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# Savant Syndrome: A Review of Research Findings

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# **Savant Syndrome: A Review of Research Findings**

by

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## Chapter I: Introduction

Autism is a neurobiological developmental disorder that occurs along a spectrum (Rimland, 1978). Autism spectrum disorders (ASD) have long been defined by three significant characteristics: deficits in social interaction, impairments in communication, and manifestation of restrictive/repetitive traits and/or motor movements (American Psychiatric Association [APA], 2000). When Leo Kanner (1943) first described the syndrome of autism, he also observed that some children had special or unusual talents and skills in addition to severely limited communication and social abilities. *Autistic savant syndrome* is the most common term used to refer to children with autism who display such special or unusual talents (APA, 2000).

Children with autistic savant syndrome have a so-called “island of genius” in 1 of 5 general areas: music, art, calendar calculating, mathematics or mechanical/visual-spatial skills (Treffert, 1989). It is generally accepted that approximately 10% of individuals diagnosed with autism fall within the savant category (Rimland, 1978) and that there are approximately five males for every one female with savant skills (Kaufman, 2014). Although individuals with other developmental disabilities have been known to display savant skills, these skills are most closely associated with ASD (Heaton & Wallace, 2004). The purpose of this starred paper is to describe the research conducted with individuals with autism who have savant skills. Specifically, I focus on three areas of savant skills: art/drawing, numeracy, and musical skills.

## Overview of Savant Syndrome

Individuals with savant skills were first mentioned by Down in 1887. He used the term *idiot savant* to describe individuals who were intellectually impaired with unusual abilities. At this time, the term *idiot* was the accepted classification system for individuals with an IQ less than 25 (Hallahan, Kauffman, & Pullen, 2009). Today, these individuals may be referred to as *monosavants* if they have a splinter skill in one particular area. This is the most common type of savant (Straus, 2014). The term *savant syndrome* is typically used, although technically this term refers to individuals with multiple exceptional skills (Heaton & Wallace, 2004).

Savant skills are always characterized by exceptional memory, particularly within specific domains (Heaton & Wallace, 2004; Straus, 2014). Calculating skills are observed in calendar calculating or the ability to calculate large numbers or prime numbers—and may occur even when individuals are unable to complete simple arithmetic tasks. Mechanical or spatial skills include the ability to measure distances precisely without instruments and the ability to accurately construct complex models or maps, as well as other direction-finding skills (Wallace, 2008). Other savant skills are also reported such as polyglot (extraordinary language skills), synesthesia (experiencing crossed stimuli—such a “hearing” colors), and exceptional knowledge of a particular topic (Darold & Treffert, 2010).

Treffert (1989) emphasized that just like autism itself, savant skills occur along a spectrum. *Savants with splinter skills* are individuals who are obsessively preoccupied with memorizing facts or sounds. *Talented savants* are those in whom music, art, or other abilities are highly developed, particularly when compared to their disability. *Prodigious savants* are

those very rare individuals in whom the skill is so spectacular, it would be difficult to find such a skill in a developmentally average individual. It is estimated that as few as 50 individuals in the world are prodigious savants (Treffert , 2001).

### **Theoretical Background**

Overwhelmingly, savant skills tend to be a function of the right brain hemisphere that is typified by “concrete, directly perceived” skills (Darold & Treffert, 2010, p. 23).

Neuroimaging studies have revealed that the right hemisphere compensates for left hemisphere damage (Steel, Gorman, & Flexman, 1984). Others have suggested that this compensatory action couples with individual habits of concentration and intense practice as well as reinforcement by adults in the individual’s environment (e.g., Mottron, Dawson, Soulières, Hubert, & Barack, 2010). It is hoped that ongoing improvements in neuroimaging will contribute to a better understanding of brain functioning in persons with savant abilities.

Neuropsychological theories have also been postulated to explain why or how savant skills occur. Wallace (2008) reported that three theoretical models have been most frequently cited to explain the occurrence of savant abilities in some individuals with autism: Weak Central Coherence (WCC), Enhanced Perceptual Functioning (EPF), and Extreme Male Brain Theory (EMB). Each of these theories is discussed in this section.

**Weak Central Coherence Theory.** The theory most frequently cited to explain autistic functioning is the Weak Central Coherence Theory. Frith (1989) observed that individuals with autism are very good at noticing details but very poor at seeing the “big picture.” Their obsession with details and their extremely focused interests make it difficult if not impossible for them to integrate details into a whole to make sense of their world (Roth,

2010). This is the case when young children with autism are unable to identify faces or comprehend context or inferences in text (Burnette et al., 2005). The way individuals with autism process information is referred to as *local or detailed cognitive processing*, which contrasts with *global cognitive processing* (Frith, 1989). Lack of central processing results in deficits in language and socialization, and in some may result in advanced skills in mathematics or engineering (Burnette et al., 2005).

The performance of individuals with autistic savant syndrome on the Block Design subtest of the Wechsler Intelligence Scales and the *Embedded Figures Task* (EFT; Shah & Frith, 1993) has been cited to support the WCC theory (Burnette et al., 2005; Wallace, 2008). The object of the Block Design test is to arrange nine cubes that are half-red and half-white, divided diagonally. The cubes must be arranged to match a pattern presented on the page, and individuals with savant syndrome consistently complete this task more quickly and more accurately than control subjects. The EFT requires individuals to find a simple image or shape that is embedded somewhere in a picture or a jumble of lines that is designed for distraction. Those who process information in parts rather than the whole would do better at these two tests (Burnette et al., 2005).

The performance of individuals with autistic savant syndrome on some verbal-spatial tasks has also been cited to support the WCC theory. For example, when individuals were presented with homographs (words with identical pronunciation but different meanings), they were unable to use the words in context compared to a comparison group (Happé, 1997). They could not process information in its context. These types of difficulties also contribute to problems with social interaction (Burnette et al., 2005).



**Enhanced Perceptual Functioning Theory.** The Enhanced Perceptual Functioning (EPF) theory has also been developed to explain savant skills. This theory holds that superiority of low-level perceptual operations contributes to savant cognitive operations, not global versus local information processing (Mottron, Dawson et al., 2006). These lower-level visual and auditory discrimination skills interfere with the development of higher-level perceptual skills.

This theory is based on the key role of atypical perception and memory in the cognitive functioning of individuals with savant skills. Commonly, individuals with autism often display enhanced perceptual abilities when they work on visual search, visual discrimination, and embedded figure tasks. This theory suggests that the visual system is a much stronger sensory processing mechanism than in non-autistic individuals (Mottron, Dawson et al. 2006).

**Extreme Male Brain Theory.** The Extreme Male Brain Theory is a third theoretical model postulated by Baron-Cohen (2002) to explain savant skills in individuals with autism. In this theory, “male brain” and “female brain” are concepts used to explain gender differences in cognition (Baron-Cohen, 2002, p. 235). According to this theory, infants are exposed to excessive testosterone in utero.

In developing this theory, Baron-Cohen (2002) cited the ratio of males to females with autism. He also cited studies that reported that males overall are stronger in skills such as mathematical reasoning, finding a part within a whole, mental rotation, some spatial skills compared to females, who perform stronger in measures such as empathy, social judgment, ideational fluency, verbal fluency, and fine motor coordination.

In this theory, individuals with autism are viewed as *systemizers* as opposed to *empathizers*. According to Foden and Anderson (2010), overall males are more adept at systemizing, or analyzing or constructing systems that follow predictable rules. On the other hand, females overall are thought to be better empathizers, or able to identify others' thoughts and feelings. Foden and Anderson suggest that individuals with autism may be *hyper-systemizers*. Also, the Extreme Male Brain Theory is supported by the findings of high fetal testosterone concentrations. Many developmental psychologists asserted that a link between autism and testosterone exists. According to Baron-Cohen (2006), children who had been exposed to high concentrations of testosterone as a fetus are more likely to exhibit autistic traits. Recently, more researches have been conducted to examine the association between high fetal testosterone levels during pregnancy and autistic traits in children.

Like these three theoretical hypotheses, the occurrence of savant abilities is commonly related to the neuropsychological or cognitive brain mechanisms. Even though a number of researches have been proposed to explain the causation of savant skills, there is still no theory that can account fully for why and how savant syndrome develops.

### **Research Questions**

Three questions were investigated in this review of literature:

1. What research has been conducted to evaluate the performance of individuals with autism who demonstrate savant musical skills?
2. What research has been conducted to evaluate the performance of individuals with autism who demonstrate savant numeracy skills?

3. What research has been conducted to evaluate the performance of individuals with autism who demonstrate savant artistic skills?

### **Focus of the Paper**

In Chapter II of this paper, I review nine studies that examined research pertaining to the savant skills of children, adolescents, and adults with autism. Specifically, I examine the research literature in three savant areas: art, music, and numeracy. Two to three studies in average were selected to illustrate the research in each of these three areas. Quantitative and qualitative research studies from 2003 to 2015 were included for review. Both domestic and international studies were included.

I began my search using the Academic Search Premier and PsycINFO databases. Several terms and combinations of terms were used to search for articles and studies including *savant syndrome*, *high-functioning autism*, *exceptional skills*, *splinter skills*, and *music/art/numeracy savants*. I also searched the table of contents of *Autism and Development Disorders*.

### **Importance of the Paper**

Ten percent of children with autism purportedly have savant skills (Treffert, 2014). Although the condition is relatively rare, it is a condition that fascinates researchers and the public. Different theories have been developed to explain this phenomenon, but at this time, they have not reached consensus.

I also find this topic to be a fascinating topic. When I lived in Korea and volunteered in a middle school, I met a student who had savant skills. He had the ability to memorize the names and models of cars and trucks, as well as possessing savant calendar skills. I met with

him every day in the library, and he shared information on these topics with me. At that time, I thought he must be a genius, but then I learned he was receiving special education services.

When I was a senior in college and in my educational studies, I learned about savant syndrome and realized this student was not a genius but instead had savant splinter skills.

As part of my studies at St. Cloud State University, I have been learning about a variety of disabling conditions and how they affect the lives of students and families. I hope that more of our Korean teachers will acquire such knowledge so that students can be included in our general education classrooms.

### **Definitions**

**Autism.** The Individuals with Disabilities Education Improvement Act of 2004 (IDEIA, 2004) defined as:

a developmental disability significantly affecting verbal and nonverbal communication and social interaction, usually evident before age 3 that adversely affects a child's educational performance. Other characteristics often associated with ASD are engagement in repetitive activities and stereotyped movements, resistance to environmental change or change in daily routines, and unusual responses to sensory experiences. The term does not apply if a child's educational performance is adversely affected because the child has an emotional disturbance. [34 C.F.R. 300.8(c) (1)]

**Proband.** A term used most often in medical genetics and other medical fields to denote a particular subject (person or animal) being studied. The proband is "the individual in a family whose genetic disorder forms the center from which an investigation into the prevalence of the disorder in the rest of the family is started" (Psychology Dictionary, n.d.).

**Receiver operating characteristic (ROC) curves.** In statistics, a receiver operating characteristic (ROC), or ROC curve, is a graphical plot that illustrates the performance of a binary classifier system as its discrimination threshold is varied. The curve is created by

plotting the true positive rate (TPR) against the false positive rate (FPR) at various threshold settings (Xiaofei, Junling, & Stephen, 2013).

**Self-regulation.** Executive function and self-regulation skills are the mental processes that enable us to plan, focus attention, remember instructions, and juggle multiple tasks successfully. Executive function and self-regulation skills depend on three types of brain function: working memory, mental flexibility, and self-control. These functions are highly interrelated, and the successful application of executive function skills requires them to operate in coordination with each other (Hallahan et al., 2009).

**Subitize.** To perceive the number of (a group of items) at a glance and without counting (Ansari, Lyons, van Eimeren, & Xu, 2007)

## Chapter II: Review of the Literature

The purpose of this paper was to examine the research literature in individuals with three savant areas: music, numeracy and art. In this chapter, findings of nine studies are reviewed that address performances and characteristics of children and youth with autism who have savant skills. Summaries are organized in ascending chronological order and organized according to the three-savant skills area.

### Musical Savant Studies

Individuals with savant syndrome can also possess extraordinary skills in the area of music. Some individuals with musical savant skills can play a song on a musical instrument after hearing the music just once. Others have perfect pitch. In this section, three studies were reviewed to examine musical savant abilities.

Brown et al. (2003) conducted a study to examine the autism-related language, personality, and cognition in individuals with absolute pitch (AP). They speculated that the AP abilities were related to the cognitive and social characteristics of ASD. To examine this, 13 musicians with strictly defined AP and 33 musician controls (MC) without AP were assessed by the standardized interviews and tests. Participants with AP were recruited from a music-related department, and the MCs were members of a local volunteer orchestra. The age of APs ranged from 20 to 69, and the age of MCs were ranged from 18 to 76.

The AP and MC groups conducted the interviews and five tests. First, during a 45-min interview, the participants completed the *Modified Personality Assessment Schedule* (PAS; Tyrer and Alexander, 1988) that assessed rigidity, aloofness, anxiety/

worry, and hyper-sensitivity. Second, one of the experimenters completed the *Pragmatic Rating Scale* (PRS; Landa et al., 1992) by observing social aspects of language such as the ability to greet and chat, follow a conversational turn, and discuss a various topic. Last, participants were assessed using four performance subtests of the *Wechsler Adult Intelligence Scale-Revised* (WAIS-R; Wechsler, 1981): Block Design, Picture Completion, Object Assembly, and Digit Symbol. Based upon participants' communication style and nonverbal behavior, they were classified as *socially eccentric*, *somewhat eccentric*, or *not eccentric*.

The mean scores of the AP group were almost double the mean of the MC group on the PRS and PAS (AP group: PRS mean = 5.69, PAS mean = 4.92; MC group: PRS mean = 5.69, PAS mean = 2.45). During these interviews, 46% of the AP group and 15% of the MC were classified as socially eccentric ( $p < .03$ ). The participants displayed severe impairments in communication and social behaviors, which are typical of high-functioning autism or Asperger's syndrome. This result suggests that the musicians with absolute pitch had some of the personality, language, and cognitive characteristics associated with autism.

On the WAIS subtests, participants in the AP group performed similarly to individuals with ASD in that they scored much higher on the Block Design test than other subtests. In the MC group, minimal differences were between the Block Design and other subtests. According to the researchers, these data support the hypothesis that individuals with AP are more likely to manifest autism-related characteristics.

With these findings, Brown et al. (2003) concluded the gene of AP possessors might be among the genes that contribute to autism. The researchers demonstrated the importance of heredity and environment in the development of AP. On the other hand, the study is limited by the small sample of AP subjects. With the small number of the AP possessors, it is difficult to generalize to others in the AP population.

Bonnel et al. (2003) assumed that individuals with autistic savant syndrome excelled at pitch categorization because of a greater sensitivity to sounds than typical individuals. To test their assumption, the authors developed two psychoacoustic tasks: pitch discrimination and categorization. Twelve high-functioning individuals with autism and 12 normally developing individuals were assessed via an audiometric screening test and two experiments with a professional audiologist. To represent their performance on these tasks, receiver operating characteristic curves (ROC curves) were used. The ROC curve is a basic tool for diagnostic test evaluation. It is a plot of the true positive rate against the false positive rate for the different possible cut-points of a diagnostic test.

**Experiment 1: Pitch discrimination.** Pitch discrimination tasks were assessed at first. Pairs of two 100-msec long pure tones were presented one by one. The frequency of the first tone pair was 1 of 4 values: 500, 750, 1000, or 1500Hz. The frequency of the second tone pair was same, with the first tone or higher than that. When the second tone was different, the frequency of second tone was 1%, 2%, or 3% higher than the first tone. After listening to a series of pairs of tones, participants



responded whether the tone pairs were the same or different. A 1-sec silent interval occurred between the first and second tone.

According to the observed ROC curves in each condition (1%, 2%, and 3% higher frequency), the group of high-functioning individuals with autism performed much better in two easiest conditions (3% and 2%). For the most difficult condition that was 1% higher than first tones' frequency, no significant difference was observed between two groups. In all three conditions, sensitivity on the tasks of high-functioning individuals was significantly superior to normal individuals ( $p < .05$ ).

**Experiment 2: Pitch categorization.** To determine whether high-functioning individuals with autism had high sensitivity on high/low pitch categorization tasks, a 1000-Hz pure tone served as the low reference tone with 1.5-sec intervals. One of the two tones was 3%, 2%, or 1% higher than the other tone. Participants had to answer to the question about which tone was high or low.

The group of high-functioning individuals showed superior performance to the group of normal-developing individuals in all three conditions (3%, 2%, and 1%). In addition, the sensitivity of the high-functioning group was also higher than normal developing group in all conditions.

In this study, high-functioning individuals with autism were strongly sensitive at pitch processing and less sensitive to change-of-task requirements. This indicates the AP possessors use a similar cognitive strategy when they engaged in the two different pitch discrimination tasks. Also, the AP possessors can recognize the difference

between the two tasks much more easily, and they can adjust to the different tasks quickly.

Loui, Li, Hohmann, and Schlaug (2010) investigated the musical savant skills of individuals with autism, especially absolute pitch (AP) ability. According to Japanese researcher, Miyazaki (1988), AP is a special ability that can subitize any given pitch without reference. Because AP is so rare, it is usually described as musical gift. The researchers assumed that AP maybe affected by extended brain connectivity. In general, the loss of connection in a brain (hypo-connectivity) causes poor performance at the perceptual, learning, or productive tasks. On the other hand, the extended connectivity in brain (hyper-connectivity) leads to outstanding performance at such tasks.

Twelve AP musicians and 12 non-AP musicians participated in various experiments after completing IQ and language tests. Researchers obtained information regarding first language, other languages they spoke, musical instruments they played, and onset age of musical performance.

**Experiment 1.** AP testing was conducted through a listening test in which subjects had to identify 52 sine wave tones. After listening, participants were asked to write down the letter name of each given pitch. Results revealed a significant difference between AP possessors and the control group. The mean performances of AP possessors was 97% (range = 92-100%), whereas the mean performance of the control was 36% (range = 19-77%). AP possessors were superior at pitch categorization ( $t_{(22)} = 5.8$ ,  $p < .001$ ).

**Experiment 2. Image acquisition.** Using a *3-T General Electric Scanner*, the authors obtained anatomical brain images to determine differences in brain structure between AP possessors and non-AP possessors. From this experiment, they could observe connectivity and volume of tracts in the brains of individuals with savant abilities. Fiber tracts are a bundle of nerve fibers having a common origin, termination, and brain function. The fiber tracts connected from the posterior superior temporal gyrus to the posterior middle temporal gyrus were analyzed for all participants.

Results showed a positive correlation between the number of left tracts and absolute pitch ability. In other words, a person who had greater connections in the left superior temporal lobe performed better and more accurately at naming pitch. The results showed that AP possessors had higher volume and fiber number of the tracts than non-AP possessors ( $F_{(1, 44)} = 16.6, p < .001$ ). The sum of left and right tracts volume was significantly larger in AP group than non-AP group ( $t_{(22)} = 3.9, p < .001$ ). Moreover, the AP group showed higher number of fiber tracts than the non-AP group ( $t_{(22)} = 2.4, p < .05$ ), and these fiber tracts were one-sided in the left hemisphere. These data confirm the authors' hypothesis that AP musicians have hyper-connected brain structures linked to AP possession. Furthermore, early musical training contributed to larger volume of left hemisphere tracts. This suggested that environmental factors could also affect the development of the pitch categorization ability.

## Numeracy Savant Studies

Without counting, accurate measurement of a large number of objects is difficult for most people. Some individuals can measure a large number of objects without counting. Other individuals can quickly calculate a particular date in the distant future or a decimal fraction without hesitation. These individuals have numeracy savant skills. This section includes four studies that examine numeracy savant skills.

Cowan and Carney (2006) investigated the exceptional skills of the individuals with calendrical savant skills. Calendrical savants can calculate dates on the calendar and identify the day of the week a specific date falls on in any given year. Participants included four male adults with autism and calendrical savant skills and John Conway, a distinguished professor of Mathematics at Princeton University with outstanding calendrical skills. Two experiments were conducted as part of this study to determine which process developed and enhanced calendar savant skills: practice or the use of an internalized formula.

**Experiment 1.** To investigate whether the individuals with calendrical savant skills have an internalized formula of calculating dates, participants completed one task that required guessing orally presented 20<sup>th</sup>-century dates and one nomination task. In the first task, the participants received two sets of dates: a set of 20<sup>th</sup>-century dates in a particular period and a set of remote future dates in a particular period. In the nomination task, the participants received eight questions for guessing future years and months. All participants' response times were recorded and compared to those of Professor Conway.

To analyze participants' response time, separate ANOVAs were conducted. The two-way (calculators and periods) ANOVA on the response time showed a significant interaction

between the participants and the period of questions. The four participants' response times varied and tended to slow over time. Yet, Professor Conway's response times were similar over all periods ( $SD = 1.3, p < .003$ ). This difference suggested that Professor Conway used a different calculating method than the four participants with savant calendrical skills. But, when it comes to knowledge of calendrical regularity, the four participants with savant skill were quicker to access knowledge of regularities than Professor Conway, which might result from their obsessive preoccupation with calendars.

**Experiment 2.** To determine whether calendarical savant skills can be developed by practice, researchers conducted an experiment with only one participant with savant skill, GC (1 of the 4 participants). He received the six sets of remote future dates, and all dates in these sets were presented visually and orally over five sessions. GC was presented those six set of questions sequentially, and his performances were observed.

A one-way ANOVA revealed GC's performances became more efficient and more accurate across sets. At the beginning of the task, he solved the questions by writing down several years. By the end of the task, he solved most of the questions by mental calculation and identified the dates even more accurately ( $p < .001$ ). This contributed to faster response times over time ( $F_{(5,105)} = 7.57, p < .0005$ ). The results showed that GC gradually developed his calendrical skills from using time-consuming written methods to the point of using the mental calculation.

The findings of this study support the authors' initial hypothesis that savant calendrical skills were due to practice, not from exceptional cognitive features. Even though the mathematician did not show better performance at finding the calendrical regularities than

the group of savants, he demonstrated his superiority by solving the problem using his own calculation method. Additionally, from the data analysis of the second experiment, the authors demonstrated that, even though the savant skill is innate ability, it could be developed with practice.

Mottron, Lemmens, Gagnon, and Seron (2006) assessed the algorithmic explanation of savant calculation skills in DBC, an 18-year-old male of average intelligence with savant skills. Previous research suggested that calendar calculation is performed by applying algorithms that consist of “successive application of different steps,” that are activated by features such as year, month, and day (Mottron, Lemmens et al., 2006, p. 239).

DBC was able to read and write by age 5 without his parents’ help. He began practicing calendar calculation at about 12 years of age, when he showed exceptional memory for dates and numbers. He could read and write numbers into the millions and could solve simple multi-digit arithmetic problems on paper, but not mentally. He was able to retrieve calendar information with about 88% accuracy when questions were about the years from 1990 to 2000. He became obsessed with calendars in 1990, and for dates prior to this year he had a lower than chance probability of successfully retrieving calendar information. This was also the case for dates after 2002. Two experiments were conducted to assess his skills.

**Experiment 1. Direct questions.** The purpose of Experiment 1 was to determine if DBC’s pattern of response times (RTs, or errors) were distributed systematically. According to Mottron, Lemmens et al. (2006), a calendar algorithm should result in unequal distribution of RTs. Non-algorithmic calendar information would show no difference in error rates. DBC responded to 700 questions in an attempt to determine how he solved the calculation.

Reaction times and answers were recorded. Five 90-min sessions with breaks were conducted over a 2-month period.

**Experiment 2. Reverse questions.** Following Experiment 1, a single 90-min session was conducted to demonstrate whether DBC could solve problems when reversed questions were posed. Commonly, calendar calculators can guess the date of the week when given a certain date. Some calendar calculators are capable of answering reverse questions when given the day of the week. In other words, they are able to calculate with given calendar information by guessing from the day of the week reversely. From DBC's correct responses in Experiment 1, 72 reversed questions were prepared. Of these, 24 had a date as answers (e.g., which day was the second Monday of May, 1992), 24 had months as answers, and 24 had years as answers.

**Experiment 3. Test-retest stability of errors and reaction times.** The purpose of Experiment 3 was to examine if the error of the first experiment predicted the accuracy of the answer to the same question in another session. One year after the first experiment, DBC responded to 39 questions correctly, while he got the forty correct answers on same questions.

Response times for correct answers were used for data analyses; RTs of more than 1 minute were discarded from analysis. Results showed that DBC's success rates for both direct and reverse questions were almost the same, rating 100% on direct questions and 91.7% on reverse questions. He performed better at reverse question tests than direct question tests. Three major findings were reported: (a) estimation of all dates in a year showed random distribution of errors, (b) retesting on the same dates 1 year later showed that DBC's errors did not occur equally for all test sessions, and (c) DBC could calculate dates at three types of

reversed questions. Therefore, the authors concluded DBC's calendar information retrieval did not rely upon typical calculating mechanisms or knowledge of rules or algorithmic processes. They also suggested his long-term memory systems relied on low-level perceptual systems to process information.

Cowan and Frith (2009) investigated the individuals with calendrical savant skills to determine whether they used calculation or memorization skills to answer questions regarding dates. They conducted several experiments with 1 average, typical adult male and 2 males with savant calendrical skills and IQ scores of 97 for GC and 82 for MW.

GC and MW completed arithmetic and calendrical tasks, and a functional magnetic resonance imaging scan (fMRI) was used to figure out abnormalities in savants' brain structure. The control participant completed only the arithmetic task. The experiments were conducted during two sessions. The first session was comprised of the arithmetic task and the first calendrical task. The second session involved the second calendrical task. During both sessions, the MIR was conducted to observe the participants' brain activation or any abnormalities of brain.

**First session.** At the arithmetic task test, participants' accuracies and mean correct response times were scored. The mean percent of accurate responses was high for GC (96%) and MW (97%), and response times were fast (GC:  $M = 4.68$ , MW:  $M = 3.42$ ). However, the control participants also showed short response time ( $M = 2.86$ ,  $SD = 0.86$ ). At the first session's calendrical task, GC and MW were asked dates from the 1940s to 2020s, both participants' responses were highly accurate (97-98%), and their response times were not significantly different. However, from MRI scanning, a difference was observed between the



control subject and the savants. Unlike the control subject, the brain of GC showed an increased parietal activation during the session (MW's data could not be analyzed due to his head movement).

**Second session.** During the second session, the task was divided into three periods by remoteness: close (1970s and 1980), medium (1940s and 2020s), and remote period (1910s and 2050s). Unlike the first session, their mean accuracies generally decreased as the time periods became more remote. Specifically, GC's accuracy for medium and remote dates ( $M = 81$  and  $85$ ) was lower than that for close periods ( $M = 96$ ). Their response times also increased as the remoteness of year increased. According to data analysis of log response times, response times varied with remoteness of years (GC:  $F_{(2,141)} = 24.22, p < 0.0005$ ; MW:  $F_{(2,174)} = 67.70, p < 0.0005$ ). Moreover, the MRI brain scanning revealed a correlation between participants' response time and brain activity in the parietal cortex. According to this, their neural activity of brain increased when the date remoteness increased. This indicated that they solved the problem using a mental calculating method showing an excessive brain activity. The authors concluded from these findings that the calendrical savant skills result from intensive practice or calculation, not from brain abnormalities brain. Instead of the abnormality of brain structure, the authors suggested that savants' exceptional skills on calendar calculation resulted from intensive practice with calendar using mental calculating methods. Also, their findings help researchers to understand why the calendrical savants took longer to answer questions about more remote dates.

Soulières et al. (2010) conducted eight experiments with two 9½ -year-old children with autism spectrum disorder and savant skills. G.T. and K.T were tested for estimation of

rank, numeracy, time, weight, length, surface, distance, and precise enumeration for small numbers. G.T. displayed extraordinary calculation and estimation abilities and had a good command of language. But, he talked primarily about factual information, which resulted in difficulty communicating with others. K.T. also had outstanding estimation skills. He had below-average skills in attention, speech and language, working memory, and long-term memory.

In addition to G.T. and K.T., participants included a comparison group of six children matched in age, gender, and IQ. The mean age of all comparison children was 11.1 years and mean IQ was 110. Computerized and non-computerized tasks were alternated to assess eight estimation skills and to determine if skills were different between the two groups. Each task required approximately 5 min to complete. Prior to each task, participants were trained to complete the task, but received no feedback. Each participant completed all eight tasks within 1 or 2 days. *t* tests were used to analyze data.

**Experiment 1: Small numerosities.** In this computerized task, participants had to identify how many squares were presented on a screen by responding quickly and accurately. G.T and K.T had a similar to pattern of error and response time as the comparison group.

**Experiment 2: Numerosity of ordering.** Participants were required to compare and rank two sets of squares, one on the left side of the computer screen and the other on the right. Twenty pairs of stimuli were presented. This resulted in pairs such as “131 versus 143” and “135 versus 149” (p. 267). Participants had to indicate which side contained more squares by pressing appropriate a response key.

G.T. produced 68% correct responses, in contrast to comparison responses of 66.4%. K.T. had 82% correct responses, which was significantly different from the comparison group ( $t = 2.01, p = .05$ ).

**Experiment 3: Estimation of numerosity.** Stimuli were presented on the computer screen and consisted of small squares with numerosities from 1 to 150. The squares were presented on the screen in random during 3-s intervals. Participants were told they would not have time to count the squares and that they had to estimate.

No significant difference was reported between G.T.'s performance and the comparison group until larger numerosities were presented. For segment from 16 to 60, his performance was significantly inferior to comparison participants ( $t = 4.23, p = .004$ ). K.T. also tended to overestimate numerosities, but his performance was not significantly different from comparison group performance of 48%. However, his performance was much more variable.

**Experiment 4: Elapsed time estimation.** Participants were instructed to estimate in seconds the length of time between two auditory signals. G.T. outperformed all participants, but the difference was not statistically significant. Even when G.T. was distracted from the task by conversing with other or reading a chapter book, his performance was the best. No significant differences were reported between K.T.'s performance and the comparison group.

**Experiment 5: Weight estimation.** Participants had to verbally guess the weight of 12 goblets according to large, small, light, and heavy. The goblets were placed into participants' hands and they were instructed to estimate weight without moving it. G.T.'s performance on the task exceeded the performance of the comparison group. G.T.'s deviation

rate was 31%, compared to the comparison average rate of 230%. K.T.'s performance was 160%.

**Experiment 6: Length estimation.** Participants were required to estimate the length of straight and curved segments. Segments were placed randomly in front of each participant, who was asked to estimate length without touching it. G.T.'s performance was exceptional compared to comparison groups. His deviation rate was the lowest of all participants, especially for straight lines. On this task, he estimated the closest in 4 of 5 trials. However, because of high variability among comparison participants no statistical difference was reported for either straight or curved lines. K.T.'s performance fell within the normal range and did not differ significantly from the control group.

**Experiment 7: Surface estimation.** Participants had to estimate verbally the surfaces of various gray shapes drawn on white sheets. Rectangles, ellipses, and complex geometric shapes were presented. G.T.'s mean deviation rate for estimating rectangles was 9.3%, for complex shapes, it was 10.1%, and for ellipses, it was 25.1%. This result was much higher than comparison participants' result, whose deviation rate for rectangles was 98.9%, ellipses was 72% and complex figures was 93.7%. These differences were significantly different ( $t = 2.21, p = .04$ ). K.T. did not complete the task because it was too difficult for him.

**Experiment 8. Estimation of distance in a natural setting.** Five straight lengths and two circumferences were represented at various distances. Participants estimated distances verbally without walking to measure the distance. Results revealed that the mean deviation rate of the comparison group was 25.9% ( $SD = 8$ ) for straight distances and 37.7% ( $SD = 16$ ) for circumferences. G.T.'s performance was markedly superior to all participants,

with a 14.3% average deviation rate. However, K.T.s mean deviation rate was similar to comparison participant, with 33.1% for straight lines and 42% for circumferences.

As hypothesized, children with autism showed subitizing abilities. Findings of these estimation experiments showed that G.T. outperformed all participants on 7 of 8 experiments. G.T. presented remarkable estimation of quantity. He scored highly in most of the tasks, especially estimating numerosity, surface, and distance. However, his estimation of rank was in normal range. On the other hand, K.T. performed similarly to the comparison group on quantity estimation, but he displayed outstanding ability at estimating rank. Outcomes for both participants in the precise enumeration task show that subitizing is not the mechanism they used to perform the tasks.

These results suggest that some individuals on the autism spectrum do have superior and highly outstanding skills in estimation/calculation. Soulières et al. (2010) discussed these findings in relation to “veridical mapping,” which is the concept that precision does not decrease for larger magnitudes” (p. 274). This was the case for control group participants. G.T. and K.T. were more accurate and more linear in their estimates even at larger magnitudes. Therefore, they relied upon veridical mapping and not subitizing to perform estimation tasks.

### **Artistic Savant Studies**

Savants demonstrated genius and exceptional skills not only in math and music, but also in art. These skills include outstanding drawing ability and visual memory, although less research has been conducted in this area. In this section, two studies are reviewed.

Crane, Pring, Ryder, and Hermelin (2011) investigated the executive abilities of nine children with ASD. Executive functions have to do with managing oneself and self-regulating one's behavior in order to achieve a goal. All were diagnosed as a graphically gifted savant or artistic savant, 5 were diagnosed with autism, 3 with Asperger syndrome, and 1 with atypical autism. The 7 males and 2 females ranged in age from 23 to 43 ( $M = 34.55$ ,  $SD = 5.13$ ).

The nine individuals with artistic savant skill were compared individually with participants in two non-talented comparison groups. The first comparison group included nine adults with a formal diagnosis of ASD and no artistic talent. The second comparison group included eight adults with general learning difficulties but without ASD or a related pervasive developmental disorder. Experiments were conducted individually in a quiet room at the participants' day center.

**Experiment 1. Design fluency task.** This task was contrived to examine the executive function of individuals who have language difficulties using a nonverbal analogue. The task was implemented in two conditions: free and fixed. During the free condition, participants were asked to draw as many designs or patterns as they could in 4 minutes. The purpose of the free-condition setting was to examine monitoring and perseveration when the experimenter provided negative feedback in the form of a warning for each mistake. After a break, participants participated in the fixed condition task. During this condition, participants were instructed to complete the same task, but each response had to contain only four single lines that did not have a sharp corner (e.g., a circle, curve, or spiral). All responses were scored by overall fluency, perseverative responses, and novel responses. The overall fluency

is the total number of responses that included errors. The perseverative responses indicated the repeats of visually similar responses, and the novel responses were the number of novel or acceptable responses in each condition.

**Experiment 2. Wisconsin Card Sort Task (WCST).** The WCST (Grant & Berg, 1948; Heaton, 1981) included two packs of 64 cards and four stimuli cards that differed in color, shape, and number. Participants had to classify a pack of cards following a rule that was not revealed by experimenter. After placing the cards, the experimenter informed them whether participants classified the cards correctly or incorrectly. When the participant classified the six cards correctly, the experimenter changed the rule (color, shape, and number) without informing participants. So, from the next trial, participants had to perceive this change using the experimenter's feedback.

ANOVAs were used to analyze design fluency data by condition (free or fixed) and group (savant, ASD or MLD). In total number of responses, the savant artists and MLD groups produced a significantly higher number of responses than the ASD group ( $t_{(17)} = 3.23$ ,  $p < .01$ ). No significant group differences were reported on the measure of the perseverative responses, although the savant artists produced a significantly higher percentage of the acceptable novel responses than the ASD group ( $t_{(17)} = 2.07$ ,  $p < .05$ ).

The researchers concluded the savant artists performed better than the ASD comparison group on the fluency and monitoring. But, the savant artists showed better in perseveration at the design fluency task. This result showed that the non-talented individuals with ASD had deficits in this fluency and monitoring executive functions, whereas the savant artists had enhanced executive abilities. With regard to the card sort task, a series of one-way

ANOVAs indicated there were no significant group differences. The performances of the savant artists were not significantly different from those of ASD and MLD groups.

Although this study identified fluency and monitoring as two executive abilities of the savant artist through the design fluency task, the study failed to discriminate between groups in the card sort task. The WCST was not sensitive enough to discriminate between the groups. This finding indicates the WCST cannot be used to assess the executive function of individuals who have low levels of intelligence (such as participants in the savant group)

Pring, Ryder, Crane and Hermelin (2012) established four groups to investigate the issue of creativity in artists with savant skills. Participants included 9 savant artists with ASD, 9 talented art students, 9 non-art talented with ASD, and 9 with mild/moderate learning difficulties. The savant artists included 5 with autism, 3 with Asperger syndrome, and 1 with atypical autism. The savant artists were A-level art students and selected by their art teacher in school. In a quiet room, participants were asked to perform two experiments to examine creativity.

The first task used the incomplete repeated figures tasks of the *Torrance Test of Creative Thinking* (TTCT; Torrance, 1971). Participants received 10 meaningless squiggles and had to produce new picture with each squiggle. For the repeated figure task, participants received 10 sets of parallel lines that were three different widths apart (two sets at 8 mm apart, four sets at 13 mm, and four 20 mm apart). With these sets of line, participants were asked to make a representational and named picture. All TTCT tasks were scored by four measures: flexibility, fluency, elaboration, originality.



For the second task, individuals completed the *Figure Synthesis Task* (FST, Finke & Slayton, 1988) to examine subjects' creativity outside of the savants' domain of expertise. Eight shapes, five common shapes (square, triangle, rectangle, circle, semi-circle), and three uncommon shapes (a cross, letter J, figure eight) were given to participants. They had to respond at the four different conditions in 5 minutes. For example, they were instructed to make and name a new picture that "looked like real ones" with two given shapes (Pring et al., 2012, p. 51). Participants' performances were evaluated by measure of fluency (total/recognizable) and originality.

The authors used ANOVAs and *t* tests to analyze TTCT and FST data. The TTCT results showed that creativity of art talented students was superior to the other three groups (savant, ASD, and MLD) on all four measures. However, in a measure of elaboration, the responses of savant group were more elaborate than ASD and MLD groups. According to the authors, this suggests that elaboration is an important domain in savant artistic talent.

On the FST, the savant and art-talented groups produced significantly more original outputs than the ASD ( $p < .01$ ) and MLD ( $p < .01$ ) groups. At the same time, the performances of the savant and art-talented group were scored similarly on the measure of originality. But, the art-talented students responded more frequently than the savant group ( $t = 2.29, p < .05$ ). Relatively, the savant group produced less original responses on the TTCT than FST. They showed high originality on FST. The authors surmised that this inequality arose from different definition and measurement of originality.

This study contradicted the typical stereotype of the savant artist. Commonly, it was thought that all individuals with savant skill would show superiorities in all art domains.

However, the author of this study provided evidence that the savant artists were not much better than other comparison groups at artistic creativity.

## Chapter II Summary

Chapter II provides a review of nine studies that examined the performance of individuals with savant skills in music, math (numeracy), and art. These findings are summarized in Table 1 and discussed in Chapter III.

Table 1: Summary of Chapter II Findings

AUTHORS	PARTICIPATION	PROCEDURE	FINDINGS
Musical Savants			
Brown et al. (2003)	13 musicians with strictly defined absolute pitch (AP) in autistic disorder and 33 musician controls (MC) without AP	Participants were assessed with standardized interviews and tests (included <i>Pragmatic Rating Scale</i> , <i>Personality Assessment Schedule</i> , and WAIS performance subtest) to identify the broad autism phenotype seen in the relatives of autistic probands.	Participants who were musicians with absolute pitch (AP) represented some of the personality, language, and cognitive features associated with autism.
Bonnel, Mottron, Peretz, Trudel, Gallun, & Bonnel (2003)	Two groups of 12 high-functioning individuals with autism and 12 normally developing individuals	A “same-different” discrimination task and “high-low” categorization task were used to assess high-functioning individuals with autism and normally developing individuals.	Subjects with autism had higher pitch sensitivity, with a more pronounced advantage over control participants in categorization tasks.
Loui, Li, Hohmann, & Schlaug (2010)	12 absolute pitch (AP) musicians and 12 non-AP musician controls	Participants completed a behavioral screening questionnaire to understand their language and musical background, the <i>Shipley-Hartford Retreat Test</i> , AP Testing, and Image Acquisition using a 3-T General Electric Scanner.	Absolute pitch musicians have hyper-connectivity in bilateral superior temporal lobe structures linked to AP possession. In addition, a volume of tracts connecting on specific parts of brain had relevance with AP performance.
Numeracy Savants			
Cowan & Carney (2006)	Four autistic male adults with calendrical savant were compared with a mathematician in Experiment 1. One participant with calendrical savant	In Experiment 1, all participants had to answer to the question when asked a date of remote future years. In Experiment 2, one of the participants was asked to answer to the question for remote future date, and his development was observed.	The findings from this study were consistent with the previous view that calendrical savants develop their ability through practice.

	was assessed with Experiment 2.		
Mottron, Lemmens, Gagnon, & Seron (2006)	An 18-year-old teenager with autistic savant skills and normal intelligence was assessed.	Testing of all dates in a year (including direct questions and reserved questions) and re-testing were conducted.	Calendar calculators used a non-algorithmic retrieval of calendar information. Solving problems in a non-algorithmic way were characterized as savant performances.
Cowan & Frith (2009).	A typical adult male and 2 two males with savant calendrical skills (GC and MW) were assessed.	Participants completed a mental arithmetic and calendrical tasks 1 and 2. MRI scanning was conducted to observe their brain structure.	The exceptional calendrical skills of savants resulted from their intensive practice or calculation, not from abnormalities of brain structure.
Soulieres, Hubert, Rouleau, Gagnon, Tremblay, Seron, & Mottron (2010)	2 children ages 9-9.5 years old with ASD and extraordinary abilities in estimation and 6 typically developing children	Computerized and non-computerized experiments were alternatively assessed to participants within 1 or 2 days and included 1 to 8 experiments.	Certain individuals with ASD may develop superior and highly specialized abilities in estimation.
Artistic Savants			
Crane, Pring, Ryder, & Hermelin (2011)	9 graphical gifted savants with ASD were compared with non-talented adults with ASD or MLD.	To explore an executive ability (fluency, perseveration and monitoring) in savant artists with ASD, the participants were assessed with a <i>Design Fluency Task</i> and <i>Wisconsin Card Sort Task</i> (WCST) on two conditions: free and fixed.	From only the design fluency task, the participants with artistic savant showed the enhanced executive abilities compared than the non- talented ASD group.
Pring, Ryder, Crane, & Hermelin (2012)	9 savant artists with ASD, 9 non-talented adults with ASD, 8 non-talented adults with MLD, 9 artistically talented students, and 9 non-artistically talented students	Participants conducted <i>Torrance Test of Creative Thinking</i> (TTCT) and <i>Figure Synthesis Task</i> (FST) to examine their artistic creativity.	A creativity of art talented students was superior to the groups of savant, ASD, and MLD. But, as for elaboration, the savant group showed more elaborated responses than other groups.

### **Chapter III: Conclusions and Recommendations**

What research has been conducted to evaluate the performance of individuals with autism who demonstrate three domains of savant skills? These were the research questions I addressed when conducting this literature review. In Chapter I, I discussed background information regarding autism and savant syndrome, as well as theoretical models that have been developed to explain savant skills. In Chapter II, I summarized nine studies between 2003 and 2012 and reported the findings of each study. In Chapter III, I present conclusions I derived from the literature review, recommendations for future research, and implications for current practice.

#### **Conclusions**

Findings are discussed according to the type of savant skill.

**Musical savant studies.** Individuals with autism who have musical savant skills have a greater sensitivity on pitch and sound than control group (Bonnell et al., 2003; Brown et al., 2003; Loui et al., 2010). Bonnell et al. (2003) proved that individuals with savant absolute pitch showed a strong sensitivity at pitch processing. Also, all three studies supported the hypothesis that musical savants would be superior in pitch processing to the normal control group. Loui et al. (2010) reported there were physical differences in brain structure between the savant group and control group, which were determined by using an MRI.

*Numeracy savant studies.* Individuals with calendrical calculation savant skills could develop their ability through intensive practice (Cowan & Carney, 2006; Cowan & Frith, 2009; Soulieres et al., 2010). Although many types of numeracy savant skills exist, multiple studies

were based on subjects who represented calendrical calculation skills (Cowan & Carney, 2006; Cowan & Frith, 2009; Mottron, Lemmens et al., 2006; Soulieres et al., 2010).

Unlike the MRI image acquisition finding reported by Loui et al. (2010), Cowan and Frith (2009) discovered no differences in brain structure between savant group and normal group. Another difference is with regard to group composition. That is, unlike the three studies that collected data from group samples, Mottron, Lemmens et al. (2006) conducted experiments with one teenager who had autistic savant skills.

**Artistic savant studies.** Two studies investigated savant skills in the artistic domain (Crane et al., 2011; Pring et al., 2012). Crane et al. discovered savant artists had more enhanced executive abilities than the control group, and Pring et al. (2012) demonstrated that savant artists do not perform better than the control group in all domains. According to these finding, the creativity of savant artists was not superior control group. Instead, Pring et al. reported that savant artists were superior to control group in elaboration (precise, detailed aesthetic expression), and this can be seen in the features of autism.

**Summary.** Individuals with autism who have savant skills have innate ability that is enhanced by personal practice. With practice, they showed greater development of savant skills. In each study, most of the individuals were superior to the subjects in a control group.

### **Recommendations for Future Research**

Previous research was conducted using short-term studies and showed that some individuals with savant syndrome had strongly developed skills even during the course of the study (Cowan & Carney, 2006). Further long-term research studies should examine the development of savant skills over time.

Brown et al. (2003) suggested that the samples of the previous research were too small to represent all savants' characteristic. Of course, it is not easy to find out an individual who has extraordinary savant skills, given the low prevalence rate. Studies with more participants could allow researchers to examine the correlation between subjects' performance and their age and include age-matched groups. .

Loui et al. (2010) recommended that much more research is needed with regard to brain function and savant ability. The studies in this literature review examined a small area of the human brain (Cowan & Frith, 2009; Loui et al., 2010). However, we have so much to learn about the brain, and technology that is more sophisticated may provide researchers with this opportunity. Future research needs to the hyper-connectivity in savant's brain.

I noticed that most of the studies were based on population samples from America or Western countries and that were no studies from Europe or the East Asia. It would be interesting to determine if there are differences in individuals from various regions of the world.

### **Implications for Current Practice**

This literature review definitely helped me understand the characteristics of individuals with savant syndrome. Prior to conducting this review, my understanding of the topic was vague and undefined. I regarded the individuals with autistic savant syndrome as a kind of genius. My thinking has now changed completely. In my experience, many general education teachers feel as I once did. This is particularly true in Korea, where more students with various disabilities are included in Korean schools and teachers lack the background

knowledge they need. I am more interested in learning how to provide an educational program that can support these students in educational programs in Korea.

### **Summary**

This literature review described the savant abilities of individuals with autism and explored how these skills were developed. In an attempt to understand savant syndrome, researchers compared individuals with savant skills to control subjects who also had advanced skills but were not diagnosed with autism. Using a high level of scientific technique, such as Brain Magnetic resonance imaging (MRI), researchers have learned much about savant syndrome. But there is so much yet to learn. I hope the more developed scientific technology will enable researchers to make many breakthroughs in this field and make more.

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