# The development of calendrical skills

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Running Head: Calendrical Calculators

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Abstract

Calendrical calculation is the unusual ability to name days of the week for dates in the past and sometimes the future. Previous investigations of this skill have concerned savants, people with pervasive developmental disorders or general intellectual impairment. This research has yielded a hypothesis about how calendrical skills develop but no direct evidence. This study attempts to learn about the development of savant skills by investigating the development of calendrical skills in two boys (aged 5 and 6) along with more general cognitive and social assessments. Consistent with the hypothesis, they initially demonstrated knowledge of regularities but limited range and accuracy in answering date questions and they were slower than many adult savants. At follow up, neither had improved their calendrical skills and they were less willing to answer date questions. Possibly this is because, unlike savants, they had developed interests more commonly shared by their peers and they now received praise for more conventional achievements.

# The development of calendrical skills

The ability to name weekdays corresponding to dates is a skill rarely found in normally functioning people. However, it is one of the more common skills shown by savants, people who show extraordinary levels of skill despite pervasive developmental disorders or general intellectual impairment (Hermelin, 2001; Miller, 1999; Nettelbeck, 1999; Treffert, 1989). How and why they acquire this ability remains uncertain. This paper reports a study of two young children that provides suggestive evidence on how and why calendrical skill develops.

Memorization of day-date combinations is the simplest explanation of how this skill develops. This is the most likely explanation for those savants whose range of years is limited to those they have experienced or seen calendars for (Young & Nettelbeck, 1994). However, some savants have much greater ranges and others show systematic deviations from the calendar and so memorization alone cannot explain their proficiency (Cowan, O'Connor, & Samella, 2003).

One hypothesis is that these savants develop their skills by discovering calendrical regularities. They then construct a method for answering date questions by using the regularities in conjunction with memory for specific day-date combinations and mental arithmetic. Initially slow and limited to a few years, they become faster with practice and increase their range as their knowledge of specific dates and regularities expands. Several findings support this: adult calendrical savants know and use calendrical regularities (Cowan, O'Connor, & Samella, 2001; Hermelin & O'Connor, 1986; Ho, Tsang, & Ho, 1991; O'Connor & Hermelin, 1984), show superior recall of dates (Heavey, Pring, & Hermelin, 1999), are proficient in mental arithmetic (Cowan et al., 2003), and that range of years correlates with knowledge of regularities (Cowan et al., 2001). In addition, some savants make consistent errors and these can be explained by the use of false regularities: the errors on remote dates made by Kit (a case study reported by Ho et al., 1991) were consistent with his

false belief that the calendar repeats every 700 years. Similarly, false regularities were the most likely cause of the consistent errors for previous centuries made by two savants studied by O'Connor, Cowan, & Samella (2000).

Direct evidence, however, of calendrical skills developing as hypothesised is missing. O'Connor and Hermelin (1992) tracked two 10-year-old boys, both with IQs of 90, for 18 months but neither improved substantially. However, they had become interested in calendars several years before and so may have already extensively practised and developed their expertise. Their levels of skill contrasted markedly: one explicitly stated the 28-year regularity, had a range of at least 50 years and was already faster than several adult savants. The other became slower and was much more distractible. The more able calculator had been diagnosed as autistic. As a teenager, he took part in the studies by O'Connor et al. (2000) and Cowan et al. (2003). By then, he had become substantially faster and his range exceeded 6000 years. Now in his twenties he continues to have social difficulties and has never had paid employment. Like other calendrical savants, his calendrical skills are his most notable achievement.

The present study investigates the hypothesis of how savants develop calendrical skills by studying the changes in date skills of two boys who were first seen before they were 7. Two years later, we reassessed their calendrical skills and investigated personal characteristics that have been linked with calendrical calculation, namely arithmetic ability, and other savant skills, namely difficulties in social relationships and obsessive preoccupations: O'Connor and Hermelin (1991) found savants showed more obsessional and repetitive behaviours than controls matched for IQ and diagnosis.

One of the boys to be described was reported to have exceptional reading skills. Research has identified two forms of exceptional reading ability: hyperlexia (Healy, 1982; Jackson & Coltheart, 2001) and precocious readers (Stainthorp & Hughes, 1999). Both

groups show word reading accuracy at least two years above their mental age and are skilled at reading non-words. They differ in their reading comprehension, which is typically limited in children with hyperlexia but advanced for precocious readers, though not as advanced as their reading accuracy. Precocious readers also show advanced receptive vocabulary, typically two years above chronological age (Stainthorp & Hughes, 1999). Verification of exceptional reading skills will be obtained from performance on standardised reading, vocabulary, and non-word reading tests. Comparing accuracy with comprehension will allow discrimination of hyperlexia from precocious reading. Hyperlexia but not precocious reading has been reported in autistic savants (O'Connor & Hermelin, 1994).

## Method

### Participants

JF was 5 years 7 months and attending a mainstream school when first seen. He is the elder of two children with an 18 months younger sister. He had an early conductive hearing loss, which was resolved after insertion of grommets at age 3. Speech was delayed until this point. He was reported to show good concentration. He appeared to have both good number and letter recognition from about 18 months, was recognising words at 3 and reading sentences at 4 years. Number recognition appeared to be more spontaneous but he was taught the letters directly at home. He is achieving well in school.

He showed a degree of tantrum behaviour that was often related to the disruption of routines. This disappeared when speech emerged and the hearing loss was resolved. He is not a risk taker but weighs up the situation before undertaking new activities. Socially he is competitive with his sister but does play amicably with her. He also plays successfully with friends who visit. He is not very good at drawing and construction but is good with the video and computer games. Football and computer games emerge as major areas of interest and he regularly attends matches with his father.

His fascination with numbers began at an early age and remains. He watched Sesame Street with the Count character. He learned to tell the time from observing LED digital clocks. He is also sensitive to numbers in the environment such as car registrations, house numbers, people's birth dates, supermarket receipts and statistics from television game shows. His memory for these is remarkable. The family play competitive board games and he particularly likes those with numbers.

He has a rich literacy environment in the home. His mother read to him everyday from babyhood. He enjoys browsing through encyclopaedias and dictionaries. When last interviewed, his favourite reading was Harry Potter and the Goosebumps series.

CF was 6 years 11 months and attending a mainstream school when first seen. He is the youngest of three offspring having a brother and sister who were both teenagers when the interview took place. He has a significant visual impairment in one eye and wears correction spectacles. His parents felt that this had reduced his physical activity. His concentration skills were reported to be very good. There was no evidence of exceptionally early number or letter recognition and no direct teaching of these took place in the home prior to school. His teacher considered him to be advanced in science but was concerned about his speed of working.

There was no reported evidence of tantrum behaviour or a requirement for strict routines to be observed. At an early age, he went through an extended phase of pretending to be an animal and often responded with the appropriate animal noise rather than language. He is not a risk taker. He plays happily with friends but is also content to be on his own. He is learning to play the violin and piano. He is a good draftsman and likes drawing cartoon characters and maps. He is very interested in cars and planes and has a detailed knowledge of their statistics memorised from game cards. Games did not feature largely in the home, though he likes playing monopoly.

He watched Sesame Street but his parents did not report any particular fascination with numbers, other than his calendrical calculation ability, which they noticed when he was 6. He had a specific interest in dates rather than numbers *per se*, although maths and science are his favourite school subjects.

He was not an early reader but learned easily when taught in school. He enjoyed reading non-fiction and humorous history books.

Tasks and tests

Calendrical skills. Range was assessed with orally presented dates. Speed and accuracy in answering date questions was assessed initially with a computer-presented task with dates from the years 1997-1999. At follow up, we added items to cover 1997-2002. To assess knowledge of calendrical regularities we used a test given to a sample of adult calendrical savants (Cowan et al., 2001). This assessed knowledge of regularities within a year, the one year, one day rule, and the 28-year rule. Ability to nominate calendrically similar years was tested as in O'Connor et al. (2000).

Cognitive profile: Intelligence and Arithmetic. Intelligence was assessed with the third UK edition of the Wechsler Intelligence Scale for Children (WISC III$^{UK}$, Wechsler, 1992) and arithmetic ability with the Wechsler Objective Numerical Dimensions (WOND, Rust, 1995).

Cognitive profile: Reading, Vocabulary, and Phonological Abilities. To assess reading ability we used the Wechsler Objective Reading Dimensions (WORD, Wechsler, 1993), and the second revised British edition of the Neale Analysis of Reading Ability (NARA II, Neale, 1997). Receptive vocabulary was assessed with the second edition of the British Picture Vocabulary Scale (BPVS II, Dunn, Dunn, Whetton, & Burley, 1997) and phonological abilities with the Phonological Abilities Battery (PhAB, Frederickson, Frith, & Reason, 1997).

Social, Emotional and Behavioural Profile. To establish whether either showed unusual characteristics we asked their mothers to complete the parent version of the Strengths and

Difficulties Questionnaire (SDQ, Goodman, 1997). This questionnaire is sensitive in detecting emotional and behavioural problems (Goodman, Ford, Simmons, Gatward, & Meltzer, 2000; Mathai, Anderson, & Bourne, 2002). It asks about 25 attributes, and requires a rating of the child for each attribute on a 3-point scale. The attributes are divided between 5 scales of 5 items: 4 of these concern difficulties (hyperactivity/inattention, emotional symptoms, conduct problems, and peer relationship problems) and the other assesses strength in prosocial behaviour. The scores for the areas of difficulty are summed to generate a total difficulties score. In addition, items elicit the parent's view of whether their child has difficulties and asks about their severity, chronicity, and impact on the child and the family.

### Procedure

All assessments took place over several sessions at the boys' homes. The calendrical tasks were administered during the initial visits and the follow-up visits. The other tests, interviews, and questionnaires were conducted during the follow-up sessions.

## Results

### Initial calendrical skills

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Insert Table 1 about here

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Neither boy successfully answered the oral questions that covered a range of 10 years and they had difficulties remembering the dates. Both were above chance level (ps < .05) on the computer-presented date verification task but they were slow. As Table 1 shows, their ranges are substantially below any adult calendrical savant studied by O'Connor et al. (2001). Their accuracies are also inferior and they are slower than most adults. In contrast, as Table 1 also shows, both boys demonstrated knowledge of regularities comparable with adult savants.

In addition, both nominated calendrically similar years but JF made a substantial number of errors and was below the least successful adult savant.

Calendrical skills at follow up

As Table 1 shows, two years later neither boy had improved substantially in any aspect of calendrical skill. JF was faster but less accurate and CF had declined in both accuracy and speed. Both were, however, still better than chance. Their knowledge of regularities had declined but was still comparable to the adults. JF's ability to nominate calendrically similar years had plummeted: he now wrongly believed that years are identical if they are seven years apart. CF's ability was still within the adult savant range and he had correctly discovered that two nonleap years 11 years apart are the same.

Cognitive profile: Intelligence and Arithmetic

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Insert Table 2 about here

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The scaled scores and IQs are shown in Table 2. JF has an average IQ but a very odd profile. Comprehension and Picture Arrangement tap implicit social skills that people with autistic spectrum disorders find very difficult and he scores poorly on these. CF shows the pattern of a highly able child with average scores on only two subtests, Digit Span and Coding. Both are frequently low in dyslexic individuals. Both boys were superior on the arithmetic subtest of the WISC and, consistent with this, both were substantially above average on the WOND. JF achieved WOND scores that were much greater than those predicted from his IQ (predicted-achievement method, all discrepancies $\underline{p}s < .01$, Rust, 1995). JF is therefore extraordinarily able in arithmetic and very much better than his general IQ would suggest. As CF's IQ is much higher, his predicted WOND scores are higher and no

discrepancies are significant. Therefore, although CF is markedly above average in arithmetic this is in keeping with his general IQ.

Cognitive profile: Reading, Vocabulary and Phonological Abilities

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Insert Table 3 about here

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As Table 3 shows, both standardized reading tests (WORD, NARA II) and the PhAB identify JF as an exceptional reader. His WORD Basic Reading, a measure of reading accuracy, and Spelling scores were very considerably higher than those predicted from his IQ. His NARA II reading accuracy age is almost three years higher than his chronological age (7:06). Estimates of his reading comprehension vary but both suggest it is substantially lower than his reading accuracy. So hyperlexia remains a possibility despite comprehension estimated as consistent with his chronological age and general ability according to WORD, and as about one and a half years above his chronological age, according to NARA II.

JF's above-average scores on several subtests of the PhAB, and in particular his performance on non-word reading, are consistent with him being an exceptional reader, with well developed decoding strategy and sublexical route to reading, and a generally high level of phonological awareness. The only discrepancy in the pattern of high phonological abilities arises from his performance on the alliteration tasks.

CF presents a very different profile from JF. Consistent with his pattern of performance on the WISC, he shows several characteristics of dyslexia: his reading abilities are below what would be consistent with his IQ and receptive vocabulary as indicated by his BPVS II score. On the WORD, he performed at a level lower than expected from his IQ on every subtest but only in the case of Spelling, is the discrepancy significant ($p < .05$). CF's NARA II scores are consistent in indicating a problematic discrepancy with his general ability: his reading

comprehension is only roughly in line with his chronological age and his reading accuracy is somewhat lower. Further indications of dyslexia are the poor phonological abilities shown by his performance on the PhAB tests, particularly naming speed.

Social, Emotional and Behavioural profile

Table 4 shows the ratings of the boys on the SDQ. JF has a borderline rating on Peer problems and an abnormal rating on Conduct Problems. CF has no difficulties. Neither child was judged to have difficulties that substantially affect them. Both boys score within the normal range for Prosocial Behaviour. These data indicate psychiatric disorder is unlikely in either child but JF might need later reassessment to determine whether his symptoms had progressed or resolved (Goodman et al., 2000).

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Insert Table 4 about here

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## Discussion

When first seen, these boys displayed calendrical skills that most people never develop. Like most calendrical savants, both had developed these without being taught. Their initial skills were meagre but then they were very young. Consistent with the hypothesis of how savants develop calendrical skills, the boys had detected regularities in the calendar and their date answering skills were initially rudimentary.

Two years later, however, they had not become notably faster or more accurate in answering date-day questions and their ranges had not substantially increased. This limits the support for the hypothesis of savant skill development. Indeed, both were quite reluctant to answer date questions and CF had become substantially slower and less accurate. The investigations of their cognitive characteristics revealed that neither is typically developing but psychiatric disorder is unlikely according to the SDQs.

The boys' calendrical skills raise questions about why they developed them at all and why they have not progressed. The answer to the first must remain speculative but the histories taken indicate that both boys have long been content to occupy themselves and have some experience of isolation. JF was cut off from others through his hearing problem. CF was cut off from other pursuits by his visual abilities. Mitchell's (1907) analysis of prodigious mental calculators identified isolation from peers as a factor in the development of extraordinary arithmetical abilities. What is clear is that the boys' calendrical prowess has never been inconsistent with their general arithmetic ability. Whereas Snyder and Mitchell (1999) saw the appearance of calendrical calculation in savants prior to much arithmetical instruction as paradoxical, this paradox dissolves if the skill only requires addition, subtraction and detection of simple numerical patterns such as those in calendrical regularities. Even young children can carry out the necessary calculations if they can concentrate. Indeed both JF and CF demonstrated such concentration when first assessed. Both solved subtractions such as 47-21 by accurately counting down in ones.

Neither boy was reported to have any obsessive preoccupations with dates or calendars but both had displayed exceptional memory for dates, a feature that Heavey et al. (1999) found characterised calendrical savants. JF had surprised his parents with his memory for birthdates and CF astonished his mother with his memory for dates, e.g. he asked when she applied some hand cream in March, "Is the same cream you put on me on 26$^{th}$ September?". She was able subsequently to confirm the date as correct. Possibly arithmetic ability, memory for dates, and isolation sufficient to detect regularities and construct a method are all that is necessary to develop calendrical skills.

If they possessed the ingredients for calendrical expertise, then why have their skills not advanced? One possibility is that they may yet do so: after all, the boys are still young. However, some observations suggest this is unlikely. On the later visits, neither was keen to

answer date questions. This contrasts markedly with adult savants who enjoy having their date skills assessed. The boys have lost interest in dates: JF reported he did not do them as much now, and CF said if he started doing dates again, he would commit suicide. He explained he felt the ability was not normal and he did not want children in his school asking him date questions all the time. Also, the boys have developed interests that are much more likely to be shared with peers, such as football and cars, and their ability to remember numerical information in these areas is more likely to be admired. They are also developing skills in areas that are more likely to receive general approval from adults, such as reading, maths, and playing the violin. These may be important considerations in the development of exceptional skills. Adult savants may be relatively unmotivated to develop interests that can be shared by peers or relatively unaware of what these may be. In addition, the difficulties they have may make achievement and consequent social reinforcement in more conventional domains particularly difficult. Possibly what encourages adult savants to develop their skills to extraordinary levels is the praise and approval they get from demonstrating their prowess.

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Table 1 Initial (T1) and Follow Up (T2) Calendrical Skills of JF and CF in Comparison with Adult Calendrical Savants

| | JF | | CF | | Adult savants | |
|---|---|---|---|---|---|---|
| | T1 | T2 | T1 | T2 | Median | Range |
| Date – weekday questions | | | | | | |
| Range of years | <10 | <10 | < 10 | < 10 | 293 | 57 – 817,000[a] |
| Accuracy (%) | 76 | 71 | 79 | 65 | 100 | 82 – 100[b] |
| Latency (seconds) | 13 | 11 | 11 | 21 | 4 | 2 – 12[b] |
| Knowledge of regularities | | | | | | |
| Within year (%) | 75 | 75 | 88 | 63 | 100 | 63 – 100[c] |
| One year, one day (%) | 100 | 100 | 100 | 83 | 83 | 67 – 100[c] |
| 28-year (%) | 75 | 50 | 0 | 0 | 75 | 0 – 100[c] |
| Nomination of calendrically similar years | | | | | | |
| Correct nominations | 3 | 0 | 3 | 6 | 32 | 2 - 85 |
| Errors | 9 | 8 | 0 | 2 | 2 | 0 - 5 |
| Correct proportion (%) | 25 | 0 | 100 | 75 | 91 | 29 – 100 |

[a] Range for 10 adult savants with orally presented dates.

[b] Data from all 5 adult savants who have done the computer-presented date task

[c] Data from the 7 adult savants who understood the task

Table 2 Individual Scaled Scores and IQ by Test with Discrepancies between Actual and Predicted WOND Scores

| Test | Test/ Subtest | JF | CF |
|---|---|---|---|
| WISC | Full Scale IQ | 105 | 141 |
| | Verbal IQ | 115 | 145 |
| | Digit Span | 13 | 10 |
| | Similarities | 13 | 19 |
| | Information | 16 | 19 |
| | Arithmetic | 16 | 17 |
| | Vocabulary | 11 | 17 |
| | Comprehension | 6 | 16 |
| | Performance IQ | 94 | 133 |
| | Block Design | 9 | 16 |
| | Object Assembly | 7 | 13 |
| | Picture Completion | 12 | 17 |
| | Picture Arrangement | 4 | 15 |
| | Coding | 14 | 11 |
| WOND | Composite | 147 | 134 |
| | Discrepancy | 43** | 5 |
| | Mathematical Reasoning | 147 | 137 |
| | Discrepancy | 43** | 7 |
| | Numerical Operations | 133 | 120 |
| | Discrepancy | 28** | - 4 |

* * $p < .01$

Table 3 Standardised Scores on WORD and PhAB and Age Equivalents (Years: Months) on NARA II and BPVS II when JF was 7:06 and CF was 8:11

| Test | Subtest | JF | CF |
|---|---|---|---|
| WORD | Basic Reading | 135 | 113 |
| | Discrepancy | 32** | -12 |
| | Spelling | 142 | 101 |
| | Discrepancy | 39** | -20* |
| | Reading Comprehension | 100 | 117 |
| | Discrepancy | -3 | -10 |
| | Composite | 131 | 112 |
| PhAB | Alliteration | 102 | 100 |
| | Rhyme | 131 | 107 |
| | Spoonerisms | 131 | 111 |
| | Non-word Reading | 131 | 102 |
| | Naming Speed (Pictures) | 128 | 88 |
| | Naming Speed (Digits) | 131 | 81 |
| | Fluency (Alliteration) | 109 | 103 |
| | Fluency (Rhyme) | 118 | 115 |
| | Non-phonological Fluency (Semantic) | 126 | 120 |
| NARA II | Accuracy | 10:04 | 8:05 |
| | Comprehension | 9:01 | 8:10 |
| BPVS II | | 7:09 | 11:03 |

* $p < .05$; ** $p < .01$

Table 4 Strengths and Difficulties Questionnaire Scores with Normative Data

| | JF | CF | Mean for boys 5-10 years (SD) |
|---|---|---|---|
| Hyperactivity | 5 | 0 | 4.1 (2.8) |
| Emotional Symptoms | 3 | 0 | 1.8 (2.0) |
| Conduct Problems | 4 | 0 | 1.8 (1.8) |
| Peer Problems | 3 | 1 | 1.5 (1.7) |
| Total | 15 | 1 | 9.3 (6.0) |
| Impact | 0 | 0 | 0.4 (1.2) |
| Prosocial Behaviour | 6 | 9 | 8.4 (1.7) |