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# Child prodigy: A novel cognitive profile places elevated general intelligence, exceptional working memory and attention to detail at the root of prodigiousness

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ABSTRACT

Child prodigies are unusual for their early and exceptional adoption of what are traditionally thought of as adult abilities. As part of an effort to better understand the underpinnings of these extraordinary individuals' talent, the researcher examined the cognitive and developmental profiles of eight child prodigies by taking their developmental histories and administering the Stanford-Binet 5th ed. full scale intelligence test and the Autism-Spectrum Quotient (AQ). The collected data reveals a startling picture. While each of the prodigies demonstrated an at least moderately elevated level of intelligence, the prodigies' full scale IQ scores were not consistently on the extreme end of the spectrum. What was consistently extraordinary, however, was the child prodigies' working memory scores—a category in which every prodigy tested in the 99th percentile. Additional results suggest a previously unknown connection between child prodigies and autism. The prodigies' family histories yielded an unlikely number of autistic relatives. And the child prodigies received elevated AQ scores with respect to attention to detail, a trait associated with autism. The prodigies did not, however, display many of the other traits typically associated with autism. This result raises the possibility of a moderated autism that actually enables the prodigies' extraordinary talent.



## 1. Introduction

The term prodigy is most often used to identify individuals who reached professional status in a demanding field at a very young age. By all accounts, child prodigies are unusual in their early adoption of traditionally adult abilities. They are found most often in the rule-based fields of music, mathematics, art, and chess. The limited research available to date indicates that most child prodigies display their talent in a single domain.

But despite some agreement regarding who qualifies as a prodigy, no consensus yet exists regarding the underpinnings of such prodigiousness. This paper will first survey existing theories regarding child prodigies and then, based on the assessment of eight prodigies, propose a new way of understanding the foundation of such extreme talent.

Existing theories regarding the causation of prodigiousness range from an emphasis on inherent ability (nature) to extreme training (nurture). Feldman and Morelock (2011) fall into the first group. Feldman and Morelock propose that, to become a child prodigy, one must have at least a moderate level of general intelligence, coupled with exceptional skill in a specific domain. According to this theory, higher levels of general intelligence may be associated with certain domains, such as mathematics, and with "omnibus prodigies," children who are exceptional across many different domains.

Putting forth an evolutionary explanation, Vandervert (2009) argues that child prodigies are the product of the improved working memory and visual spatial abilities that

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may have occurred about 10,000 years ago. At that time, humans experienced a marked increase in the ratio of cerebellum to cerebral cortex in the brain. While an increase in cerebellar mass is generally thought to enhance dexterity in humans, it has been suggested that the newest sections of the cerebellum may play an integral role in boosting the efficiency of information processing in the cortex (Vandervert, 2009). This would increase working memory and visual spatial abilities, which Vandervert argues are integral to prodigiousness.

On the other end of the spectrum, some researchers argue that child prodigies are the product not of evolution, but of intense training. This extreme environmental approach credits advanced contemporary training techniques and upwards of ten years of deliberate practice as the root of all exceptional achievement (Howe, 1990; Ericsson, 1996; Ericsson, Krampe, & Tesch-Romer, 1993), including the exceptional achievements of child prodigies. One such researcher, Ericsson, posits that child prodigies are the product of superior training and intense intervention usually carried out by the parents of child prodigies. This theory is pervasive in the public consciousness, and was even one of the focal points of journalist Malcolm Gladwell's bestseller, *Outliers*.

Detterman and Ruthsatz (1999) first suggested a multivariate approach to exceptional performance, arguing that all exceptional achievement is the product of at least three variables: general intelligence, domain-specific skill, and practice. Turning their attention to the exceptional achievement of child prodigies, the researchers proposed that, because the latter variable, deliberate practice, could not have reached the ten years necessary to support Ericcson's nurture-driven theory, there must be an elevation in the first two variables: general intelligence and domain-specific skills (Ruthsatz & Detterman, 2003).

It was while testing this theory that a chance meeting with a child prodigy's severely autistic first cousin prompted the researcher to first consider the possibility of a familial link between child prodigies and autism. A pilot study by Ruthsatz (2007) explored the possibility that child prodigies are on the autistic spectrum by comparing the biological first-degree relatives of child prodigies and the biological first-degree relatives of individuals with autism with a control group using the Autism-Spectrum Quotient (AQ) designed by Baron-Cohen, Wheelwright, Skinner, Martin, and Clubley (2001). The first-degree family members of autistic individuals and the first-degree relatives of child prodigies reported the broader phenotype for autism in three of the five AQ categories: social skills, attention switching, and attention to detail.

Child prodigies would not be the first group with some form of autism to manifest exceptional achievement. Savants, generally defined as individuals who display talent beyond their expected level of achievement given their general intelligence, often display their talents despite a disability, often autism (Treffert, 2010; Nettelbeck & Young, 1996).

The purpose of the present study is to further investigate the cognitive underpinnings of prodigiousness, including any potential link to autism, and to refine current theories regarding what allows child prodigies to display extreme talent at such a young age.

## 2. Methods

### 2.1. Participants

The interviewer identified nine child prodigies through the internet, television specials, and by referral. To be selected for the study, the participant had to have reached professional status in a rule-based system at a remarkably young age, usually before the age of 10. The group includes one art prodigy, one math prodigy, four musical prodigies, and two who switched domains (from music to gastronomy and from music to art). All of the child prodigies identified are so exceptional that they have been featured on national and international television programs that highlighted their early accomplishments.

The interviewer contacted the nine identified child prodigies by letter, email, or telephone. If the child prodigy was still a minor, initial contact was made with the parents. All of the contacted child prodigies agreed to participate in the study.

Of the nine prodigies contacted, eight have been tested. The ninth remains untested due to timing constraints. The child prodigies ranged from seven to thirty-two years of age at the time of testing. The group included six males and two females.

### 2.2. Procedure

The assessment process usually took place over a two- or three-day time span in a location chosen by the participant. Assessment of the child prodigies included both a descriptive component and a testing component.

The parents of six of the child prodigies provided a detailed description of their child's accelerated development. The thirty-two-year-old and nineteen-year-old child prodigies reported their own development.

The investigator administered the Stanford-Binet 5th ed. (Roid, 2003) full scale intelligence test to seven of the participants. The full scale Stanford-Binet 5th ed. sub-tests are: fluid reasoning, knowledge, quantitative reasoning, visual spatial abilities, and working memory. The second participant, who was not a native English speaker, was only administered the working memory and fluid reasoning sub-tests, which are not heavily dependent on language.

Of the Stanford-Binet 5th ed. sub-tests, the working memory sub-test deserves special consideration because of its importance to the findings. Working memory on the Stanford-Binet 5th ed. assesses the individual's ability to store and sort information in both the verbal and nonverbal domains. In the verbal domain, participants are asked to listen to a series of sentences and to repeat the last word of each sentence after the entire series is read. In the non-verbal domain, participants watch as the examiner taps on a number sequence and then the participant is asked to recall in order the numbers that were tapped.

Additionally, the researcher administered the Autism-Spectrum Quotient assessment (AQ) to the child prodigies. The AQ is a 50-question screening survey that scores the level of autistic traits for individuals with a normal level of intelligence. The survey is divided into five sections, all related to autism: attention to detail, communication, imagination,

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social skills, and attention switching. Typical questions on the AQ are (I find social situations easy) and (I tend to notice details that others do not). There is a forced choice format and the individual may agree or disagree with the statement. About half the questions require agreeing with the statement to score a point and half a negative answer to score a point. Higher scores on the AQ are related to the presence of more autistic traits. Several studies report moderate test–retest reliability ranging from r = .63–.78 and a positive predictive value of 0.84 and a negative predictive value of 0.78 (Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005). The current study compared the child prodigies' AQ scores to the scores of a control group who were comprised of 174 (76 males and 98 females) adults. The control group for the AQ was obtained by mail. The AQ was sent randomly to 500 individuals in the East Anglia area and 174 returned the survey. The scores from 58 individuals (45 males and 13 females) with high functioning autism/Asperger's syndrome, were individuals with a diagnoses of autism or AS and had IQ's in the normal range and both groups were reported by Baron-Cohen et al. (2001). Due to the rare occurrence of prodigies and dearth of published academic material discussing their precocious abilities, the development and testing results of each prodigy is first reviewed individually in the Results and then in the aggregate. Due to confidentiality concerns, the prodigies' AQ scores and reports of autism within the prodigies' families are discussed only in the aggregate.

## 3. Results

### 3.1. Individual prodigy results

#### 3.1.1. Prodigy one

*3.1.1.1. Development description.* The first prodigy was 15 years of age at the time of testing. He is an only child who was born seven weeks early. He weighed 4 lbs and 11 oz. His mother was 41 and his father was 50 at the time of his birth. His mother reports that his physical development was typical. However, he began to show an unusual ability to master puzzles at the age of 18 months, programmed computers by age three, and reproduced complicated musical pieces such as *The Entertainer* after only one or two hearings at age four. He had reached a prodigiousness level of musical achievement by five years of age. He became interested in cooking at 10 years old and did his first catering event at the age of 11. He organized a staff for the next 10 catering jobs that he did that summer, most of which were charity benefits. He recently appeared in a nationally televised reality show to design the kitchen of a house for troubled teenagers. He has won many awards for his original culinary dishes; he invented many of these dishes through molecular gastronomy, a rule-based method that predicts creative and unusual dishes. Eminent authority and founder of the discipline This (2006) defines molecular gastronomy as follows:

> I will start by distinguishing between cooking and gastronomy: the first is the preparation of food, whereas the latter is the knowledge of whatever concerns man's nourishment. In essence, this does not concern food fashions…but rather an understanding of food; and for the more restricted molecular gastronomy, it is the physics behind the preparation of any dish: for example, why a mayonnaise becomes firm or why a soufflé swells.

*3.1.1.2. Testing.* The prodigy, tested using the Stanford-Binet 5th ed. intelligence test, demonstrated a full scale IQ of 140, which places him more than two standard deviations above the mean.

He also demonstrated remarkable working memory. He scored a 146, which places him at the 99.9 percentile for this test (see Table 1). All of the pair-wise comparisons were done using the S.E. of the Stanford-Binet 5th ed. listed in the manual. The prodigy's working memory and visual spatial scores were significantly higher beyond the .05 level than the other three indexes of knowledge, fluid reasoning, and quantitative reasoning. His working memory and visual spatial scores were not significantly different from each other. The difference between the working memory score and the score for fluid reasoning is very rare; it is found in only about 5% of the normal population. He had a Non Verbal IQ (NVIQ) of 149, which is significantly higher beyond the .05 level than his Verbal IQ (VIQ) of 127. See Table 1 for the first child prodigy's full IQ scale scores.

#### 3.1.2. Prodigy Two

*3.1.2.1. Development description.* The second prodigy was born in Paris, France and was 32 years old at the time of testing. He is the second child of an intact family of five. He has an older brother and a younger sister. He began playing musical instruments at the age of four and was considered a musical

**Table 1**
Stanford-Binet scores with percentages for eight child prodigies.

| | FSIQ | NVIQ | VIQ | FR | K | QR | VS | WM |
|---|---|---|---|---|---|---|---|---|
| Prodigy one | 140 | 149 | 127 | 121 | 131 | 133 | 140 | 146 |
| Percentage rank | 96 | 99.9 | 96 | 92 | 98 | 99 | 99.6 | 99.9 |
| Prodigy two | | | | 118 | | | | 152 |
| Percentage rank | | | | 91 | | | | 99.9 |
| Prodigy three | 129 | 122 | 130 | 106 | 126 | 119 | 126 | 141 |
| Percentage rank | 90 | 93 | 98 | 66 | 96 | 90 | 96 | 99.7 |
| Prodigy four | 142 | 143 | 139 | 138 | 145 | 130 | 123 | 146 |
| Percentage rank | 97 | 99.8 | 99.5 | 99 | 99.9 | 98 | 94 | 99.9 |
| Prodigy five | 121 | 122 | 127 | 121 | 117 | 116 | 111 | 152 |
| Percentage rank | 92 | 93 | 96 | 92 | 87 | 86 | 77 | 99.9 |
| Prodigy six | 108 | 105 | 110 | 103 | 117 | 94 | 71 | 149 |
| Percentage rank | 70 | 63 | 75 | 58 | 87 | 34 | 3 | 99.9 |
| Prodigy seven | 112 | 112 | 112 | 100 | 128 | 100 | 88 | 138 |
| Percentage rank | 79 | 79 | 79 | 50 | 97 | 50 | 21 | 99 |
| Prodigy eight | 147 | 145 | 140 | 118 | 134 | 141 | 152 | 146 |
| Percentage rank | 98 | 99.9 | 99.6 | 88 | 99 | 99.7 | 99.9 | 99.9 |
| Child prodigies average scores | 128 | 128 | 126 | 115 | 125 | 118 | 115 | 147 |

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prodigy at eight. His father was a musician. The prodigy reports that both of his parents were sensitive to his artistic talent. By 10 years of age, he could write, play, and produce musical pieces using several instruments. At 17, he toured as the lead guitarist of a well-known rock band. He has written, performed, and produced recordings that went platinum in France, and has a series of internationally renowned albums.

The prodigy became interested in art after a visit to New York's Museum of Modern Art; his artwork is currently on display in prestigious art galleries the world over, as well as within the United Nations building in New York. He continues to produce eminent work in the fields of visual art and music.

*3.1.2.2. Testing.* The prodigy was tested using the Stanford-Binet 5th ed. Intelligence test. Because English is not his first language, only the two sections that did not rely heavily on language were administered: the fluid reasoning section, which is a series of matrices, and the working memory subtests. He scored a 118 on fluid reasoning and a 152 on working memory, which places him at the 88 percentile for fluid reasoning and the 99.9 percentile for working memory. See Table 1 for the second child prodigy's reported IQ scores.

### 3.1.3. Prodigy three

*3.1.3.1. Development description.* The third child prodigy was 18 years old at the time of testing. He is the oldest child of two. His mother reported that he had advanced physical skills and was crawling by four months old and walking purposefully by 10 months of age. At 18 months, he was speaking in complete sentences, and by 22 months he was reading 1st and 2nd grade readers cover-to-cover, sounding out unfamiliar words.

At 28 months, the prodigy's parents gave him a small violin. His mother reports that he demonstrated extraordinary facility with the bow, and unusual agility with his left hand (fingering hand) from the time he began playing. He completed in a month or two tasks that usually take children two years to learn. By four, he had learned all of the Suzuki volumes of classical music. In doing so, he was aided by his prodigious ability in reading music and his almost photographic memory for music. He could hear a song and play it back almost immediately. By five, he was winning regional competitions against much older students, and soon thereafter he made his professional Lincoln Center and Carnegie Hall debuts as a soloist with major orchestras. At seven, he was recognized by the great virtuosos of our time and a pedagogue considered a star maker of violin prodigies took him on as her youngest student. He attended Juilliard's Pre-College. He began to tour nationally by age 13 with a huge repertoire, including several different concerti and concert pieces that he had committed to memory.

*3.1.3.2. Testing.* The prodigy was tested using the Stanford-Binet 5th ed. intelligence test. His full scale IQ was 129, placing him almost two standard deviations above the mean. His score was 141 on working memory, a score at the 99.7 percentile (see Table 1). All of the pair-wise comparisons were done using the S.E. of the Stanford-Binet 5th ed. listed in the manual. Pair-wise comparisons between the five factors found a statistically significant elevation for working memory when compared to the other four subtests of fluid reasoning, knowledge, quantitative reasoning, and visual spatial. Again the difference between fluid reasoning and working memory is found in the normative population only about 1% of the time. When the scores between his NVIQ (122) and VIQ (130) were compared, the difference fell just short of significance at the .05 level. See Table 1 for a complete IQ report.

### 3.1.4. Prodigy four

*3.1.4.1. Development description.* The next musical prodigy was seven years old at the time of testing. He is the older of two children from an intact family in the Midwest. His mother reports normal gross motor development. He began to walk at about 13 months of age and produced his first words around the same time. After that, his developmental track accelerated. By 15 months, he was speaking in full sentences, and he began to read at 2 years and 3 months of age. After his family received a DVD of a classical performance, he became fascinated with classical music and watched the DVD repeatedly. At age three, he began to reproduce from memory on the piano the music he had watched. He began to take lessons with a local instructor at three years and six months. He committed over 100 pages of music to memory with little effort within the first few months. He has played at Carnegie Hall and had a guest appearance on CBS's *Early Show*. He enjoys playing for benefits and with his local symphony.

*3.1.4.2. Testing.* The prodigy was tested using the Stanford-Binet 5th ed. intelligence test. His full scale IQ was 142, nearly three standard deviations above the mean. He scored a 146 on working memory, placing him at the 99.9 percentile in this test. All of the pair-wise comparisons were done using the S.E. of the Stanford-Binet 5th ed. listed in the manual. His working memory score was significantly higher beyond the .05 level than his quantitative reasoning and visual spatial skills scores. It was not significantly higher than his fluid reasoning or knowledge scores. The difference in his working memory and visual spatial scores is only found in about 6% of the normative population. His VIQ and NVIQ were not significantly different. See Table 1 for a full IQ report.

### 3.1.5. Prodigy five

*3.1.5.1. Development description.* The next musical prodigy was nine years of age at testing. She is the youngest of three children from an intact family in the Midwest. She is not from a musical family, no one in her immediate family plays a musical instrument. She began reproducing music at the age of two while visiting with her grandmother. By three, she was formally composing. She had her first lesson a week before her 5th birthday. She began to perform professionally at the age of five and has played internationally since the age of six. She has appeared repeatedly on CBS, ABC, NBC and Fox News. When she was six, she performed at the White House. She has written and produced original musical work. She is currently nine years old and touring internationally.

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*3.1.5.2. Testing.* The prodigy was tested using the Stanford-Binet 5th ed. intelligence test. Her full scale IQ was 121. She demonstrated an extraordinary working memory, scoring a 152, which places her over three standard deviations above the mean. All of the pair-wise comparisons were done using the S.E. of the Stanford-Binet 5th ed. listed in the manual. A comparison between the factor scores found working memory was significantly higher than all four of the other factors at the .05 level. The discrepancies found are rare when compared to the standardized population with each sub test occurring less than 2% of the time. There was no significant difference between this prodigy's VIQ and NVIQ. See Table 1 for a complete IQ report.

### 3.1.6. Prodigy six

*3.1.6.1. Development description.* The sixth prodigy was 15 years of age at the time of testing. He began earning money playing his violin at the age of seven. He has played at jazz festivals in Europe and the United States and is best known for his ability to improvise and create music. He has not had any formal composition lessons. At nine years of age he won an award from ASTA (American String Teachers Association) for the best improvisations in the under 13 category. He also won the award from the American Embassy in Hungary for excellence in musical performance. He has done the scoring for three films and is the youngest person to perform with Wynton Marsalis at Lincoln Center.

*3.1.6.2. Testing.* The prodigy had a full scale IQ of 108, placing him at the high end of the normal range, and an extraordinary working memory of 149. His working memory score was significantly higher than all of the other factors at the .05 level. The frequency of the differences reported below are rarely found in the standardized population with the discrepancy between working memory and visual spatial abilities reported less than 0.3% of the time. There was not a significant difference between the NVIQ and VIQ. See Table 1 for complete IQ scores. All of the pair-wise comparisons were done using the S.E. of the Stanford-Binet 5th ed. listed in the manual.

### 3.1.7. Prodigy seven

*3.1.7.1. Development description.* At the time of testing, prodigy seven, a self-taught painter, was nineteen years of age. Although she had been interested in arts and crafts for as long as she could remember, she did not begin to paint until she was 13 years old. She said she was inspired by a young art prodigy she saw on television. After just eighteen months of painting, the prodigy won the National Gold Key award, the most prestigious art award given to high school students, at the age of 15. She was one of 50 recipients of the award across the country. At nineteen, her work is selling for thousands of dollars and is displayed in prestigious art museums around the world.

*3.1.7.2. Testing.* Prodigy seven was tested using the Stanford-Binet Intelligence 5th ed. Her full scale IQ was 112 which is the high end of the normal range. The prodigy scored a 139 in working memory. Her working memory score was significantly higher beyond the .05 level when compared to the other four factors. The most notable difference was between working memory and visual spatial (50 points) which is reported less than .03% of the time in the standardized population. The results for prodigy seven did not find a significant difference between NVIQ (112) and VIQ (112). See Table 1 for complete IQ scores. All of the pair-wise comparisons were done using the S.E. of the Stanford-Binet 5th ed. listed in the manual.

### 3.1.8. Prodigy eight

*3.1.8.1. Development description/ce:section-title>*The prodigy was thirteen at the time of testing. He is the oldest of three children in an intact family in the Midwest. His mother reports a very difficult pregnancy. She started labor nine times between the 29th and 37th weeks of her pregnancy and required medication to stop the labor. During the 35th week of her pregnancy, her water broke and she had a 105-degree fever from an infection in her uterus. The child prodigy did not have a soft spot at delivery.

The prodigy said his first words at three months of age and knew the entire alphabet by eight months of age. He produced short sentences at nine months. He began reading before one year of age and memorized the atlas between eleven and fourteen months of age. At eighteen months of age, he stopped talking and avoided eye contact. He was diagnosed with autism at the age of three. He began to speak again at two years and eight months. His parents report that details are very important to him. He insists on accuracy. For example, during a lecture he attended at a local university when he was three, he corrected the lecturer about the exact distance from Mars to Earth. He began taking classes offered at the university at age eight and at the age of nine was admitted to the university. He tested out of college calculus, astronomy and U.S. history. He has developed a new discipline in mathematics and, at the age of thirteen, had a paper accepted for publication in a mathematics journal.

*3.1.8.2. Testing.* This prodigy had a full scale IQ score of 147, placing him over three standard deviations above the average score of 100. His working memory, visual spatial abilities, knowledge and quantitative reasoning were significantly higher than fluid reasoning at the .05 level. His visual spatial score was significantly higher than knowledge at the .05 level. The discrepancy between working memory and fluid reasoning is found less than 4% of the time in the standardized population, as is the difference between visual spatial and fluid reasoning. The prodigy did not have a significant difference between VIQ and NVIQ scores. All of the pair-wise comparisons were done using the S.E. of the Stanford-Binet 5th ed. listed in the manual. See Table 1 for a full report of IQ scores.

## 3.2. Aggregate prodigy results

### 3.2.1. Development description

All of the eight child prodigies began to display unique talent at a very early age and consistently had an accelerated path to high levels of achievement. Of the eight tested prodigies three had a diagnosis of Autism Spectrum Disorders and four of the eight families reported ASD diagnoses in first or second degree relatives, with three of the four families

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reporting multiple members in their families with autism. The three families report a total of eleven first or second degree relatives with an autism spectrum diagnosis.

#### 3.2.2. Stanford-Binet testing

The full scale average IQ scores for the seven child prodigies who completed the assessment was 128 and the scores ranged from 108 to 149. This data supports Feldman and Morelocks statement that only moderately enhanced general intelligence is necessary in the case of some child prodigies.

The only consistently enhanced sub-test on the Standford-Binet was working memory with an average score of 147 and a range of 139–152. This data supports part of Vanderverts theory on child prodigies as being reliant on enhanced working memory but calls for refinement on his statement that child prodigies are also dependent on enhanced visual spatial abilities. As a group the average on visual spatial abilities was 115 with a range of 71–152. See Table 1 for child prodigies average IQ scores.

#### 3.2.3. AQ testing

The child prodigies' total average AQ score, a number derived from the five sub-tests, was a 22.38. A 22.38 total average AQ score places the prodigies between the total average AQ score of the control group (16.4) and that of the group with high functioning autism or Asperger's syndrome (35.8) of the Baron-Cohen et al. (2001) sample. A one-sample *t*-test between the child prodigies and the control group supported child prodigies as significantly higher on the AQ $t(7)=3.30$, $p<.01$ when compared to the controls. The child prodigies scored higher on every sub-category of the AQ than the control group but not at a significant level and they scored lower on every sub-category of the AQ than the HFA/Asperger's syndrome individuals, with one exception: attention to detail. Within this sub-category of the AQ, the child prodigies scored higher than both the control group and the HFA/Asperger's syndrome individuals. The results of a one-sample *t*-test between the control group established by Baron-Cohen and the child prodigies for attention to detail $t(7)=6.42$; $p<.001$ support that the child prodigies were significantly higher in that category when compared to the control group. See Table 2 for average scores on the AQ for all eight child prodigies.

## 4. Discussion

The prodigies consistently displayed several traits during testing: an elevated level of general intelligence and exceptional working memory, both as measured by the Stanford-Binet Intelligence test, and a spike in attention to detail, as measured on the AQ. The prodigies' family pedigrees, moreover, yielded an over-representation of relatives with autism. This paper will discuss each of these findings, and their implications for understanding the underpinnings of prodigious performance, in turn.

### 4.1. Elevated intelligence

The average full scale intelligence score as measured on the Stanford-Binet 5th ed. was in the gifted range (see Table 1). The full scale IQ scores ranged from 108 to 147 with a mean of 128 ($X=128$, $SD=15.30$) Thus while five of the prodigies scored in the 90th percentile or above, one scored at the 70th percentile and another at the 79th percentile. These data support the suggestion by Feldman and Morelock (2011) that, in the case of at least some prodigies, a modest elevation in general intelligence is sufficient to support their prodigious talent.

### 4.2. Exceptional working memory

In addition to having at least a modest elevation in general intelligence, each of the prodigies demonstrated exceptional working memory. The range in working memory scores for the eight child prodigies tested was 139–152 with a mean score of 147 ($X=147$, $SD=5.32$). Each prodigy scored well above the general population mean of 100; on average, the prodigies scored over three standard deviations above the mean for working memory. Every prodigy scored in the 99th percentile on this measure; all but two of the prodigies scored in the 99.9th percentile.

This finding is consistent with the results of a previous child prodigy case study in which the prodigy scored a 158 in working memory on the Stanford-Binet 4th edition (Ruthsatz & Detterman 2003). It similarly aligns with a previous account of child prodigies that gave an in-depth descriptive account of Erwin Nyiregyhazi and a historical description of Mozart, both of whom the author characterized as having exceptional memories for musical pieces (Revesz, 1925).

**Table 2**
Mean and *SD* for AQ with sub scale scores by group.

| | | Communications | Social | Imagination | Details | Attention | Total | Switching AQ |
|---|---|---|---|---|---|---|---|---|
| *Group 1* | | | | | | | | |
| HFA/AS | *X* | 7.2 | 7.5 | 6.4 | 6.7 | 8.0 | 35.8 | |
| (n=58) | *SD* | 2.0 | 1.9 | 2.1 | 2.3 | 1.8 | 6.5 | |
| *Group 2* | | | | | | | | |
| Controls | *X* | 2.4 | 2.6 | 2.3 | 5.3 | 3.9 | 16.4 | |
| (n=174) | *SD* | 1.9 | 2.3 | 1.7 | 2.3 | 1.9 | 6.3 | |
| *Group 3* | | | | | | | | |
| Prodigy | *X* | 2.5 | 3.1 | 3.7 | 8.5 | 4.8 | 22.4 | |
| (n=8) | *SD* | 1.2 | 1.3 | 2.3 | 1.9 | 1.9 | 5.2 | |

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While these results evidence exceptional working memory among the prodigies, the statements of one child prodigy regarding his memory raise the possibility that the prodigies not only have exceptional *working* memory, as captured by the Stanford-Binet sub-tests, but also exceptional *long-term* memory. This child prodigy reported that at times he pretends that he does not remember things because people seem uncomfortable with the clarity of his recollections. "People assume I must be thinking about them 24/7 when I am not," he explains, "it's just that I can remember every detail of the past." Such statements suggest that, at least in the case of this prodigy, the exceptional working memory captured by the Stanford-Binet may work in conjunction with an equally excellent long-term memory. More research, including additional testing, needs to be done to explore this possibility.

### 4.3. Autistic traits

Perhaps the most striking data, however, was that which identified autistic traits among the prodigies and brought to light the prevalence of autism in the prodigies' families.

The prodigies had an over-representation of autism in their families. Autism occurs in 1 in 120 individuals. Of the eight prodigies, four of the families either have an autism diagnosis themselves or have a first- or second-degree relative with an autism diagnosis. A prodigy in a previous study, moreover, also had an autistic second-degree relative.

This finding dovetails with the results of a previous study that compared the families of child prodigies to the families of children with autism and the families of a control group using the AQ (Ruthsatz, 2007). The first-degree family members of autistic individuals and the first-degree relatives of child prodigies reported the broader phenotype for autism in three of the five categories on the AQ: social skills, attention switching, and attention to detail.

The prodigies themselves, however, showed a slightly different AQ profile. While the prodigies thus showed a general elevation in autistic traits as compared to a control group, this elevation was, on average, even slighter than that of those with the high functioning/Asperger's diagnoses. In fact, the prodigies displayed only a very minimal level of many of the deficits commonly associated with autism. But the prodigies tested differently in one particular subcategory of the AQ: attention to detail, where the prodigies average score was higher than both the control group *and* the HFA/Asperger's syndrome group. It is important to note that the three child prodigies with an autistic diagnosis are not driving the scores in attention to detail. The three have an average of 8 in that sub category while there is an overall score of 8.5 for the entire group of child prodigies.

The prevalence of autism in the prodigies' families combined with the prodigies' elevated scores on attention to detail suggest significant new common ground between child prodigies and another group of exceptional performers: autistic savants. Both child prodigies and autistic savants present a paradox—extreme talent—when and where it should not exist. Based on the child prodigies' AQ scores and family histories, it appears that both groups also have a connection with autism.

The two groups share many other similarities. Like child prodigies, savants display elevated attention to detail (Baron-Cohen, Ashwin, Ashwin, Tavassoil, & Chakrabarti, 2009), exceptional memories (Treffert, 2010; Nettelbeck & Young, 1996), and display their talents in specific rule-based fields (Feldman & Morelock, 2011; Nettelbeck & Young, 1996). Despite the small sample size it moreover is also worth noting that both savants and the child prodigy sample evince a skewed gender split: both groups include far more males than females. The eight child prodigies assessed for this study plus the child prodigy assessed in the 2003 pilot study (Ruthsatz & Detterman, 2003) include seven male and two females, a 3.5:1 ratio similar to that reported in the autistic population (Treffert, 2010).

But while autistic savants display many of the deficits commonly associated with autism, the child prodigies do not. One possible explanation for the child prodigies' lack of deficits is that, while the child prodigies have a form of autism, a biological modifier suppresses many of the typical signs of autism but leaves attention to detail—a quality that actually enhances their prodigiousness—undiminished or even enhanced. This possibility offers the first potential look at a moderator for autism. Additional research is required to investigate this possibility.

### 4.4. Other factors

Equally revealing are the traits that the child prodigies did not consistently display: visual spatial skills, ten years of deliberate practice time, and, potentially, domain-specific skills.

Contrary to Vandervert (2009), the child prodigies did not consistently display extraordinary visual spatial skills. The seven prodigies who took the visual spatial assessment obtained a wide range of scores, from a 71 (3rd percentile) to a 152 (99.9th percentile). Three other prodigies scored in the 94th percentile or better, while two others scored below the 25th percentile. Elevated visual spatial ability thus does not seem necessary to display prodigious talent.

Many of the prodigies, moreover, displayed their extreme talent before reaching ten years of age, undercutting the nurture-based theories that credit contemporary training techniques and upwards of ten years of deliberate practice as the root of all exceptional achievement (see Howe, 1990; Ericsson, 1996; Ericsson et al., 1993). All of the prodigies in the current study began to display extraordinary achievement at a very young age. In addition, two of the prodigies in the current study switched domains and were quickly able to reach exceptional levels of performance.

The development descriptions, moreover, universally credit the child, as opposed to the parents, with pushing their own talent forwards (Ericsson, 1996).

Further testing is needed to see if child prodigies' talents are the product of domain-specific skills, as proposed by both Ruthsatz and Detterman (2003) and Feldman and Morelock (2011) or a more general construct such as working memory which can transfer across several rule based systems. Two of the assessed prodigies switched domains, displaying the same extraordinary talent in the new field as they had in the initial field: one from music to cooking, and the other from music to art.

## 5. Conclusion

The prodigies consistently displayed an elevated level of general intelligence and exceptional working memory and

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attention to detail. The exceptional attention to detail combined with the over-representation of autism in the prodigies' families suggests a link between prodigiousness and autism. The fact that the prodigies operate without many of the deficits commonly associated with the condition, however, suggests the presence of a modifier of some sort that prevents the child prodigies from displaying these deficits. The existence of such a modifier could have significant benefits for the autistic community. Additional research should be conducted to explore this possibility and identify any such moderator.

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