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The cognitive bases of exceptional abilities in child prodigies by domain: Similarities and differences

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ABSTRACT

Child prodigies are defined as those individuals who reach a professional level of achievement in a culturally relevant domain before the age of 10 or adolescence. Although child prodigies are often the object of historical wonder and modern day awe, because of the difficulty involved with assembling a large sample of prodigies, until recently, little was known about the source of their achievements. Recent studies have begun to tackle this enigma, and a few traits have surfaced as key underpinnings of prodigiousness across domains: an average or higher IQ, extraordinary working memory, and a heightened attention to detail. The present study investigated whether the prodigies' cognitive profiles differed according to their area of specialty. Using the Stanford Binet 5th ed. intelligence test the investigator assessed the cognitive profiles of 18 child prodigies across the domains of art, music, and math. The results suggest that prodigies in each domain have distinct cognitive profiles. While all of the child prodigies had exceptional memories, the music and math prodigies scored significantly higher on working memory than the art prodigies. The math prodigies displayed the highest levels of general intelligence and extraordinary visual spatial skills. The art prodigies displayed a surprising deficit in visual spatial skills, obtaining scores much lower than both the math prodigies and music prodigies. The differences in the prodigies' cognitive underpinnings across domains may have implications for the general population.

1. Introduction

Child prodigies, most commonly defined as children who reach professional levels of achievement in a culturally relevant domain before the age of ten (Feldman, 1986) or before adolescence (McPherson, 2006), generally specialize in one of just a few fields, most commonly art, music, math, and chess. Recent research has suggested that their precocious abilities hinge on elevated IQ, extraordinary memory, and exceptional attention to detail, regardless of the domain in which they specialize (Ruthsatz & Urbach, 2012). Until recently, however, prodigy studies have lacked sufficient numbers to consider whether and how the profiles of child prodigies across various domains might differ from one another. Using a sample of 18 prodigies, the present study investigates whether the prodigies' cognitive profiles differ in significant ways across domains.

Children who can accomplish seemingly impossible feats have always generated significant scientific and popular interest. But, until recently, relatively little was known about what allowed them to perform so brilliantly, so early in life. Early accounts of child prodigies were descriptive case studies, leaving us with more questions than answers about how someone so young could be so exceptional (Revesz, 1925; Ruthsatz & Detterman, 2003).

Despite the lack of data about prodigies, several researchers suggested theoretical frameworks that might account for the prodigies' unusual abilities. Based on a historical examination

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of Mozart as well as a contemporaneous child prodigy case study, Revesz (1925) postulated that music prodigies rely on high IQ and exceptional music memory, the latter of which is today considered a domain specific skill. Detterman and Ruthsatz (1999) argued that all exceptional performance could be explained by the Summation Theory, which posits that general intelligence, domain specific skills, and practice time all play a critical role in developing extraordinary talent. A later study supported this theory, finding that professional musicians had significantly higher IQs, increased domain specific skills, and greater amounts of practice time than amateur high school musicians (Ruthsatz, 2000). After initially theorizing that prodigies were the product of domain specific skills (1986), Feldman, too, suggests that exceptional talent is the product of both domain specific abilities and general intelligence (2011).

A recent study by Ruthsatz and Urbach (2012), combined with an older study by Ruthsatz and Detterman (2003), provided the first data against which to consider whether these theories of exceptional performance might apply to child prodigies. The two studies together included nine child prodigies, eight of whom had risen to considerable acclaim in art, music, or mathematics. The ninth prodigy had shown promise as a music prodigy before becoming a cooking prodigy specializing in a science-based method of cooking. The investigators administered the Stanford-Binet 4th or 5th ed. intelligence assessment to all of the prodigies and the Autism Spectrum Quotient (AQ) to all but one of the prodigies.

The results of these tests revealed intriguing similarities in the prodigies' profiles across domains. All of the prodigies possessed elevated—but not necessarily extraordinary—IQs. The prodigies had a mean general intelligence score of 128, almost two standard deviations above the mean for the general population. Their overall scores varied fairly widely, from 100 to 147. Their scores on the working memory subtest, however, were consistently exceptional. The prodigies here achieved an average score of 147, over three standard deviations above the mean for the general population. The variance here was much narrower, with the prodigies' scores ranging only from 138 to 152. Finally, the prodigies exhibited a spike in attention to detail on the AQ. They had a mean score of 8.5, a score that was significantly higher not only than that of the non-autistic population, but also than those with Asperger Syndrome. This finding, combined with the prodigies' significant number of close family members with autism, led the authors to suggest a possible tie between prodigious ability and autism.

Due to the relatively small sample involved in these studies, however, the question of whether the prodigies' profiles differed across domains remained open. While no one had previously collected data on this question, in a recent chapter in The Handbook of Intelligence, Feldman and Morelock (2011) suggest that, from a theoretical standpoint, math and physics prodigies might need a relatively higher IQ than other types of prodigies, while for art prodigies, a high IQ might actually act as an impediment. In the present study, the investigators use data on the cognitive profiles of 18 prodigies—the largest sample of child prodigies ever assembled—to examine whether the prodigies' cognitive profiles differ across domains. The ensuing analysis suggests that prodigies in different domains possess distinctly different cognitive profiles—a finding with not only significant implications for the prodigies, of course, but also may have implications for the general population.

2. Method

2.1. Participants

The current study deemed a child to have prodigious talent if he or she had achieved national or international acclaim by adolescence. The current study draws on data collected from the nine child prodigies discussed in two previous studies (Ruthsatz & Detterman, 2003; Ruthsatz & Urbach, 2012). These included seven music prodigies, one math prodigy, and one art prodigy.[1] An additional nine child prodigies were recruited for the present study, including one music prodigy, four math prodigies, and four art prodigies. Together, this resulted in a sample of eight music prodigies, five math prodigies, and five art prodigies. This sample includes 13 males and 5 females. Four of the five females are art prodigies; the fifth is a music prodigy. At the time of testing, the prodigies had an average age of 13, with a range of 6 to 32.

2.2. Procedures

The investigator identified child prodigies through news coverage and by referral. In the seventeen cases in which the prodigy was still a minor, the investigator initiated contact with the prodigies' parents. The investigator contacted the prodigy who had already entered adulthood directly. The parents of the 17 child prodigies who were still minors at the time of contact supplied descriptive accounts of their early development. The prodigy who had already reached adulthood supplied his own developmental history.

All of the child prodigies were individually tested in their homes or at a location of their choosing. Sixteen of the child prodigies were tested using the Stanford-Binet 5th ed. full scale intelligence test. In the case of the child prodigy whose first language was not English, the investigator administered only those sections of the Stanford-Binet 5th ed. full scale intelligence test that were not heavily reliant on language: the fluid reasoning and working memory subtests. The child prodigy tested as part of the 2003 investigation was assessed using the Stanford-Binet 4th ed. full scale intelligence test.

3. Results

The average full scale Intelligence score was obtained for 17 of the 18 child prodigies (see Table 1). The child prodigies as a group had an average score of 126, almost two standard deviations above the mean. Their scores varied widely, ranging from 100 to 147. The range was narrower, however, when prodigies within particular domains were considered separately. The math prodigies had an average score of 140, with a range from 134 to 147. The music prodigies had an average score of 129, with a range from 108 to 142. The art prodigies had an average score of 108, with a range from 100 to 116. A Post Hoc analysis on the three domains found a difference between groups for the average full scale intelligence score. The math prodigies and the music prodigies' scores were significantly higher than the scores of the art prodigies. There was not a

[1] One of the prodigies that I have included in the music cohort showed prodigious musical talent before switching his focus to molecular gastronomy, a science-based method of cooking.

Table 1
Average Stanford-Binet scores by domain.

		N	Mean	SD	Effect size
FSIQ standard score***	Art	5	108.4	6.07	
	Music	7	129.14	11.23	
	Math	5	139.8	5.50	
	Total	17	126.18	14.99	$\eta^2 = .74$
FR standard score*	Art	5	100.6	3.91	
	Music	7	116.14	12.29	
	Math	5	125.4	19.1	
	Total	17	114.29	15.82	$\eta^2 = .39$
KN standard score**	Art	5	111.8	14.15	
	Music	6	125.5	11.20	
	Math	5	139.6	9.18	
	Total	16	125.63	15.70	$\eta^2 = .52$
QR standard score**	Art	5	101.6	11.76	
	Music	7	119.86	12.98	
	Math	5	132.8	6.87	
	Total	17	118.29	16.23	$\eta^2 = .58$
Visual spatial standard score***	Art	5	88	6.00	
	Music	6	116.67	24.25	
	Math	5	142.2	10.01	
	Total	16	115.69	26.88	$\eta^2 = .68$
WM standard score*	Art	5	132	6.36	
	Music	8	148.38	5.52	
	Math	5	134.8	15.52	
	Total	18	140.06	11.77	$\eta^2 = .43$

Note.
* p < .05 on One-Way ANOVA.
** p < .01 on One-Way ANOVA.
*** p < .001 on One-Way ANOVA.

significant difference between the full scale intelligence scores of the math and music prodigies.

A One-Way ANOVA revealed that the groups differed statistically on all five of the Stanford-Binet subtests. The smallest, though still statistically significant, effect was found on the fluid reasoning subtest $F(14,2) = 4.55$, $p = .03$, $\eta^2 = .39$. Post hoc analysis revealed that the math prodigies scored significantly higher than the art prodigies. There was not a significant difference between the music prodigies and the math prodigies or between the music prodigies and the art prodigies.

The child prodigies as a whole had an average knowledge subtest score of 126, with scores ranging from 91 to 151. There was a significant difference between groups $F(13,2) = 7.11$, $p = .008$, $\eta^2 = .52$. A post hoc comparison found that the math prodigies scored significantly higher than the art prodigies. There was not a significant difference between the music prodigies and the math prodigies or between the music prodigies and the art prodigies.

The child prodigies as a group had an average quantitative reasoning score of 118, with scores ranging from 86 to 141. The difference between groups was significant $F(14,2) = 9.84$, $p = .002$, $\eta^2 = .58$. A post hoc analysis revealed that both the math and the music prodigies scored significantly higher than the art prodigies. There was not a significant difference in quantitative reasoning between the math prodigies and the music prodigies.

The child prodigies as a group had an average visual spatial score of 116, with scores ranging from 71 to 152. The difference between groups was significant $F(13,2) = 13.71$, $p = .001$, $\eta^2 = 68$. The post hoc comparison revealed the most surprising trends: The math prodigies and the music prodigies scored significantly higher than the art prodigies. The art prodigies not only scored lower than the math and the music prodigies, but they also scored significantly lower than the average score for the standardized sample reported using a one sample *t* test: $t(4) = -4.72$, $p = .011$).

On the final subtest, working memory, the child prodigies as a group had an average score of 140, almost three standard deviations above the average. Despite this extraordinary average score, differences persisted between the prodigies in the three domains. The difference between groups was $F(15,2) = 5.69$, $p = .01$, $\eta^2 = .43$. The musicians had the highest level of working memory, and a post hoc test revealed that their scores were significantly higher than those of the art prodigies. The difference between the music prodigies' scores and the math prodigies' scores was marginally significant.

4. Discussion

As discussed above, it appears that all prodigies share certain characteristics, including an at least average general intelligence score, an extraordinary working memory, and a heightened attention to detail (Ruthsatz & Urbach, 2012). Across domains, however, the present investigation revealed significant differences in the prodigies' cognitive profiles.

The math prodigies had higher levels of general intelligence than the music or the art prodigies ($M = 140$, $SD = 5.50$). They also scored extraordinarily well on both the visual spatial subtest ($M = 142$, $SD = 10.01$) and the working memory subtest ($M = 135$, $SD = 15.15$).

Surprisingly, the art prodigies displayed a deficit in visual spatial skills ($M = 88$, $SD = 6.00$), scoring below average for all test takers, with a range of 82 to 94 as measured by the

Stanford-Binet. A possible explanation for this seemingly counter-intuitive result may be found by considering the work of Milbrath (1998). The author suggests that talented young artist perceive objects differently than less talented young artist and use figurative processes which focus on attention to detailed surface features. Additionally, talented young artists are able to remember those details when drawing. Milbrath (1998) calls this the “seeing, remembering, and doing” hypothesis. Less talented young artist seems to depend on operative thought processes, which bias the artist to use a categorical approach to art. As Milbrath (1998) suggested after working with young artists, children who are skilled at art view the world in a distinct way and their keen ability to focus their attention on details and to remember those details provides them with a predisposition to be talented in the art domain. Additionally, the artist may have scored a deficit in visual spatial skills as reported by the Stanford-Binet because the test highlights operative talent at the expense of figurative talent.

In contrast to the math prodigies' high general intelligence scores, the art prodigies tested closer to average on the full scale test ($M = 108$, $SD = 6.07$), with a range of 100–116. The art prodigies did, however, share the extraordinary working memory of the math prodigies, a trait that has been observed in non-prodigy artists (Dennis, 1992), and that, in combination with the artists' heightened attention to detail (Ruthsatz & Urbach, 2012), likely aids their efforts to reproduce objects and scenes. Anecdotally, one of the art prodigies explained that she uses her extraordinary memory to pull up images in her mind when painting. She said that she could even remember how shadows fell on an object and paint the scene from memory.

While all of the child prodigies had extraordinary working memories ($M = 140$, $SD = 11.77$) the music prodigies had significantly higher working memory scores ($M = 149$, $SD = 5.53$) than the art prodigies ($M = 132$, $SD = 6.36$). Their scores were higher to a marginally significant level than those of the math prodigies ($M = 135$, $SD = 15.52$). The music prodigies seem to employ this extraordinary memory in learning their craft. Every music prodigies' parents reported that their child began to reproduce from memory music that they had heard; the ability to read music came later in their development.

While child prodigies are incredibly rare, the fact that their cognitive profiles differ by domain has profound implications for the way general intelligence and domain specific skills interact not just in prodigies, but also in the general population, to predispose individuals toward certain fields. The data converges with Feldman and Morelock (2011) and Detterman and Ruthsatz's (1999) argument that all exceptional achievement is best understood from a multivariable approach in which general intelligence, domain specific skills and practice influence achievement, suggesting that these same factors also influence career path. It suggests the need for additional research into the cognitive profiles of high-achieving non-prodigies in art, music and mathematics to assess if there are natural predispositions coupled with life experiences that incline individuals toward certain career paths in the normally developing population.

References

Dennis, S. (1992). Stage and structure in the development of children's spatial representations. In R. Case (Ed.), *The mind's staircase: Exploring the conceptual underpinnings of children's thought and knowledge* (pp. 229–245). Hillsdale, NJ: Lawrence Erlbaum.

Detterman, D. K., & Ruthsatz, J. M. (1999). Toward a more comprehensive theory of exceptional abilities. *Journal for the Education of the Gifted*, *22*, 148–158.

Feldman, D. H. (1986). *Nature's gambit: Child prodigies and the development of human potential.* New York: Basic Books.

Feldman, D. H., & Morelock, M. J. (2011). Prodigies and savants. In R. Sternberg, & S. Kaufman (Eds.), *The Cambridge handbook of intelligence* (pp. 210–234). New York, NY: Cambridge University Press.

McPherson, G. E. (Ed.). (2006). *The child as musician: A handbook of musical development*. Oxford, UK: Oxford University Press.

Milbrath, C. (1998). *Patterns of Artistic Development in Children.* Cambridge: University Press.

Revesz, G. (1925). *The psychology of a musical prodigy.* New York: Harcourt Brace ((1989). published 1942).

Ruthsatz, J. (2000). *Predicting expert performance within the musical domain: A test of summation theory (doctoral dissertation) ProQuest Dissertations and Theses.*

Ruthsatz, J., & Detterman, D. K. (2003). An exceptional memory: The case of a musical prodigy. *Intelligence*, *31*, 509–518.

Ruthsatz, J., & Urbach, J. (2012). Child Prodigy: A novel cognitive profile places elevated general Intelligence, exceptional working memory and attention to detail at the root of prodigiousness. *Intelligence*, *40*(5), 419–426.