (e.g. 33 + 49, 84 - 59); Level 3, three digit with no carrying or borrowing (e.g. 235 + 142, 894 –513); and Level 3A, three digit with carrying or borrowing (e.g. 523 + 168, 681 - 214). The test comprises four items for each level, two additions and two subtractions. Calendrical Sum items were constructed to be analogous to the Graded Computation items for Level 1A and above in terms of the number of digits in the addend or subtrahend and the necessity for carrying or borrowing. In these, the initial quantity was a four digit number described as a year and the problems were described as being about the ages of people or buildings, e.g. 1926 + 72 was posed as " When will someone born in 1926 be 72 years old?", or posed simply as being about years , e.g. for 1952 - 14, "What year came 14 years before 1952?" The Calendrical Sums test comprised twenty items, four for each level with two additions and two subtractions. Both the Graded Computation and the Calendrical Sums items are presented in writing as well as orally and may be solved either mentally or with paper and pencil. The tests began with the lowest level addition items and proceeded until both items at a particular level are failed. The order of testing was Graded Computation Addition, Calendrical Addition, Graded Computation Subtraction, and then Calendrical Subtraction.

Results

GDA. Testing was not possible with three savants as they failed the practice items. Scale scores are shown in Table 4. The savants who could be tested obtained reliably higher scores on the GDA than the WAIS Arithmetic Subscale (Wilcoxon, $T = 0$, $n = 7$, $p < .05$). Indeed MW and DM performed at ceiling on the GDA but much worse on the WAIS.

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Graded Computation and Calendrical Sums. Savants were credited with the highest level at which they succeeded on at least one of the items for a particular operation in each test. Table 5 shows the achievement of each savant. BL failed all items apart from Level 1 Graded Computation Addition. Although DK responded 'Don't know' to the calendrical items, conversation established that he knew what years he would be 44 and 75 years old. As he is unlikely to have been told this information, these answers imply he is capable of Level 2A Calendrical Addition. JG failed both Level 1A Calendrical Subtractions but in subsequent conversation was able to say how many years 1989 and 1926 were before 1997. As Table 5 shows only one savant, PM, was consistently more successful on calendrical versions of sums and half the sample succeeded at the highest level on both versions of addition and subtraction items.

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Insert Table 5 about here

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Discussion

This study assessed the mental and written arithmetic of calendrical savants to determine whether they could use a method based on calculation and whether they would be more successful on arithmetical problems set in a calendrical context. The GDA (Jackson & Warrington, 1986) tested mental arithmetic. It provided clear evidence of arithmetical competence for six calendrical savants: three demonstrated exceptional mental arithmetic skill (HP, MW and DM) and three showed average mental arithmetic skill (JB, PE, and GC). The method of answering date questions by calculations involving calendrical regularities is clearly within these savants' ability.

Incidentally, although the GDA correlates highly with the WAIS Arithmetic Subscale (Jackson & Warrington, 1986), three savants (MW, DM, and JB) were markedly more successful than their WAIS Arithmetic Subscale scores would suggest. These discrepancies are significant because they imply that the WAIS test may underestimate savants' arithmetical ability. This is consistent with Ho et al. (1991).

None of the other savants demonstrated adequate skill on the GDA. However this may not be due to absolute incompetence in arithmetic as this was a test of mental arithmetic and previous studies indicate some calendrical savants reveal greater competence when tested with problems set in calendrical contexts (Howe & Smith, 1988). Arithmetical competence and its variation with problem context were assessed in this study with the Graded Computation and Calendrical Sums tests. Unlike the GDA, problems were presented visually as well as orally, savants could use pencil and paper if they wished, and there were no constraints on the time they took to respond. These tests did elicit displays of arithmetical competence with two digit numbers from most savants but only PM benefited from problems being set in a calendrical context. The only savant who did not demonstrate competence in two-digit arithmetic was BL.

The arithmetical competence displayed by savants in the present study offers some support for the attributions of method on the basis of performance characteristics in Expt 1. Four savants were credited with a method involving calculations because their range exceeded perpetual calendars and they deviated consistently from the calendar in answering date questions from remote years (MW, HP, DM, & GC). All displayed average or exceptional mental arithmetic skill on the GDA and performed at ceiling level on Graded Computation and Calendrical Sums. Two other savants were suggested to use calculations; JG because he deviated from the calendar and DK because his latency increased when asked questions about future years. Both displayed the necessary competence but only on the Graded Computation or Calendrical Sums tests or in conversation. So these savants would appear capable of solving date questions concerning remote years by calculating their correspondence with years closer to the present.

General Discussion

This investigation has attempted to determine the basis of calendrical skills in a group of ten calendrical savants. Three characteristics were proposed to distinguish a method based on calculation from one based solely on memorization of calendars: a range exceeding perpetual calendars, consistent deviations from the Gregorian calendar, and variation in latency with remoteness from the present.

The first study revealed that several savants showed the first two characteristics and all except one showed significant variation in latency with remoteness from the present. The first two criteria unequivocally differentiate a method based on calculation from one restricted to memorization of dates, but the third is ambiguous. It could result from a greater incidence of calculation in solving questions from remoter years or it could reflect variation in practice of dates from different periods. Further research may be able to resolve this uncertainty. For example if calculations are involved in determining more remote dates but not in closer dates then performance in different periods may be differentially affected by concurrent memory tasks.

Some investigators of calendrical savants have rejected calculation on the grounds that savants have very limited arithmetical ability. The second study accordingly explored the arithmetical abilities of our sample. The results were that most are quite capable of calculation and some are exceptional in their mental arithmetic. How typical they are is uncertain but three features of the results suggest that it is easy to underestimate savants. First, some were much more successful on tests than their scores on the WAIS Arithmetic subscale would suggest. Secondly, one resembled the savant studied by Howe & Smith (1988) in showing considerably more competence when set problems in calendrical context. Finally some revealed competence in the context of conversations that they did not show during tests.

One savant who displayed little arithmetical competence showed none of the characteristics suggested to reflect a method based on calculation. Perhaps her skill is based simply on memorization of dates. Certainly her memory for calendrical information is unusual, even for calendrical savants. She has a remarkable memory for birthdays and dates of birth for relatives and acquaintances: for almost every day in a month she can name a person whose birthday falls on that date.

Whether a calendrical savant's skills derive from memory alone or from a combination of memory with calculations exploiting calendrical regularities, some retention of calendar information in long-term memory is involved (Heavey, Pring, & Hermelin, 1999). Although this retention is remarkable it does not appear to be the result of generally superior memory functioning. Heavey et al. (1999) compared calendrical savants with controls matched for age, verbal IQ and diagnosis and found that the savants were much better at recalling dates but no different from controls in recalling words. Also Cowan, O'Connor & Samella (2001) found few discrepancies between calendrical savants' IQs and their Wechsler Memory quotients.

Although the feats of calendrical savants are exceptional, they do not appear to require exceptional arithmetical skill either. These are important points for discussions of the implications of savant skills for theories of intelligence and cognition. Gardner (1983) adduced calendrical savants in support of his notion of mathematical intelligence however the analysis proposed here suggests that calendrical savants are not mathematically talented. Furthermore the idea of a single mathematical or arithmetical ability is difficult to reconcile with evidence from a wide variety of sources (Dowker, 1998).

Snyder & Mitchell (1999) proposed that mathematical savants, including calendrical savants, depend on privileged access to some previously unsuspected lower level of integer processing. They based this provocative hypothesis on several claims, notably that savants cannot articulate their methods, have difficulties with learning arithmetic, do not benefit from practice, and that some develop their abilities suddenly after an accident or illness. None of these is both well substantiated and compelling. First, as discussed earlier, there are several possible explanations of why they may not readily describe how they answer date questions. Secondly this study illustrates how the arithmetical competence of calendrical savants may be easily missed, and most revealed arithmetical competence in contexts other than answering date questions. Furthermore, the role of practice has been little studied and so firm conclusions about its importance cannot be drawn. Although an earlier study showed little change in speed by two boys over a period of two years (O'Connor & Hermelin, 1992), one of these subsequently became much faster and his range is believed to have extended considerably. Last, there is no reported case of a calendrical savant who suddenly developed their skill after an accident, illness, or brain operation.

Snyder & Mitchell (1999) attempted to explain all savant skills in terms of direct access to lower levels of information. They credited savant artists with privileged access to visual information, and savant musicians with privileged access to auditory information. Whatever the merits of their account of savant artists and musicians, it may not be fruitful to consider calendrical savants as analogous. Indeed Anderson (1992) differentiates calendrical from artistic and musical savants in his theory of intelligence.

Much remains to be learnt about calendrical savants and their extraordinary skills. For example, on the basis of their performance we have credited some with knowledge of calendrical regularities such as the one year one day rule and the 28 year rule. A separate study shows that most savants can use these regularities to answer date questions outside their range (Cowan et al., 2001). However whether they were aware of these before they started incorporating them into their method of answering date questions is unknown. Spitz (1995) suggested some may extract and use regularities before becoming aware of them and indeed this seems to happen briefly in ordinary children's arithmetic (Siegler & Stern, 1998).

Another issue concerns motivation. We know little about what disposes someone to develop this skill initially or what results in them continuing to develop it to the levels these savants display. Ericsson & Faivre (1988) suggested that the uncertainty about motivation is no different from the situation confronting cognitive psychologists seeking to explain why people develop extraordinary levels of skill in more ordinary cognitive tasks. Without such an account it is not possible to judge whether the motivation to develop this unusual skill is itself unusual.

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Table 1 WAIS IQs of calendrical savants and the years and ages when their calendrical skills were noticed

Calendrical Savant	WAIS IQ	Year	Age
JB	60	before 1983	less than 36
BL	50	1983	17
PM	58	1968	13
PE	94	1966	14
DK	74	1969	12
JG	54	1956	8
MW	82	1985	7
HP	96	1973	8
DM	52	1985	13
GC	97	1971	8

Note. The IQs are from " Calendrical Calculation and Intelligence" by N. O'Connor, R. Cowan, & K. Samella, 2000, Intelligence, 28, p. 38.

Table 2. Median correct response latencies in seconds (interquartile ranges in parentheses) for each period in the range 1770-2170

	Period								
Calendrical savant	1772-1777	1828-1836	1912-1919	1940-1947	1968-1976	1992-1997	2017-2024	2072-2080	2157-2165
JB				6.4 (8.0)	2.0 (2.0)	3.0 (3.0)			
BL				3.8 (2.4)	1.2 (2.4)	3.4 (3.7)			
PM			12.8 (51.1)	10.8 (7.2)	4.8 (3.4)	9.4 (7.7)			
PE			11.5 (7.5)	6.5 (7.6)	2.2 (2.7)	5.2 (13.9)			
DK		8.5 (8.2)	4.6 (2.7)	2.1 (1.0)	1.1 (0.5)	1.3 (1.2)	2.5 (1.8)	8.2 (7.2)	
JG	1.9 (1.4)	4.5 (4.5)	3.0 (1.7)	4.4 (4.1)	1.5 (0.7)	2.2 (0.8)	6.1 (5.9)	3.4 (2.2)	2.7 (3.2)
MW	3.3 (3.3)	4.1 (1.7)	3.2 (2.5)	2.7 (2.0)	1.7 (0.6)	1.7 (1.3)	2.5 (1.9)	2.8 (4.3)	4.0 (6.1)
HP	5.8 (7.9)	3.6 (3.8)	2.5 (4.2)	4.4 (3.3)	1.5 (1.1)	2.1 (3.3)	6.9 (10.1)	5.3 (13.6)	5.4 (9.6)
DM	4.9 (5.2)	3.8 (3.2)	1.6 (0.9)	1.0 (0.4)	0.7 (0.8)	0.7 (0.6)	1.1 (1.5)	4.1 (3.8)	8.2 (5.7)
GC	25.4 (12.3)	14.6 (21.1)	3.6 (2.4)	2.5 (2.5)	1.3 (0.7)	2.0 (1.2)	3.1 (3.5)	1.6 (2.7)	15.0 (17.8)

Table 3 Variation in latency with year – Spearman correlations

	Past		Future
Calendrical savant	1940-1976	Remote	2017- limit
JB	- .53**		
BL	- .42		
PM	- .76***	-.79***	
PE	- .40	-.59***	
DK	- .46*	-.76***	.60***
JG	- .78***	-.10	- .37*
MW	- .62***	-.44***	.09
HP	- .57**	-.44***	- .05
DM	- .13	-.76***	.78***
GC	- .74***	-.82***	.50***

* p <.05; ** p <.01; *** p <.001

Table 4 Arithmetical abilities of calendrical savants: scaled scores for WAIS Arithmetic and Graded Difficulty Arithmetic (Jackson & Warrington, 1986)

Calendrical Savant	WAIS	GDA
JB	4	9
BL	2	-
PM	3	-
PE	9	12
DK	1	3
JG	3	-
MW	8	17
HP	13	17
DM	2	17
GC	12	14

Note. The WAIS Arithmetic scaled scores are from " Calendrical Calculation and Intelligence" by N. O'Connor, R. Cowan, & K. Samella, 2000, Intelligence, 28, p. 38.

Table 5 Arithmetical abilities of calendrical savants: levels on Graded Computation (Graded C) (Dowker, 1998) and Calendrical Sums

	Addition		Subtraction	
Calendrical Savant	Graded C	Calendrical	Graded C	Calendrical
JB	3A	2A	1A	2A
BL	1	-	-	-
PM	1A	2A	1	2A
PE	3A	3A	3A	3A
DK	1A	(2A)[a]	1A	-
JG	2	2A	2A	(2)[a]
MW	3A	3A	3A	3A
HP	3A	3A	3A	3A
DM	3A	3A	3A	3A
GC	3A	3A	3A	3A

Note. Levels correspond to highest arithmetical competence: 1 is success limited to single digit addition or subtraction with no carrying or borrowing, 1A is single digit addition or subtraction involving carrying or borrowing, 2 is two digit addition and subtraction with no carrying or borrowing, 2A is two digit addition and subtraction involving carrying or borrowing, 3A is three digit addition and subtraction involving carrying or borrowing

[a] Competence revealed only in conversation