

# Savant skills in autism: psychometric approaches and parental reports

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Most investigations of savant skills in autism are based on individual case reports. The present study investigated rates and types of savant skills in 137 individuals with autism (mean age 24 years). Intellectual ability ranged from severe intellectual impairment to superior functioning. Savant skills were judged from parental reports and specified as 'an outstanding skill/knowledge clearly above participant's general level of ability and above the population norm'. A comparable definition of exceptional cognitive skills was applied to Wechsler test scores—requiring a subtest score at least 1 standard deviation above general population norms and 2 standard deviations above the participant's own mean subtest score. Thirty-nine participants (28.5%) met criteria for either a savant skill or an exceptional cognitive skill: 15 for an outstanding cognitive skill (most commonly block design); 16 for a savant skill based on parental report (mostly mathematical/calculating abilities); 8 met criteria for both a cognitive and parental rated savant skill. One-third of males showed some form of outstanding ability compared with 19 per cent of females. No individual with a non-verbal IQ below 50 met criteria for a savant skill and, contrary to some earlier hypotheses, there was no indication that individuals with higher rates of stereotyped behaviours/interests were more likely to demonstrate savant skills.

**Keywords:** autism; savant skills; adults with autism

## 1. INTRODUCTION

### (a) *What are 'savant skills'?*

Reports of individuals who despite having severe intellectual impairments nevertheless show remarkable skills in a particular area can be traced back centuries (see Southall 1979; Smith 1983; Heaton & Wallace 2004). Down (1887) was the first to coin the term 'idiot savant' in his description of 10 individuals who exhibited outstanding abilities in specific areas but whose level of general ability was so poor that they were unable to live independently. Subsequently, the American Association on Mental Deficiency (AAMD; Grossman 1983) defined 'savants' as 'persons with obvious mental retardation who are capable of performing in sharply circumscribed areas (e.g. arithmetic, calendar calculating) at a remarkably high level'. Miller (1998) argued that the term savant should be used for those individuals who show (i) normatively superior performance in an area and (ii) a discrepancy between their performance in that area and their general level of functioning. Miller (1999) also noted that very few savants for whom assessment details were available had IQ scores below 50, and many had at least some subtest scores within the normal range. Treffert (1989) differentiated 'prodigious' savants (i.e. individuals possessing an exceptional ability in relation to both their overall level of functioning and the general population) from 'talented' savants (individuals

showing an outstanding skill in comparison with their overall level of functioning). There is a parallel literature on the marked intra-individual discrepancies in the cognitive profiles of many individuals with autism (Joseph *et al.* 2002; Kuschner *et al.* 2007). Typically, cognitive peaks involve visuospatial skills (notably block design and object assembly) or rote memory; scores tend to be lowest on tests involving verbal abstraction or comprehension. Curiously, there has been no systematic comparison between these isolated exceptional cognitive skills and savant skills as usually conceptualized. That comparison constituted a key aim of our study.

### (b) *Savant skills in individuals with neurodevelopmental disorders*

Savant skills are reported much more frequently in males than in females (ratio approximately 3 : 1), and have been identified in a wide range of neurological and neurodevelopmental disorders (Miller 1998; Treffert 2000). Specific skills, in relation to overall levels of function but not population norms, have also been reported in genetic conditions such as Smith–Magenis syndrome (computing and memory; I. A. Horn 1999, unpublished thesis; C. Webber 1999, unpublished thesis), Prader–Willi syndrome (memory and visuospatial skills; Milner *et al.* 2005) and Williams syndrome (music and memory; Howlin *et al.* 1998; Levitin *et al.* 2004). However, the condition in which both prodigious and talented savants are most frequently reported is autism/autism spectrum disorder (ASD).

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One contribution of 18 to a Discussion Meeting Issue 'Autism and talent'.

**(c) Specific areas of savant skill**

Early anecdotal accounts of savants and more recent experimental studies (see Young 1995; Miller 1998; Heaton & Wallace 2004 for reviews) indicate that savant skills fall within a fairly circumscribed range. The most commonly reported are mathematical skills (calendrical calculations, lightening arithmetic and prime number calculations), music (especially the ability to replay complex sequences after only one exposure), art (complex scenes with accurate perspective either created or replicated following a single brief viewing) and memory for dates, places, routes or facts. Less frequently reported are 'pseudo-verbal' skills (hyperlexia or facility with foreign languages), coordination skills and mechanical aptitude (Tredgold 1952; Rimland 1978).

**(d) Savant skills in autism**

In Kanner's (1971) follow-up of his original 11 cases, six individuals were described as having an outstanding skill, mainly in the areas of music and rote memory. Two of the four cases described in detail by Asperger (1944, translated by Frith 1991) had outstanding calculating skills; another had exceptional spelling skills. Rimland (1978), in a postal survey of 5400 parents of children with autism, found that 531 (9.8%) were reported to have savant skills. Of those with reported skills, the most common were music (53%), memory (40%), mathematical/calculating skills (25%) and art (19%); 53 per cent had multiple special abilities (Rimland & Fein 1988). Bölte & Poustka (2004), in a study of 254 individuals with autism, identified 33 (13%) with at least one special skill as assessed on the Autism Diagnostic Interview—Revised (ADI-R; Le Couteur *et al.* 2003). Exceptional memory was the most frequently reported and 29 individuals had multiple savant skills. Treffert (2000) concluded that approximately 50 per cent of individuals with savant skills described in the literature appeared to meet criteria for autism/ASD—a prevalence much higher than the less than 1 per cent figure he estimates for savant skills in other syndromes. Miller (1998) also noted that out of the total of 45 individuals described in his review, 22 had autism or showed symptoms highly suggestive of this diagnosis. Similarly, O'Connor & Hermelin (1987) reported that 50 per cent of the individuals with savant skills in their experimental studies had autism.

**(e) Association with cognitive levels and presence of stereotyped and ritualistic behaviours**

Although early studies by O'Connor & Hermelin (1984, 1987; Hermelin & O'Connor 1986, 1990) used the traditional definition of idiot savant (i.e. special skills in individuals with severe cognitive impairment), some of their participants (and *all* of those with outstanding mnemonic skills) had IQ scores within the normal range. In a later study, O'Connor & Hermelin (1991) noted that the mean IQ of savants with autism was considerably higher than that of non-savants (non-verbal IQ 72 versus 52; verbal IQ equivalent 70 versus 59). Miller (1999), in a review of studies providing more detailed IQ information, reported that the mean overall IQ/IQ estimate for the savants with autism was 71

(range 40–99), mean verbal IQ 77 (range 52–114) and mean non-verbal IQ 75 (range 47–92). Thus, although savant syndrome can occur in individuals with autism of very low IQ, in the majority of reported cases cognitive ability falls within the mild learning disability range or above.

O'Connor & Hermelin (1988, 1991) suggested that a tendency to repetitive behaviour and/or preoccupations with a restricted area of interest were crucial features of individuals with savant syndrome. They also found that 'autistic savants' showed a particular interest in one specific topic (names, buttons, birthdates, etc.) and in the repetitive ordering of possessions.

**(f) Summary**

Although there have been many single case or small group studies of individuals with autism who possess savant abilities or exceptional cognitive skills, there have been few systematic, large-scale investigations in this area. Inconsistencies in definition and wide variation in diagnostic ascertainment, ages and ability levels of the cases reported also give rise to problems, and there is little valid information on rates of savant skills in ASDs.

**2. PRESENT STUDY****(a) Aims**

The aim of the present study was to investigate the nature and frequency of savant skills in a large sample of individuals with autism who had been initially diagnosed as children. The specific issues investigated were as follows.

- (i) What are the types and frequency of savant skills or exceptional cognitive skills in individuals with a confirmed diagnosis of autism?
- (ii) What is the degree of association between the two?
- (iii) Are savant skills associated with overall levels of cognitive ability?
- (iv) Do rates of such skills differ between males and females?
- (v) What is the relationship between savant or exceptional cognitive skills and the presence of repetitive, restricted and stereotyped behaviours?

**(b) Sample**

The total sample comprised 137 individuals, first diagnosed with autism at the Maudsley Hospital, London between 1950 and 1985, who have subsequently been involved in an ongoing, longitudinal follow-up study (Howlin *et al.* 2004; Hutton *et al.* 2008; see appendix A for process of sample identification). All initial diagnostic and cognitive assessments were conducted when individuals were aged 3–16 years. No participants had experienced any prolonged period in institutional care; all were Caucasian and singletons. Follow-up cognitive data were collected when participants were aged, on average, 24 years. Parental report data on savant skills were obtained approximately 10 years later, at a subsequent follow-up (mean age 34 years).

Inclusion criteria for the present study were as follows.

- Lifetime diagnosis of autism confirmed on Autism Diagnostic Interview (ADI; Le Couteur *et al.* 1989).
- Initial IQ  $\geq 30$  (this cut-off was chosen owing to the difficulties of making a reliable diagnosis of autism when IQ  $< 30$ ).
- Aged  $\geq 11$  at follow-up (as savant skills may not be evident in early childhood).
- No evidence of a specific medical disorder possibly related to autism (e.g. tuberous sclerosis, phenylketonuria, infant spasms, neurofibromatosis) or evidence of major physical or sensory impairment. (This criterion derived from the original follow-up studies.)

### (c) *Diagnostic and cognitive assessments*

#### (i) *Autism diagnosis*

Diagnosis at follow-up (mean age 24 years) was reconfirmed using the ADI (Le Couteur *et al.* 1989). This was the precursor to the current ADI-R (Le Couteur *et al.* 2003), and although the two versions are very similar, there are some differences in the items included. The ADI-R provides a lifetime diagnostic algorithm for autism (based on scores in the domains of reciprocal interaction, language/communication and restricted, repetitive and stereotyped behaviours). To meet ADI-R criteria for autism, individuals must score above cut-off on each of the three domains, and have shown features of autism by 3 years.

#### (ii) *Psychometric tests*

Cognitive and language measures were completed for all participants. The exact battery of tests used depended on individual age and developmental level.

#### *Non-verbal ability*

Eighty-seven individuals were able to obtain a score on the Wechsler Performance Scale (Wechsler Intelligence Scale for Children, 1974 or Wechsler Adult Intelligence Scale Revised, 1984, as appropriate; PIQ mean = 79.7, s.d. 18.4, range 42–133). For the remainder, non-verbal IQ calculations were based on the Raven's matrices standard, coloured or board forms (Raven 1976) ( $n=23$ ), the Leiter (1980) ( $n=18$ ) or Merrill-Palmer Scales (Stutsman 1948) ( $n=9$ ). The mean performance IQ (based on any test) of the total sample was 69.9 (s.d. 23.1, range 28–135).

#### *Verbal ability*

Eighty-two participants scored on the Wechsler Verbal Scale (Mean VIQ 77.5, s.d. 20.4, range 44–134); for 53 individuals a verbal IQ was derived from their scores on the British Picture Vocabulary Test; two individuals were not able to score on any language scale. Mean verbal IQ/or ratio IQ estimate (based on any test) was 52.9 (s.d. 34.6, range 7–134).

#### (iii) *Ratings of preoccupations, unusual interests and repetitive behaviours*

To investigate the possible relationship of savant and exceptional cognitive skills with unusual interests,

rituals and/or repetitive behaviours, a rating was derived from five items included in the repetitive, restricted and stereotyped behaviours domain of the ADI (unusual preoccupations, compulsions/rituals, resistance to change, unusual attachments to objects, unusual sensory interests). (Range of scores for each item 0–3; maximum possible total score = 15.)<sup>1</sup>

### (d) *Statistical analysis*

Parametric analyses were used for comparisons where data permitted. Probability tests were two-tailed and, as multiple comparisons were conducted, the significance level for  $p$  was set at less than 0.01.

## 3. FREQUENCY AND NATURE OF EXCEPTIONAL SKILLS IN AUTISM

### (a) *Exceptional cognitive skills*

#### (i) *Definition*

An exceptional cognitive skill was defined as any subtest score greater than or equal to 1 standard deviation above the population mean on the Wechsler IQ test and greater than or equal to 2 standard deviations (based on population norms) above the participant's mean subtest score. (Mean score for each subtest = 10, s.d. = approx. 3.0, depending on the specific subtest.)

#### (ii) *Participants*

Cognitive assessments were completed for all participants (100 males and 37 females) when aged between 11 and 48 years (mean 24.1 years, s.d. 8.6 years).

#### (iii) *Results*

Eighty-seven individuals (64% of total sample) were able to obtain a performance, verbal or full-scale IQ score on the adult or child versions of the Wechsler IQ test. Of these, 23 (17% of total sample) met the above criteria for an exceptional cognitive skill.

Table 1 provides details of individuals meeting cognitive skills criteria. The most common *single* area of special skill was block design (BD,  $n=9$ ); followed by digit span (DS,  $n=5$ ), arithmetic ( $n=4$ ) and object assembly (OA,  $n=1$ ). In addition, three individuals met criteria on two subtests (BD and OA) and one on three subtests (BD, OA and DS).

### (b) *Parental reports of savant skills*

#### (i) *Definition*

Savant skill was defined according to the definition of Miller (1998), i.e. a skill exceptional both in terms of population norms and above the individual's overall level of ability.

#### (ii) *Source of information*

Data on special skills were derived principally from a postal questionnaire sent to parents and focusing on outcome since the cognitive assessment conducted approximately 10 years earlier. The questionnaire asked specifically about the current presence of any outstanding skills and talents 'at a level that would be unusual even for normal people' (Hutton *et al.* 2008). Examples of the kinds of skill of interest were provided and parents were requested to give details of any special skills noted.

Table 1. Details of 23 individuals meeting criteria for one or more exceptional cognitive skill. (Arranged in order of full-scale IQ score (three individuals able to complete PIQ only) arith, arithmetic; BD, block design; DS, digit span; OA, object assembly; CC, calendrical calculator.)

M/F	age (years)	Wechsler FSIQ	PIQ	VIQ	mean subtest score	score of subtest (s) meeting 'exceptional' cognitive criteria	parent-reported savant skills (blank = no parent-reported skill)
F	16	64	66	44	4.0	15 BD	
M	49	72	88	59	4.2	14 BD	
M	36	72	92	59	4.9	13 BD	
F	26	73	87	64	5.7	13 BD 13 OA	
M	33	76	66	86	6.5	19 DS	CC
M	34	78	82	78	6.7	14 DS	
M	22	83	98	76	7.0	13 BD	
M	26	84	100	76	7.0	14 BD	
M	24	85	108	75	7.7	16 BD	
M	30	87	85	92	8.2	16 DS	maths/memory
M	45	88	89	89	7.0	13 arith	CC/music/math
M	49	88	111	74	7.6	15 BD 13 OA	
F	30	90	94	91	8.0	15 DS	
M	49	94	102	89	8.5	15 OA	CC
M	48	95	80	109	8.9	16 arith	CC
M	32	96	111	87	9.2	19 BD	
M	46	98	85	111	9.6	17 arith	CC/memory
M	28	110	98	118	10.5	17 arith	
M	28	124	122	118	9.7	18 DS 19 BD 15 OA	
M	48	130	116	131	12.2	19 DS	CC
F	14		80		7.0	13 BD	
M	33		92		7.2	15 BD	
M	28		108		9.3	19 BD 18 OA	maths

(iii) *Reliability of researcher ratings of parental questionnaire data*

In total, 90 questionnaires were returned. All written information on special skills provided by parents was transcribed (removing details of name and sex) and each example blind-coded by PH and MR using the ratings below.

- 0, no outstanding skills/knowledge in relation to overall level of ability.
- 1, isolated skill/knowledge commented on by parents but unlikely to be above population norms.
- 2, outstanding skill/knowledge definitely above the subject's general level of ability *and* above the population normal level.
- 7, possible outstanding skill but not enough information to be certain.

A code of 2 was set as the criterion for a *savant* skill.

Inter-rater reliability was calculated using weighted kappas (Cohen 1968). Parents' descriptions indicated that 45 individuals had some form of special skill. Of these, 21 individuals were rated as meeting the necessary criteria (i.e. coding of 2) by one or both coders (17 by both and 4 by one rater only);  $\kappa=0.8$  (high agreement). (Agreement on three other cases was based on information from detailed case-note reports.) Any disagreement between the two raters was due mainly to the very circumscribed nature of some skills (e.g. having perfect pitch and ability to identify any musical chords, but no other musical skills; ability to memorize the names of classmates from 20 years ago). Following consensus discussion, all examples coded as 2 by at least one rater were included as meeting

criterion; three individuals coded as scoring 7 by both raters were excluded (e.g. one individual who had a form of synaesthesia; others with good but not exceptional artistic skills). (Examples of savant skills meeting criteria are provided in appendix B.)

Parents reported unusual memory skills more often than categorized here as savant. We decided to exclude personal memories of a kind that did not allow any valid assessment of the extent to which they might be above population norms. Those included did provide such information (see appendix B). Because we adopted very strict criteria, it is likely that the true number of individuals with unusual memory skills was greater than included here. For similar reasons, we did not rate as savant skills that were obtained unusually early (e.g. precocious reading).

Special skills were categorized into five principal areas: visuospatial; computational (including calendrical calculators); memory; music; and art. Inter-rater agreement on these categories (based on written transcripts for the 21 individuals meeting criteria) was 100 per cent.

(iv) *Participants*

Of the original 137 participants in the cognitive study, two individuals had died, two asked not to be contacted again and five could not be traced. Questionnaire data were obtained for 90 of the remaining 128 individuals and additional information on special skills was available for three participants from written information collected from parents by PH or MR on previous occasions. Thus, detailed parental information was obtained for 73 per cent of available participants. The average age at which the parental questionnaire data were obtained was 34.2 years (s.d. 7.8 years, range 21.0–55.0 years).



Table 2. IQ scores of individuals with or without special areas of skill.

area of skill	group	N tested Wechsler FS IQ <sup>a</sup> ; mean (s.d.) [range]	N tested PIQ; mean (s.d.) [range]	N tested VIQ/IQ estimate; mean (s.d.) [range]
exceptional cognitive	skill	N=20; 89.4 (16.9) [64–130]	N=23; 96.7 (14.7) [76–135]	N=23; 77.4 (22.4) [14 <sup>b</sup> –131]
	no skill	N=62; 73.7 (17.9) [39–126]	N=114; 64.4 (20.6) [28–133]	N=114; 47.9 (33.2) [7 <sup>b</sup> –134]
parent-rated savant	skill	N=22; 88.1 (20.1) [63–130]	N=24; 86.4 (20.3) [53–135]	N=24; 84.7 (30.4) [15 <sup>b</sup> –134]
	no skill	N=40; 74.9 (17.5) [44–124]	N=69; 69.1 (22.2) [29–122]	N=69; 50.1 (32.5) [7 <sup>b</sup> –118]
savant and exceptional cognitive skill	skill	N=7; 95.4 (16.8) [76–130]	N=8; 96.0 (20.4) [76–135]	N=8; 90.4 (33.8) [16 <sup>b</sup> –134]

<sup>a</sup>FSIQ based on Wechsler tests only. PIQ and VIQ estimates are based on a number of different tests (see text) and include all participants with parental data.

<sup>b</sup>Low verbal IQ scores based on ratio IQ estimate (language age/chronological age × 100).

#### (v) Results

Among the 93 individuals for whom data were available, 24 were identified as having one or more savant skills (total = 26%). There were 14 calendrical calculators (one also showed exceptional memory and another also showed skills in computation and music). There were four others with computational skills (in one case combined with memory and in another case with music). Visuospatial skills (i.e. directions or highly accurate drawing) were reported in three individuals. One individual had a musical talent, one an exceptional memory skill and one had skills in both memory and art.

#### (c) Relationship between exceptional cognitive savant skills and skills identified by parental report

Of the 93 individuals for whom parental questionnaire and cognitive data were available, 16 (17.2%) met criteria for a parent-rated skill, 15 (16.8%) had an exceptional cognitive skill and 8 (8.6%) met criteria for both.

All participants who met criteria for both unusual cognitive skill and parent-reported savant skill were male and, in each case, the parent-reported skill involved either mathematical or calendrical calculating abilities (table 1). For six out of these eight individuals, the exceptional area of cognitive ability identified on the Wechsler test also involved either the arithmetic or digit span subtests (one individual with exceptional mathematical ability was non-verbal and thus could not attempt the Wechsler arithmetic subtest).

#### 4. RELATIONSHIP BETWEEN SPECIAL SKILLS AND INTELLECTUAL ABILITY

The IQ levels of individuals meeting criteria for any area of savant skill were compared with those of individuals with no savant skills (table 2). Individuals with exceptional cognitive skills had significantly higher full, performance and verbal scores than the non-cognitive skill group ( $p < 0.001$  for each comparison). Since, by definition, exceptional cognitive skills were required to involve one or more subtest scores above the population norm, this difference was not unexpected. However, there were also highly significant differences between the FSIQ, PIQ and VIQ scores of the parentally rated savant/non-savant groups ( $p \leq 0.009$  for each comparison). Far more individuals in the non-savant group obtained IQ scores of less than

60 (on any test) than in the savant group. Moreover, among those with parent-rated special skills, all but two individuals were able to achieve an IQ score on the Wechsler tests and all the remainder obtained Wechsler full-scale, performance and verbal scale IQ scores above 60. The profile of Wechsler subtest scores was very similar in both groups, although, again, the means of the savant group were consistently higher.

#### 5. SEX DIFFERENCES

The total sample for whom parental and/or cognitive data were available comprised 100 males and 37 females. Overall, many more males showed some form of savant skill (32M : 7F). The M : F ratio for cognitive skill was 19 : 4 and for parent-rated skill was 21 : 3 (eight males were assessed as having both cognitive and parent-rated skills). None of these ratios differed significantly from the M : F ratio for the total group (Yates corrected  $\chi^2$   $p \geq 0.20$  for each comparison) but the small number of females in the sample necessarily limits the statistical power for detecting a sex difference. It is also notable that no female was rated as having both exceptional cognitive and parent-rated skills. There was no difference in scores on any of the IQ measures ( $p > 0.14$  for each comparison) between males and females with either savant or unusual cognitive skills.

#### 6. RELATIONSHIP BETWEEN SAVANT SKILLS AND STEREOTYPED AND REPETITIVE BEHAVIOURS/INTERESTS

Data on repetitive/stereotyped behaviours and special interests had been collected when diagnostic status was reconfirmed, by means of the ADI, during the cognitive follow-up stage of the study. ADI data were available for 93 participants. Scores from the five ADI items relating to repetitive/stereotyped behaviours and interests (unusual preoccupations, compulsions/rituals, resistance to change, unusual attachments to objects and unusual sensory interests) were summed to create a total 'stereotyped/special interests' score (range of scores for each item 0–3; maximum possible total score = 15). There was no difference in the overall scores of those individual rated as not/having skills (either cognitive or parent-reported; mean score for those with a skill = 6.9, s.d. 3.0; mean for the remainder 7.1; s.d. 3.0,  $t = 1.09$ ,  $p = 0.28$ ). On the individual items included in the repetitive/stereotyped behaviours domain, there

were no differences in the numbers of individuals in the non-versus any-skill groups reported as having severe problems (ratings of 2–3) in any area ( $\chi^2 > 0.05$  for each comparison). These findings suggest that the severity of stereotyped or repetitive patterns of behaviour/interest was not associated with special savant or unusual cognitive skills, although it should be noted that the original version of the ADI did not include circumscribed interests, which might possibly be related to savant skills. Also, of course, the diagnosis of autism required the presence of repetitive behaviours/interests, so it was only variations and their extent that could be examined.

## 7. DISCUSSION

In total, 39 participants (28.5%) met criteria for a savant skill. Cognitively, 23 individuals (17% of total sample) met criteria for one or more exceptional area of skill on the Wechsler tests. Combining the two, 37 per cent of the sample showed either savant skills or unusual cognitive skills or both—a far higher proportion than previously reported. Moreover, for reasons already noted, this estimate of 28.5 per cent for savant skills is likely to be an underestimate. It may be concluded that unusual talents are found in at least a third of individuals with autism. Theoretical models of autism and animal models will both have to account for the frequency of unusual talents as well as the presence of important deficits.

The subtest on which participants were most likely to meet the specified criteria for an area of unusual cognitive skill was block design followed by digit span, object assembly and arithmetic. On the basis of parental report, 24 individuals (26% of those for whom data were available) were rated as having a savant skill, mostly involving mathematical/calculating abilities. Generally, there was only modest overlap between individuals with savant skills based on parental report and those who had specific cognitive areas of ability. Thus, of 93 individuals for whom cognitive and parental questionnaire data were available, only eight (11.6%) met criteria for an outstanding skill on both measures. Nevertheless, that overlap is greater than the 4.8 per cent expected by chance and, among these eight individuals, the area of special skill identified by both cognitive testing and parental report was similar. All the eight individuals were reported by parents as having talents related to numerical skills (mathematics or calendrical calculations) and in all but two cases the additional cognitive area identified was either arithmetic or digit span (one of the eight individuals was non-verbal and thus could not attempt either of these subtests).

As indicated in earlier reviews (Miller 1998), there was a sex difference (albeit statistically non-significant) in the prevalence of savant skills. Almost one-third (32%) of males showed some form of savant or special cognitive skill compared with 19 per cent of females.

### (a) *Theoretical implications*

From a theoretical perspective, two rather different questions arise. First, why is the rate of savant skills among individuals with autism so high (see Heaton &

Wallace 2004)? On our findings, at least a quarter, but probably over a third, of individuals with autism show unusual skills or talents that are both above population norms and above their own overall level of cognitive functioning. Adequate studies comparing autism with other neurodevelopmental disorders have yet to be undertaken, but the rate of such unusual talents or skills seems particularly high in autism. Why? Second, within the realm of special talents, why (in autism) do these particularly involve computational skills, and is their basis the same as that underlying, say memory or artistic skills? There is plenty of speculation on both these questions but very little in the way of systematic testing of alternative mechanisms. Such research is much needed.

Contrary to suggestions that the presence of savant skills is associated with ritualistic behaviours or special interests (e.g. O'Connor & Hermelin 1991), there was no evidence in the present study that those individuals with either exceptional cognitive or parent-rated skills had higher rates of repetitive or stereotyped behaviours/interests than those who did not. Thus, although *all* participants showed abnormalities in this domain, the severity of such behaviours was not related to savant abilities.

Finally, the fact that savant skills are not unique to autism, but are reported in a number of other syndromes with very different cognitive and behavioural phenotypes (e.g. Prader–Willi, Smith–Magenis and Williams syndromes), also requires further exploration. However, to date, the very different assessment methods and varying definitions used make it impossible to draw reliable conclusions about the relative rates and types of savant skills in other disorders. This is clearly an area in which better standardized measures and ascertainment criteria are crucial if comparative studies on syndrome-specific savant skills are to progress.

Methodological differences between studies also limit conclusions concerning the overall rates of savant skills in ASD. Lack of clear diagnostic criteria, inadequate definition of savant skills, the age of the cohort studied (savant skills may be less apparent in younger children) and the sex ratio (cohorts with a higher preponderance of males may well contain greater numbers of savants) all contribute to different estimates of prevalence. Questions also remain about the most effective way of collecting valid information on savant skills. Cognitive data, although the most objective, are also the most circumscribed; parental reports, while more detailed, are frequently highly subjective. Detailed observational and experimental studies such as those of Hermelin (2001) are feasible only for individual case studies or small case series. Moreover, definitions of what constitutes a skill that is truly exceptional in terms of population norms are also variable and highly unusual characteristics may not necessarily be equivalent to special skills. One individual in the present study, for example, had synaesthesia, seeing people, objects and numbers in colours, in a way that was often distressing for him. In our view, this did not meet criteria for a savant skill but drawing distinct boundaries between this and other savant abilities clearly presents difficulties.

Although the study is not without methodological problems—in particular, the fact that cognitive and parental data were collected at different times and parental information was available for a smaller proportion (73%) of the total sample—the findings are considered valid for a number of reasons. Sample size was relatively large; standardized diagnostic criteria for autism were met in all cases; criteria for savant skills were clearly defined; data were derived from two separate sources (cognitive assessment and parental information); the parental questionnaires used provided detailed descriptions of savant-type skills; and inter-rater reliability was high. The results suggest that the rates of savant skills in autism are substantial, particularly among males, and although these estimates are higher than reported by other researchers, in other ways our findings parallel those of previous studies (e.g. Bölte & Poustka 2004). Thus, females seem less likely than males to develop savant skills, and in both this study and that of Bölte & Poustka (2004), the average non-verbal IQ of the savant group was over 80, consistently higher than that of the non-savant group. Indeed, in our study, no individual with a non-verbal IQ below 50 was judged as having any special talents. These data offer no support to claims that savant skills occur most frequently in individuals with autism who are intellectually impaired.

Despite the fact that savant abilities reported in the literature cover a relatively circumscribed range, the underlying cognitive mechanisms appear to vary widely. The ability to make rapid calendrical calculations (which is clearly *not* simply a feat of memory; Heavey *et al.* 1999;

Iavarone *et al.* 2007), to calculate prime numbers, to remember dates/places/events from many years in the past or recite a long list of digits backwards may all require very different cognitive skills. Similarly, a high level of expertise in art or music is very different from being able to score highly on tests of block design or object assembly. It is possible that an overarching explanation may exist for why certain individuals go on to develop *any* area of exceptional skill, but understanding why these skills encompass such different areas and what the underlying basis of such skills is may require a rather different, research-based theoretical approach than adopted thus far.

Finally, there is the issue of how innate talents can be developed to form the basis of truly *functional* skills. In the present study, only five individuals with exceptional abilities (four related to maths and one related to visuospatial ability) had succeeded in using these skills to find permanent employment. For the majority, the isolated skill remained just that, leading neither to employment nor greater social integration. The practical challenge now is to determine how individuals with special skills can be assisted, from childhood onwards, to develop their talents in ways that are of direct practical value (in terms of educational and occupational achievements), thereby enhancing their opportunities for social inclusion as adults.

## ENDNOTE

<sup>1</sup>Note that these domain items differ slightly from those in the current ADI-R, which now also includes circumscribed interests.

## APPENDIX A

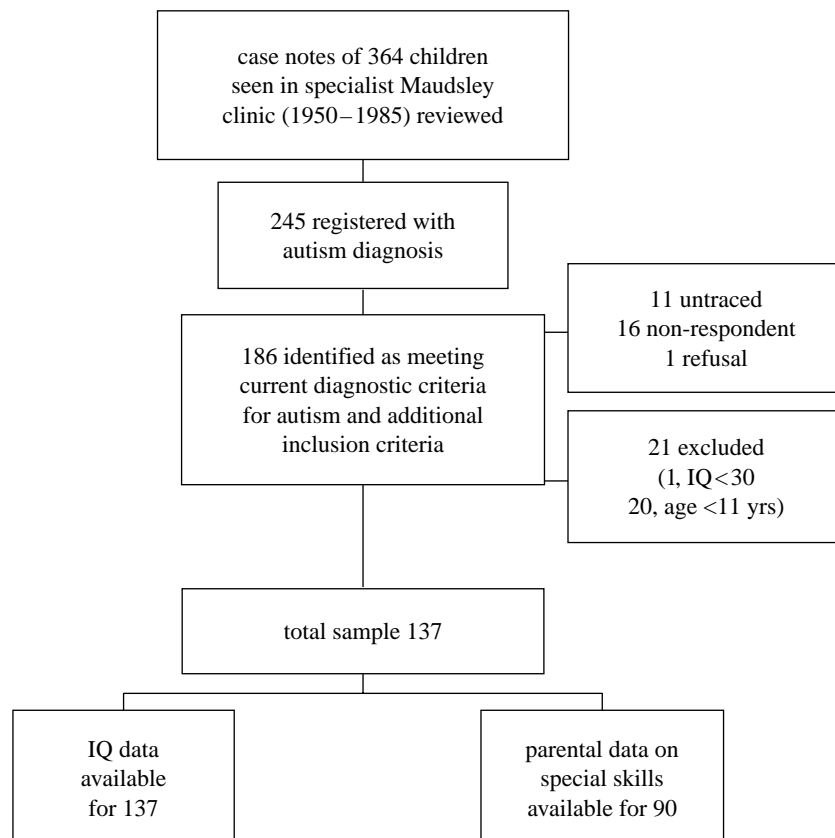


Figure 1. Sample identification.

## APPENDIX B

Table 3. Examples of savant skills reported on parental questionnaire.

computation	arithmetical calculations have become increasingly possible; easily able to multiply two numbers in the millions together in head; can tell the elevation of both the Sun and the Moon at any time on any date without reference to any book; has written a computer program about this
calendar calculations	when very young obsessed with 'time'; learned to read digital/analogue/roman dials preschool; could tell folk when their birthday would occur (day of the week/what day of the week they were born on); can work out the day of a particular date in the future; however, soon gets fed up of being asked so is rarely tested on this ability
memory	has memorized a 100-year calendar; can tell you what day, say Christmas, occurs, over that 100 years; I bought the calendar <i>ca</i> 15 years ago and he just memorized all the pages; can tell you the name of any tunes he knows as soon as he hears the opening bars; we think he has outstanding memory ability but because he is reluctant to use speech, it is difficult to gauge how good it is; some examples: a few years ago, he was bought a book which was read to him; this year we read it to him again after over a year—if we stopped he would finish the rest of the sentence quite accurately; a second example is that he is able to give the names (both first and surnames) of his classmates at school 20 years earlier
visuospatial	successful in painting portraits of friends, friends' children and selling them; has exceptional talent for dealing with children; attends art classes at college of further education every week—an excellent tutor has succeeded in encouraging him to do the most outstanding abstract paintings which he has exhibited at the college; they bought one to use on their brochure; did not show this talent as a child or adolescent
music	has perfect pitch and is able to identify chords in pieces of music with ease
multiple skills: computation, music and memory	very talented in mathematics—evident since teens; Also has a very good memory of events that happened over the past number of years, i.e. knows the dates, days of the year when household appliances purchased; helps other people to fill in their CVs with dates for schools, jobs, etc; also quite talented in art as well as music; taught self to play the clarinet and guitar
calendar calculations, computation and music	calendar calculations, perfect pitch and music in general; arithmetic—always interested and good at this (for past 2 years has had several researchers visiting him testing him for calendar work, arithmetic and music)

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