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How Well Do We Understand Autistic Savant Artists: A Review of Various Hypotheses and Research Findings to Date

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The authors investigated the artistic characteristics of autistic savant artists, hypotheses on the proximate and ultimate causes of their emergence, recent psychological and other studies about them, and psychological and neuroaesthetic studies about non-savant autistic individuals. The artistic features of autistic savant artists were significantly similar to those of outsider artists. Furthermore, the authors investigated the explanatory power of the paradoxical functional facilitation theory, the superior visual perception hypothesis, the "Hmmmmm" hypothesis, and the Neanderthal theory of autism regarding the emergence of autistic savant artists. In addition, we investigated whether an increase in savant characteristics was related to a decrease in the ability for social communication. The authors suggested that in studies on the aesthetic experience of non-savant autistic individuals, their aesthetic experience ability is never lower than that of neurotypical individuals and that some non-savant autistic individuals may potentially have artistic talent. Finally, the authors reviewed the effectiveness of the "autism savant spectrum syndromic disorder" proposed by some researchers. More scientific and systematic studies on autistic savant artists from a multidisciplinary perspective are warranted.

Keywords: Autism; Savant artist; Outsider art; Neanderthals theory of autism; Raw perception; Neuroesethetics; Otherness; Evolutionary perspective.

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INTRODUCTION

In recent years, the portrayal of savants with autism spectrum disorder (ASD) in some films, TV shows, and novels has attracted much social attention. The activities of some autistic savant artists have significantly contributed to changing the prejudice against individuals with autism. An example is Stephen Wiltshire, a British painter who looks down from helicopters over famous metropolitan cities around the globe, such as New York, London, and Rome, and draws the cityscape in great detail in a matter of days from only that short memory.

However, not all individuals with autism are savants. However, there is a high prevalence of savants among individuals with autism. One study reported a concordance rate of approximately 50% between savant syndrome and ASD [1], and another study reported that about 30% of individuals with ASD exhibited savant traits [2]. In addition, lower prevalence rates have been reported. A study reported approximately 1 in 200 individuals with ASD to be savants [3]; however, the study was criticized for underestimating the actual prevalence.

Among savants, savant traits are often prominent in cognitive areas such as memory, science, and mathematics; however, there are many cases in which savant traits are prominent in other areas, such as drawings, music, theater, and other fields of art. Stephan Wiltshire, as mentioned earlier, is active in the field of drawing. In the field of music is Glenn Gould, a master performer of Bach's music for piano, who was known to have had a high possibility of Asperger syndrome, although there was no clinical diagnosis during his lifetime [4]. It is difficult to list all autistic savant artists because of their number. In the modern "hyper-connected society," the general public can easily find and enjoy paintings, performance videos, and performance materials by famous autistic savant artists owing to the availability of the internet and SNS.

However, even though autistic savant artists are encountered much more frequently than before, studies focusing intensely on them are still rare. Currently, studies on savants target autistic savants across various talents. There has been gradual research on special features in autistic savants or individuals with non-savant autism in Korea [5,6]. However, few studies have focused on individuals with autism who exhibit artistic savant traits.

What do savant artists and non-savant autistic individuals exhibit? What hypotheses exist for the emergence of autistic savant artists, and what studies have been conducted? What are the results of psychological and neuroscientific research directly or indirectly related to these artistic savant traits? Should non-savant autistic individuals be understood differently from autistic savant artists? If so, would non-savant autistic individuals have aesthetic judgment ability or aesthetic artwork ability that is lower than that of neurotypicals? We aimed to address these issues in the review.

DEFINITION AND CHARACTERISTICS OF AUTISTIC SAVANTS

It is necessary to summarize the definition of "savant" across the category of autistic savants to investigate the various characteristics of autistic savant artists.

According to the literature, there exist records of individuals with extraordinary memory and exceptional calculation skills in Germany and the United States at the end of the 18th century. However, the first systematic depiction of savant syndrome was made by the British physician John Langdon Down in 1887 [7]. He presented 10 cases of patients with special abilities at the Medical Society of London. These individuals had special musical, arithmetic, or outstanding memorizing abilities, whereas development in other parts of the brain was markedly slow. Down created the term "idiot savant" [7].

However, savant is defined and used differently from the similar term, "genius." Camulli et al. [8] considered the possession of "paradoxical special skills amidst discernible disability or handicap" the most important characteristic when defining savant syndrome. Although Treffert [9] used the word "genius" to define savant, he expressed it as "...a rare, but extraordinary, condition in which individuals with serious mental disabilities, including autistic disorder, have some 'island of genius'..." [10]. In other words, having a handicap but paradoxically having extraordinary talent is commonly used in the two definitions mentioned above. The expression "genius" is also limited to the phrase "island of genius."

As for autistic savant artists, there seems to be no unique definition that differs from the general definitions of autistic savants. Therefore, we believe that the characteristics of autistic savants defined by Camulli et al. [8] and Treffert [9] should be included first in the definition of autistic savant artists.

Treffert [7] summarized the characteristics of the savant syndrome into eight types, as follows:

1) The condition is rare but one in 10 autistic persons show some savant skills.

2) Males outnumber females in autism and savant syndrome.

3) Savant skills typically occur in an intriguingly narrow range of special abilities.

4) There is a spectrum of savant skills.

5) The special skills are always accompanied by prodigious memory.

6) Savant syndrome can be congenital or it can be acquired.

7) Savant skills do not fade or disappear; rather a pattern of replication to improvisation to creation is often seen.

8) No single theory can explain all savants.

Although these characteristics are all important, we paid more attention to two.

One is the fourth type: "there is a spectrum of savant skills." The first stage of savant skills mentioned by Treffert [7] is "splinter skills," which describes the ability to become more preoccupied with a specific field such as music or sports. The second stage is the "talented savant," with markedly high ability in a specific field and a well-honed level of expertise that contrasts sharply with the overall level of disability. The third stage is "prodigious savant," where an individual possesses tremendous and extraordinary abilities that place them in an unequal position, even when compared to the non-impaired. Treffert [7] estimated that approximately 100 such individuals are known worldwide.

The second characteristic we considered is the fifth type: "the special skills are always accompanied by a prodigious memory." Many researchers have focused on the memorization ability of savants. Treffert linked the expression "an exaggerated form of habit" described by Barr [11] regarding the memorizing ability of their savant patient with prodigious memory to the latter of the two types of memory systems—semantic memory system and non-conscious habit formation—suggested by Mishkin et al. [12]. Mishkin et al. [12] argued that there is a higher-level corticolimbic circuit for semantic memory and a lower-level cortico-striatal circuit for more primitive habit memory in the brain of a non-impaired individual. Treffert [7] thought that this lower-level cortico-striatal circuit and the concept of habit memory, resulting from the activation of this circuit, are consistent with procedural or implicit memory. In summary, Treffert de-

scribed the characteristics of savants' memories as "automatic, mechanical, concrete, and habit-like."

However, studies on semantic and habit-like memories in autistic savants are not frequently published. Rather, Ullman and Pullman [13] proposed a "declarative memory compensation hypothesis" for memory features in some neurodevelopmental disorders, including savant syndrome. According to these authors, a declarative memory system can support a wide range of information, tasks, and functions across multiple domains and modalities. This system can enable the acquisition of not only semantic and episodic knowledge within a restricted sense of meaning and event knowledge but also lexical knowledge, images, scripts, and specific instructions. That is, this system is different from the basal ganglia-based procedural memory system or the amygdala-based fear conditioning system. Although multiple additional exposures to stimuli sometimes strengthen memory, many types of knowledge can be learned quickly with a single exposure to a stimulus. According to these authors, social deficits, often observed in autistic savants, can be compensated for by a significantly enhanced declarative memory system. Following the logic of Ullman and Pullman [13], savants' procedural memory systems can be considered to be somewhat weakened.

We believe that the verification of these two contradictory claims and more rational explanations and study results on the prodigious memory skills of autistic savants should be confirmed in future psychological and neurobiological studies.

CHARACTERISTICS OF THE ARTISTIC ACTIVITIES OF AUTISTIC SAVANT ARTISTS

Numerous autistic savant artists are known, but the case of Nadia, reported by Selfe in 1977, was perhaps the first to be reported in academic form [14]. Despite being the first report of an artistic savant, it provided sufficient information regarding how an autistic individual, particularly one with artistic savant traits, can show signs from infancy. From infancy, Nadia had different social interactions compared to typically developing (TD) infants. She did not respond when her mother called her name and lacked empathy. As she grew older, her interactions with other children were more obsessional than general social interactions. Her speech development was late, and she displayed frequent echolalia and ritualistic language use. Despite these developmental challenges, Nadia's drawing skills were remarkable. At 3 years and 5 months of age, Nadia sketched such dynamic horse drawings that one could hardly believe she could sketch at that age. Notably, her drawings were completed in a short time [15]. In addition, her first works were not made up of simple shapes or visual schematics. In other words, her paintings were a definite "work of art" from the beginning. She could start painting anywhere on the paper; she began drawing at a location, continued, and finished the drawing when it reached the edge of the drawing paper. Moreover, Nadia did not begin drawing with the face or head of the central figure or animal; she could draw from the neck or any other body part [15]. Semantic associations arise when ordinary individuals draw, but Nadia's drawings did not interfere with semantic associations. However, Nadia's prodigious drawing skills became more common as she acquired language skills and language development began.

More than 50 years after Nadia's case was discovered, the activities of autistic savants with outstanding achievements in many artistic fields have become remarkable. Some autistic savant artists are among the world's most prestigious artists. For instance, Matthew Wong was hailed by art critics as the painter to succeed van Gogh and other post-impressionists, although he sadly died at a young age [16]. He is known to have been diagnosed with autism and Tourette's disorder. Although the value of his works should not be measured by their prices alone, some of them (Fig. 1) now exceed millions of dollars. It can be said that Wong has risen to the rank of one of the most famous masters of painting. Is it possible to summarize the common characteristics of these autistic savant artists who achieve brilliant feats?

The representative trait that Cardinal [17] pointed out is called "outsider art." Outsider artists are those who received non-formal education other than orthodox art education or studied art in a self-taught manner, work outside the general art system, and produce a large number of works. Most art experts think of Jean Dubuffet, who started outsider art and led Art brut in France. Dubuffet was originally a wine merchant who picked up a brush and began to paint at the age of 42. He began to produce art pieces by studying art personally in a way that differs from the professional art world. He confessed that he was inspired by the work of the socially disadvantaged and mentally ill. The art world called the style Dubuffet pursued "Informel."

In what way do savant artists with autism exhibit the characteristics of outsider art? According to Cardinal [17], they are self-motivated, self-teaching, and extremely productive. In addition, when viewing artwork, viewers are often given a history of the unfortunate past events that happened to the artists. Furthermore, upon direct interaction with their work, viewers experience compassion and empathy for the unfortunate events experienced by autistic savant artists while gaining a "thrilling visual experience." One may think, "They must have experienced such heartbreaking events, yet they

Fig. 1. Matthew Wong, *Starry Night*, 2019, ©Matthew Wong/ARS, New York - SACK, Seoul, 2023.

created such intense artwork!" Ultimately, this experience of being tense and yet drawn, different from the everyday experience of the average viewer, is "... the chance to savor the extreme experience of *Otherness*..." [17, 18]. Happé and Frith [18] provided an opportunity for ordinary individuals to have a time of deep ontological reflection on savants with their brilliant expression of "the beautiful *Otherness* of the autistic mind."

A HYPOTHESIS ON THE EMERGENCE OF AUTISTIC SAVANT ARTISTS: PARADOXICAL FUNCTIONAL FACILITATION

What brain characteristics make these artistic savant traits possible? For the emergence of any phenomenon, we must examine its proximate and ultimate causes.

The most representative hypothesis for the proximate cause of the emergence of artistic savants is paradoxical functional facilitation [19]. This hypothesis explains the emergence of outstanding artistic talent in a subset of patients with neurological disorders. Typically, when brain damage occurs in the left frontal or temporal areas, the top-down inhibitory function of these areas is eliminated. To compensate for this, the functions of other brain regions without impairment may be overactivated. It is still unclear whether this phenomenon occurs only with the loss of inhibitory function due to functional impairment in the left frontotemporal area or if it is accompanied by a compensatory functional enhancement in other areas without impairment [20]. Nevertheless, this phenomenon has undoubtedly been observed in some neurological disorders. A sudden prodigious level of artistic activity can be expressed in patients with frontotemporal dementia [21] or primary progressive aphasia [22]. Maurice Ravel began to develop aphasia when he reached the level of a virtuoso as a musician, although there remains a debate over whether the aphasia was caused by a car accident or was primarily progressive aphasia. However, some scholars have argued that the creation of "Bolero" and "Concert for the Left Hand," the representative works of Ravel's last years, was a result of increased creativity with the heightened function of his right hemisphere when aphasia became severe due to the damage to the left frontotemporal area [23].

So why could this hypothesis be a proximate cause that explains the emergence of autistic savant artists? This is because paradoxical functional facilitation agrees with the theory of "weak central coherence" [24], best known as the theory of the cause of ASD. Central coherence is a tendency of information processing methods, and neurotypicals tend to focus on the global rather than the local aspects of an object or stimulus to obtain a higher level of meaning when perceiving an object or stimulus of interest. By contrast, individuals with ASD tend to show more dominant local processing than global processing because of the weak central coherence bias. To explain this from the perspective of the brain, the weakening of the macrocircuits, such as the fronto-cerebellar connection, in the brains of individuals with ASD can paradoxically strengthen the local microcircuits of

the temporal, parietal, and occipital cortices [4]. As a result, hyper-memory, hyper-visuospatial ability, and hyper-acoustic function can occur in ASD [4].

Interestingly, the phenomenon of paradoxical functional facilitation has been directly demonstrated in experiments with neurotypicals. Snyder et al. [25] performed repetitive transcranial magnetic stimulation (rTMS) on the left frontotemporal cortex of neurotypicals, and drawing ability was enhanced for approximately 45 min in some participants. Snyder et al. [25] argued that savant skills are latent in all individuals and that latent savant-like abilities dormant in the brain's unconscious would emerge if the top-down inhibitory function of the brain's frontotemporal region was eliminated in some way [25,26].

Happé has expressed interest in the results of the rTMS study [27] because of their agreement with the "positive aspects of reduced cognitive control for creativity" [27], which is the view Happé has supported regarding savants.

Using transitional direct current stimulation (tDCS), another brain stimulation procedure, Chi et al. [28] obtained results similar to those of Snyder et al. [25]. In their study, an increase in visual memory in NT subjects was observed only when electrical stimulation was applied after placing a cathode in the left anterior temporal lobe and an anode in the right anterior temporal lobe. In general, cathode stimulation inhibits the excitability of neurons in the area, whereas anode stimulation increases the excitability of neurons in the area. When these researchers applied electrical stimulation after placing the cathode on the right anterior temporal lobe and the anode on the left anterior temporal lobe, no increase in visual memory was observed. Chi et al. [28] demonstrated, using a different method, that functional inhibition of the left anterior temporal area was essential for paradoxical functional facilitation.

POSSIBILITIES OF THE EMERGENCE OF AUTISTIC SAVANT ARTISTS AS SHOWN BY ARCHEOLOGICAL SOURCES: AN EVOLUTIONARY PERSPECTIVE

However, the cause of the existence of many autistic savant artists in modern society needs to be considered from a new perspective and not just from proximate causes. In this regard, we argued that analyzing from an "evolutionary perspective" using archeological findings was necessary.

First, we considered the prevalence of ASD. The prevalence of ASD was 2.64%, according to a 2011 report in South Korea [29]; the prevalence of ASD in 8-year-olds was high, at 1 in 44, in the most recent report by the US. Center for Disease Control and Prevention (CDC) in 2021 [30]. If autistic traits had only recessive properties, they would have been eliminated by natural selection in the course of a long evolution. However, given the high prevalence of ASD currently being reported, it is unlikely that autistic traits comprise only recessive properties.

Therefore, a new perspective that considers the ultimate cause of the current existence of individuals with autism is required. The field of pediatric and adolescent psychiatry is not the only one that presents such new perspectives. Archeology, linguistics, aesthetic, and many other disciplines have proposed various hypotheses regarding the emergence of individuals with autism and the manifestation of savant traits.

One hypothesis was based on the results of archeological research. In response to Nadia's paintings, Humphrey [31] argued that characteristics similar to those seen in the cave art of the Upper Paleolithic Age in Europe were present in Nadia's drawings. Some examples include the focus on partial components rather than the entire shape of an object, the superimposition of forms, and an accurate visual depiction of the animal based on memory. Kellman [32] provided a similar explanation for the work of a 7-year-old autistic artist named Jamie.

A part of the lion paintings in the Chauvet cave in France from approximately 30,000 years ago, considered representative cave art of the Upper Paleolithic Age, depicts a single lion overlapping rather than several lions (Fig. 2). In other words, it was a dynamic illustration of the movements of a single lion, with a very accurate depiction of detailed movements. Spikins et al. [33] described this as "exceptional realism" and claimed that Chauvet cave paintings were created by artists of that era who possessed autistic traits and char-

Fig. 2. The frieze of lions at Chauvet Cave art, Source: https://commons.wikimedia.org/wiki/File:Lions_painting,_Chauvet_Cave_(museum_replica).jpg.

acteristics of the brain's local processing bias. Spikins et al. [33] argued that these characteristics are frequently observed in current autistic savants but also in the works of artists who do not possess savant traits.

Why do scholars pay attention to the cave art of the Upper Paleolithic Age, estimated to have existed around 50,000–12,000 years ago? This is related to the cold weather of that period, which was a natural environment covered with snow and ice owing to the Ice Age. For the ancestors of modern humans at that time, information such as where (how far outside the cave) animals lived was important. In this case, having excellent visual discernment and memory to identify the location and characteristics of the animals found in the snow and ice, returning to the cave after a long journey, and producing cave art of what they saw and remembered would have provided vital information to the ancestors of modern humans at the time. Spikins et al. [33] argued that artists with autistic traits would have been treated as important and special at that time and that autistic traits are not left as by-products of evolution but as "positive selection."

On the other hand, modern humans, or Homo sapiens, were the mainstays of the Upper Paleolithic Age. As it is generally known that Homo sapiens left numerous artworks, it was thought that all cave paintings were works of Homo sapiens. In recent years, however, it was discovered that many cave arts in Europe were produced by Neanderthals, mistakenly thought to have gone extinct about 40,000 years ago [34]. What does this mean?

EXPANSION OF THE EVOLUTIONARY PERSPECTIVE: SUPERIOR VISUAL PERCEPTION HYPOTHESIS AND "HMMMMM" HYPOTHESIS

Folgerø et al. [35] synthesized and expanded several studies and proposed a "superior visual perception hypothesis," which is more elaborate than previous hypotheses.

First, they observed "raw perception," an ability commonly found in ancient cave artists and contemporary artistic savants with ASD. According to them, raw perception seems similar to modern sensory perception, but it is an "intact perception," which is unimpeded by top-down processing, such as linguistic processing or high-order concepts.

Furthermore, Folgerø et al. [35] argued that cave artists were not the only ones with raw perception abilities. It was estimated that the majority of archaic Homo sapiens and Neanderthals had raw perception capabilities, which allowed the archaic primary consciousness held by the members of these groups, unlike the secondary consciousness of modern man, to include savant-like perceptions that enabled them to grasp the particulars of nature in detail. Drawing cave art is a difficult task. Unlike modern canvases, the cave's surface was very bumpy, making it challenging to properly draw. Additionally, cave art is often found not only close to the cave entrance but also at depths far away from the entrance. It is impossible to make such an elaborate drawing on a rugged cave surface with little help from visible light without raw perception, considerable visual memory, and elaborate upper-limb control capabilities.

To date, our review has primarily focused on visual abilities. Some scholars have developed original theories regarding our ancestors' auditory and musical abilities. Archeologist Steven Mithen focused on the auditory abilities of several apes, ancient hominids, and Neanderthals [36]. Laryngeal descent occurred as ancient hominids successfully achieved an upright gait over a long period; in addition, the completion of this laryngeal descent was accomplished in Homo sapiens, and the various anatomical changes that accompanied this laryngeal descent enabled segmented vocalization in modern humans. Therefore, individuals believe that the communicative abilities of ancient hominids before Homo sapiens would have had considerable limitations. However, many apes use vocal calls and demonstrate a sensitive response to these vocal calls, and some scholars have argued that their use of gestures has a higher communicative value than that associated with vocal calls [37]. Mithen [36] argued that ancient hominids obtained "rhythm" as they gradually developed not only the flexibility of gestures but also the freedom of the upper limbs, as well as head movement and coordination of mobility between the upper limbs, torso, and lower limbs due to efficient walking and running. He explained that ancient hominids were able to internalize their musical abilities because, in addition to these abilities, they had vocal flexibility.

This combination of gestural and musical abilities and the early communication system was described by Mithen [36] as holistic, multi-modal, manipulative, musical, and mimetic. It was termed the "Hmmmmm" communication system, combining the first alphabet of these words, and the culmination of the Hmmmmm communication ability was considered to have been achieved by Neanderthals. Such communication is quite different from that of Homo sapiens, which uses segmented vocalization. Homo sapiens acquired the process of combining segmented words to create new meanings, but Neanderthals, with the Hmmmmm communication system, used "holistic vocalization," a message that is complete in itself. In other words, their songs were holistic communication with a combination of dance and emotions, which would have given rise to musical and other artistic expressions; notably, Mithen assumed that their songs were

close to rap. Furthermore, Mithen [36] believed that due to the nature of Hmmmmm communication ability, the relative pitch would not have evolved in Neanderthals and they would have maintained the absolute pitch ability. Many scholars agree that absolute pitch is a trait that often appears in individuals with autism and savants [38,39].

Taken together, the superior visual perception hypothesis for ancient hominids' visual abilities and the Hmmmmm hypothesis for their auditory abilities agree with the assumption that ancient hominids had "raw perception" abilities, and in particular, the peaks of these abilities would have been achieved in Neanderthals. According to Folgerø et al. [35] and Mithen [36], these characteristics in Neanderthals may have appeared in the majority of the group and not in a small minority of the entire population. Therefore, some scholars call these arguments the "Neanderthals theory of autism."

IS NEUROBIOLOGICAL EVIDENCE FOR THE "NEANDERTHAL THEORY OF AUTISM" CURRENTLY BEING REPORTED?

The aforementioned researchers argued that Neanderthals possessed considerable artistic characteristics based on archeological data and that they possessed savant-like autistic traits owing to their superior visual perception and Hmmmmm communication ability. If this is the case, are there direct or indirect neurobiological studies that can support these hypotheses?

First, until a few decades ago, Neanderthals were believed to have gone extinct about 40,000 years ago. However, recent research suggests that they existed in Europe and Western Asia as recently as 30,000 years ago or later [40]. In other words, the coexistence of Neanderthals and Homo sapiens lasted for quite a long time. The possibility of "interbreeding" between Neanderthals and Homo sapiens, especially in Western Asia, has been consistently raised.

Green et al. [41] obtained genome sequences from Neanderthals' skulls and compared them to those of the French, Han Chinese, Papua New Guineans, Yorubas of West Africa, and San of South Africa in the modern era. The results showed that Neanderthals shared more genetic modifications with modern humans in Eurasia than with those in sub-Saharan Africa. That is, some modern Eurasians share some genes with the Neanderthals. These genes are primarily involved in cranial morphology and cognitive ability. These researchers estimated that 1%–4% of modern Eurasians share some of the genes carried by Neanderthals.

Several follow-up studies have since been conducted. McCoy et al. [42] suggested that the DNA sequence transmitted from Neanderthals to modern humans is not a silent remnant but may sufficiently contribute to changes in the phenotype of modern humans.

Gregory et al. [43] argued that the Neanderthal gene could affect specific anatomical structures of the brain. Gregory et al. [43] used magnetic resonance imaging (MRI) scans of the skulls and brains of more than 200 participants and calculated the so-called NeanderScore in individual participants using the known Neanderthal single nucleotide polymorphism. The results revealed that the higher the NeanderScore, the larger the sizes of the parietal, temporal, and occipital regions of the skull. Such cranial morphology is widespread in Neanderthals. Furthermore, brain studies showed a positive correlation between NeanderScore and the sulcal depth of the intraparietal sulcus (IPS) of the brain and a positive correlation between NeanderScore and the local gyrification index (LGI) of the V1 and V2 regions and the left primary visual cortex (Fig. 3). Similar results were observed in the right superior temporal sulcus. The LGI reflects cortical folding. There were also positive correlations between the volume of gray matter in these three brain regions and NeanderScore.

In a more recent study, Gregory et al. [44] examined the association of seed-based connectivity with the brain's IPS as the seed and the study participants' NeanderScore in 553 participants. The results showed that functional connectivity between the IPS and visual information processing areas, such as the occipital cortex and fusiform gyrus, was positively correlated with NeanderScore. Conversely, functional connectivity between the IPS and areas corresponding to de-

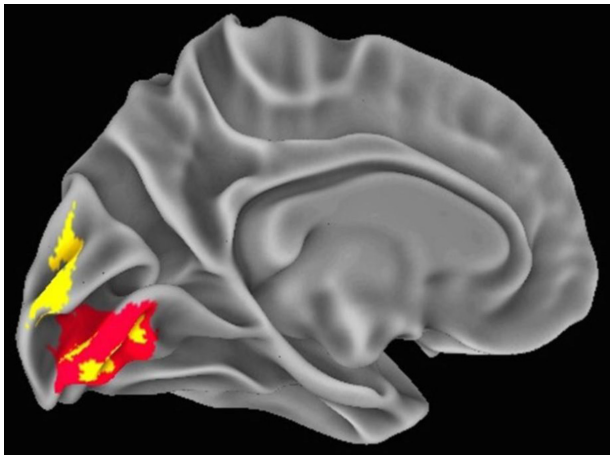

Fig. 3. NeanderScore related brain changes in the primary visual cortex. Associations between local gyrification index, gray matter volume, and NeanderScore in visual cortex. Medial view of the primary visual cortex showing areas where NeanderScore was significantly associated with local gyrification index (red; $p<0.05$ FWE-corrected) and with gray matter volume (yellow; $p<0.005$). Adapted from Gregory et al. Sci Rep 2017;7:6308. [43], under the terms of the Creative Commons Attribution License (CC BY). FWE, family-wise error.

fault mode networks, such as the superior frontal cortex, temporoparietal junction, precuneus, and posterior cingulate cortex, showed a negative correlation with NeanderScore.

Unfortunately, Gregory et al. [43,44] did not report that participants with high NeanderScores had ASD or were savants. However, we consider these findings to be indirect evidence that the "introgression" of the Neandertal gene is associated with increased superior visual perception and decreased social functioning.

What is the possibility that introgressed genes from Neanderthals contribute to the expression of ASD? Some researchers have investigated this in their studies, and it is necessary to draw particular attention to the work of Mozzi et al. [45]. Mozzi et al. [45] examined whether 68 candidate genes known to contribute to the development of ASD and other neurodevelopmental disorders, in the form of de novo mutations, were introgressed from Neanderthals and Denisovans to modern man. The results revealed that some of these genes were shared as an "ingressed haplotype" among Neanderthals, Denisovans, and a few non-African modern humans. Among these genes, the PHF1 gene regulates the transcription of GABRB1, which encodes the GABA type A receptor. PHF1 is known to play a crucial GABA-related role, especially in the neocortex and hippocampus. As shown by many ASD studies, the inhibition of the GABA system or the "excitatory/inhibitory imbalance theory" is highly considered to explain the cause or pathophysiology of ASD [46]. In that case, GABA-based inhibition in Neanderthals would have caused the inhibition of inhibitory function in the visual area of the occipital cortex, IPS, and hippocampus, which were identified as essential areas in the above-mentioned studies; in addition, this may have had a significant impact on their hyperactivity of raw perception. Mozzi et al. [45] mentioned the importance of the DYRK1A and TCF4 genes in addition to the PHF1 gene among the introgressed genes. Meanwhile, other researchers have reported that the autism susceptibility candidate 2 (AUTS2) gene, commonly cited as one of the genes implicated in ASD, was introgressed from Neanderthals to modern humans [47].

Ultimately, based on the cave art of the Upper Paleolithic Age, brain studies using Neanderthals' skulls, and studies revealing that some candidate genes for ASD and other developmental disorders were introgressed from Neanderthals, the following conclusion can be suggested: Neanderthals and ancient Homo sapiens possessed raw perception abilities for various sensory stimuli. Mithen [48] argued that Neanderthals, like Homo sapiens, had four modular types of intelligence: social, technical (e.g., tool-making), natural history (e.g., animal behavior), and linguistic intelligence. However, Homo sapiens had "cognitive fluidity" between each module, which made it possible to connect the modules. For example, social intelligence allowed for relationship-building, communication and simultaneous collaboration on tool-making through the exercise of technical intelligence. However, Neanderthals had barriers between each module so that each module could specialize and develop regardless of limited cognitive fluidity. If so, the intra-group social interaction in Neanderthal groups may have been very infrequent, unlike in Homo sapiens. Nonetheless, Neanderthals had raw perception abilities that coincided with the specialized development of cognitive modules. Hmmmmm communication was also possible. There was a period when this group of Neanderthals coexisted with Homo sapiens in Southwest Asia 30,000−40,000 years ago, during which genetic introgression occurred. Three to four percent of modern individuals carry these genes. Some modern humans who possess raw perception abilities would have the potential to exhibit artistry, and if this potential begins to manifest early, an autistic savant artist may eventually emerge.

HOW SHOULD THE SAVANT TRAITS OF AN AUTISTIC SAVANT ARTIST BE ASSESSED?

Thus far, we have outlined several hypotheses and theories regarding the proximate and ultimate causes of the emergence of autistic savant artists. Now, we will address the practical aspects of this issue. The definition of an autistic savant artist has been discussed earlier, but how can the savant traits of an autistic savant artist be assessed?

It appears that no assessment instrument known to date can solely evaluate the savant characteristics of the artistic aspects of autistic savant artists. However, there are several reports of assessment tools for evaluating the overall talents of savants and studies utilizing these tools. Such assessment instruments also include items that measure the artistic characteristics of a savant.

Until the 2000s, nearly no studies had used objective assessment tools for autistic savants. Most of the researchers' findings were case reports. The majority of the reports were from the UK, where case reports were conducted with savants with gifted talent registered in the database of the UK's Natural Autistic Society [49-51]. However, some studies have developed questionnaires to assess savant traits, and other studies using these questionnaires have been published since the 2010s. Bennett and Heaton [52] developed the "Special Skills in Autism Questionnaire." This questionnaire is a tool that can distinguish nine domains, including eight domains of memory/knowledge, mathematical/numerical, artistic, music, reading/vocabulary, spatial, information and com-

munication technology, and mechanical, and one domain for special talents that do not correspond to the previous eight. Similarly, a study in Egypt developed a questionnaire that assesses eight domains [53].

A Sussex Savant Questionnaire has also been reported [54]. This questionnaire assesses 10 categories: math, calendar calculation, musical instrument playing, music reproduction, absolute pitch, art, memory, mechanical, fluency for different languages, and other talents. Unlike the other questionnaires, the music-related area was subdivided into three categories instead of one.

Since the 2010s, questionnaires for the assessment of savant traits have been developed and utilized in research, especially in the UK. It appears that the development of questionnaires in the UK was possible because of access to individuals who were registered as savants in the aforementioned database of their National Autistic Society. However, a tool for independently assessing only the artistic characteristics of autistic savant artists has yet to be developed.

WHAT ARE THE PSYCHOLOGICAL AND COGNITIVE CHARACTERISTICS OF AUTISTIC SAVANT ARTISTS?

The development of savant trait assessment tools demonstrates that the study of savants is becoming more elaborate. This process will also further develop scientific research focused on savant autistic artists. Therefore, we aimed to first examine the current developments in studies comparing the characteristics of autistic savants with those of non-savant autistic individuals and, afterward, investigate advances in studies on autistic savant artists.

Currently, researchers' slightly conflicting opinions on the psychological, cognitive, and behavioral characteristics of savants with autism can be divided into two main categories.

The first opinion is as follows: there are common psychological and biological characteristics of autistic savants and non-savant autistic individuals. Instead, in autistic savants, the increase in savant traits, such as the detailed focusing cognitive style, is related to a decrease in social and communication skills.

In connection with this opinion, first, reports of similarities in many characteristics between autistic and non-savant autistic individuals are frequently found. Additionally, the enhanced perceptual functioning theory [55] and empathizing-systematizing theory [56], which are well-known pathophysiological models of ASD, ultimately posit that detailed local processing and systematizing abilities, the general characteristics of individuals with ASD, can directly cause savant characteristics. Similarly, Happé and Vital [57] and Happé and Ronald [58] proposed a "fractionable triad proposal" for ASD, explaining the association between savant traits and ASD characteristics. According to this proposal, the issue of "the theory of mind," with which we are familiar, is a representative characteristic of ASD. However, the theory of mind alone does not produce any unique talents in ASD. What is the starting engine of talent? This is the "detail-focused processing bias" caused by weak central coherence. That is, the increase in restricted and repetitive behaviors specific to ASD associated with detailed focus is the starting engine of talent emergence. In addition, the theory of mind issue in ASD can be the "fuel" that drives this engine. Although they are less social, focusing only on their interests and easily falling into a state of flow causes a type of increase in practice. This theory of Happé and Vital [57] and Happé and Ronald [58] is compatible with concepts introduced earlier, namely, the raw perception hypothesis in ancient Homo sapiens and the paradoxical functional facilitation theory. According to this theory, the more special talents savants may have, the more likely they are to have decreased social skills. Nevertheless, Vital et al. [59] suggested that even if their social skills are poor, their increasing savant skills may eventually contribute to an increase in their social competence [60].

The second opinion is that there is no significant difference in the social characteristics between autistic savants and non-servant autistic individuals. Savant traits appeared only in certain subgroups of individuals with ASD.

Hughes et al. [54] compared sensory sensitivity, obsessional behaviors, cognitive styles, systemizing quotients, and autism spectrum quotients using self-reporting and objective tests in autistic savants, non-savant autistic individuals, and neurotypicals. Autistic savants scored significantly higher on sensory sensitivity, obsessional behaviors, technical/spatial ability, and systemizing than non-savant autistic individuals. However, there was no significant difference between autistic savants and non-savant autistic individuals. Based on these results, the researchers concluded that savant traits were not traits that could emerge during the typical development of ASD. In other words, it was interpreted that a group of autistic individuals with traits that enable the development of prodigious talents among all individuals with ASD exists as a separate subgroup. However, Hughes et al. [54] commented that further research is needed to investigate how the savant trait is subdivided into art, mathematics, and science savants and becomes specialized. Their findings do not support the idea that local processing and enhanced perceptual ability are essential to the emergence of savants or that the increase in savant traits is associated with a decrease in social skills. Hughes et al. [54] stated that their findings support those of Simner et al. [61], arguing that the ob-

sessional trait is more important for the savant traits of autistic savants. In other words, compulsions or anxiety-related traits are important, and it is this anxiety that forces an artist to obsessively rehearse their work. It is a position that argues that obsessional anxiety is more crucial than poor theory of mind.

Other studies have shown similar results. Bennett and Heaton [52] reported no significant difference in the brain's local processing ability between autistic savants and non-savant autistic individuals.

One of the particularly contradictory points between these two arguments is whether an increase in savant traits and a decrease in social skills are significantly related. A notable study on this issue was published in 2020. Daniel and Menashe [60] investigated the Social Response Scale (SRS) scores of 712 autistic savant children, 2,032 non-savant autistic children in the existing database, and their parents. The results showed that the SRS score of autistic savant children was significantly lower than that of non-savant autistic children. In other words, the sociability of autistic savant children was higher than that of non-savant autistic children. Furthermore, there was no significant difference in SRS scores between parents of autistic savant children and parents of non-savant autistic children. The difference in SRS scores between autistic savant children and their parents was significantly larger than the difference in SRS scores between non-savant autistic children and their parents. In conclusion, the researchers argued that the social responsiveness of autistic savant children was relatively higher than that of non-savant autistic children and that the difference was less likely to result from familial traits. This study was conducted with a larger target group than that in existing savant-related studies, and the results showed that autistic savants, despite being children, had higher social responsiveness than non-savant autistic individuals and that there was little influence of familial traits on these characteristics. Contrary to the results of previous studies, the results of this support the possibility of increased social competence due to the increase in savant skills, as argued by Vital et al. [59]. In addition, we believe that the results of this study showed that autistic savants who possessed low sociability in early childhood could also increase their sociability over time if they practiced or repetitively performed skill behaviors. Thus, longitudinal studies on the savant skills and sociability of autistic savant artists are thought to be necessary.

As we have discussed, differences between the results of the researchers' studies were found for all autistic savants, not just autistic savant artists, thereby necessitating further research and showing a virtuous cycle in which new research projects are presented. How are studies of autistic savant artists currently being conducted? Few studies have been conducted. However, there is a mixture of studies limited to autistic savant artists and all talents of autistic savants that include artistic characteristics.

We summarize the findings of autistic savant artists and autistic individuals with artistic savant traits. Pring et al. [49] conducted an embedded figure test (EFT) and block design test by classifying the adult population into five groups: adult autistic savant artists, non-savant autistic individuals, individuals with mild/moderate learning disabilities (MLD), art students, and students of psychology. The EFT and block design tests were selected to determine the characteristics of local processing dominance and spatiotemporal perception dominance. The results showed no significant differences in the EFT between autistic savant artists and non-savant autistic individuals. However, savant autistic artists were significantly more successful in performing the block design test than non-savant autistic individuals. Pring et al. [49] interpreted these interesting results as EFT being more of a passive recognition test and block design testing being more of an active construction test. Besides, the block design test requires more visuomotor components than the EFT. Local processing dominance is not the only factor important in artistic savant traits, and the motor control ability to organize local processing in the brain into artwork through one's actions is more important.

In a subsequent study, Pring et al. [50] tested the creativity of autistic savant artists. The participants of this study were autistic savant artists, non-savant autistic individuals, individuals with MLD, and art students. Researchers used the Torrance Test of Creative Thinking (TTCT) [62] and the Figural Synthesis Test (FST) to test the creative abilities of each group. In the TTCT, the participants were presented with 10 incomplete squiggles and were asked to draw anything they wanted using the presented squiggles and to attach a title for each drawing. Afterward, the drawings' fluency, originality, elaboration, and flexibility were assessed to evaluate their overall creative ability. In FST (Fig. 4), the participants were presented with eight pieces of familiar geometric shapes with rectangles, triangles, and circles drawn on them and were asked to put pieces together to form anything that came to mind to resemble real things (e.g., an umbrella, a cat shape, and a camera). FST also evaluates fluency, originality, elaboration, and flexibility. In the TTCT, the art student group scored the highest in all four areas. The autistic savant artist group scored significantly higher on elaboration than the non-savant autistic and MLD groups. In the FST, the autistic savant artist and art student groups had higher originality scores than the other two groups; however, the differences were not statistically significant. The researchers suggested that in the TTCT, savant artists could have scored higher on elaboration than non-savant autistic individuals because of

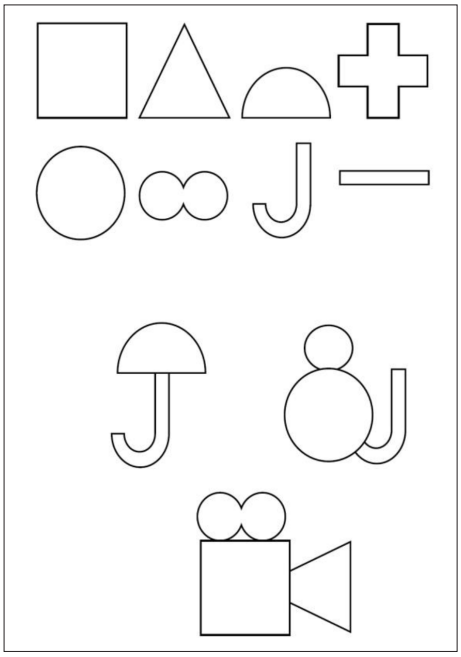

Fig. 4. Top panel: stimuli used in the Figural Synthesis Task. Bottom panel: example of acceptable outputs – umbrella, cat, and camera. Adapted from Pring et al. Autism 2012;16:45-57. [50], with permission of the The National Autistic Society, SAGE Publications 2012.

their superior manual dexterity, that is, their enhanced motor control abilities, compared to non-savant autistic individuals. Furthermore, the researchers found that, although not statistically significant, autistic savant artists showed similar originality scores as art students and a higher score than the non-savant autistic and MLD groups in the FST. Regarding the results, the researchers emphasized that due to the nature of the test, the FST can evaluate purer perceptual originality because it is less influenced by verbal abilities compared to the TTCT. Additionally, the results were interpreted to result from the FST being a task with a restricted range of responses. In other words, autistic savant artists can exhibit a much higher level of originality within a slightly constrained task. Overall, the results showed that the creativity of autistic savant artists was more domain-specific than domain-general.

Autistic savant artists' executive functions also differed from those of non-savant autistic individuals [51]. This research team compared executive functions between autistic savant artists, non-savant autistic individuals, and MLD groups. Evaluation of general executive function using the Wisconsin Card Sorting Test showed no significant differences among the three groups. However, the design fluency test, which corresponds to the word fluency test, showed different results. The design fluency test asks participants to draw as many new patterns as possible—not scribbles—in 4 minutes, instead of actual objects or symbols. The autistic savant artist group scored significantly higher on this test than did the non-savant autistic individual and MLD groups. This study conclusively supports the argument that autistic savant artists exhibit domain-specific characteristics even in executive functions. In other words, the executive function of the area associated with his artistic characteristics increased.

Meanwhile, in neuroscientific studies of autistic savant artists, there are still few statistical comparisons of characteristics between neurotypical and non-savant autistic populations. However, occasional case reports have been published. Wallace et al. [63] studied a man diagnosed with Asperger's syndrome in his early 40s. He possessed not only outstanding artistic abilities but also considerable calendar calculation ability. His painting style changed over time; he usually drew scenes and buildings during adolescence, gradually painted more abstract paintings, and afterward painted imaginary machines with various stylistic elements. The researchers compared the psychological characteristics and cortical thickness between the man and seven neurotypicals of similar age and intelligence. There was no significant difference in EFT or implicit learning, but there was a significant difference in cortical thickness. The man's brain was significantly thinner in the medial prefrontal, pre-central, and middle temporal areas than that of the neurotypicals. In contrast, the man's right superior parietal lobule was significantly thicker than those of the neurotypicals. In other words, the cortical thickness of the social cognition area decreased, whereas the cortical thickness of the visuospatial processing, calculation, and multiple sensory association areas increased. These results directly support the opinions of Happé and Vital [57], the former of the two opinions of the aforementioned savant traits, that the social characteristics of savant traits decreased relative to an increase in savant traits.

The unique characteristics of the autistic savant artists investigated thus far have been more domain-specific, whether they are psychological studies or case reports from brain imaging. However, it is too early to generalize the results because the number of studies is still small compared to studies on all autistic savants.

One idea to consider at this point is the study of the characteristics of artistic talent or artistic experience in non-savant autistic individuals. There are cases of providing art therapy, such as painting or music, as part of treatment for non-savant autistic individuals. Additionally, we have often observed non-savant autistic individuals preferring activities such as painting, music, and other artistic pursuits, although not to the extent of being savants. Studying the characteristics of the artistic experiences or expressions of non-savant autistic individuals can provide a solid basis for determining which of the contradictory arguments concerning the char-

acteristics of the aforementioned autistic savants—that savant traits may emerge during the development of non-savant autistic individuals and that autistic savants should be viewed as a subgroup different from non-savant autistic individuals—is more reasonable.

STUDIES OF ARTISTIC EXPERIENCE AND BEHAVIOR IN NON-SAVANT AUTISTIC PEOPLE

Uta Frith, a pioneer in the study of ASD, adequately described, in the book *Autism: Explaining the Enigma* [24], the importance of the theory of mind and mentalization mechanisms when appreciating The Cheat with the Ace of Diamonds, the work of the artist George de La Tour. One can fully enjoy the complex relationships between the minds of the characters playing cards and the subtle facial expressions that adequately depict these relationships. Furthermore, Frith presented the feeling a high-functioning female ASD patient felt after viewing a painting. Because the patient's mentalizing abilities differed distinctly from those of neurotypicals, the description of her feelings and her overall appreciation of the work differed from those of neurotypicals.

Indeed, the importance of the mechanism of the theory of mind in the appreciation and production of artwork has been frequently mentioned in other studies on neurotypicals [64,65]. The theory of mind is by no means a psychological mechanism that is needed only when appreciating or producing a portrait or work of art that depicts an individual as the main subject. According to Son et al. [20], the theory of mind is an essential psychological mechanism for experiencing abstract works and the sublime and appreciating music.

Therefore, individuals can guess that the aesthetic preference or experience of autistic individuals in viewing or producing artwork may not be as good as that of neurotypicals. However, do studies on non-savant autistic individuals produce such results? Published studies to date have shown that this is not the case.

Park et al. [66] recruited non-savant autistic individuals and neurotypicals and scanned them with functional MRI (fMRI) while the participants performed aesthetic preference tasks. The researchers used landscape and fractal works as stimuli and assessed how much the participants were attracted to the beauty of the work using the fMRI scan. The results showed no significant differences between individuals with autism and neurotypicals in terms of the degree of preference between all images. The degree of brain activation at the time of assessing aesthetic preference showed that relatively more diverse and broad areas were activated in individuals with autism than in neurotypicals. Specifically, when viewing landscape works, the activation of some areas of the prefrontal cortex in neurotypicals was relatively higher than that in those with ASD, whereas visuospatial association and salience network areas, including the right parietal region, posterior cingulate/precuneus, insula, and cerebellum, were activated relatively higher in autistic individuals than in neurotypicals (Fig. 5). However, it cannot be concluded from these results that non-savant autistic individuals have a low-

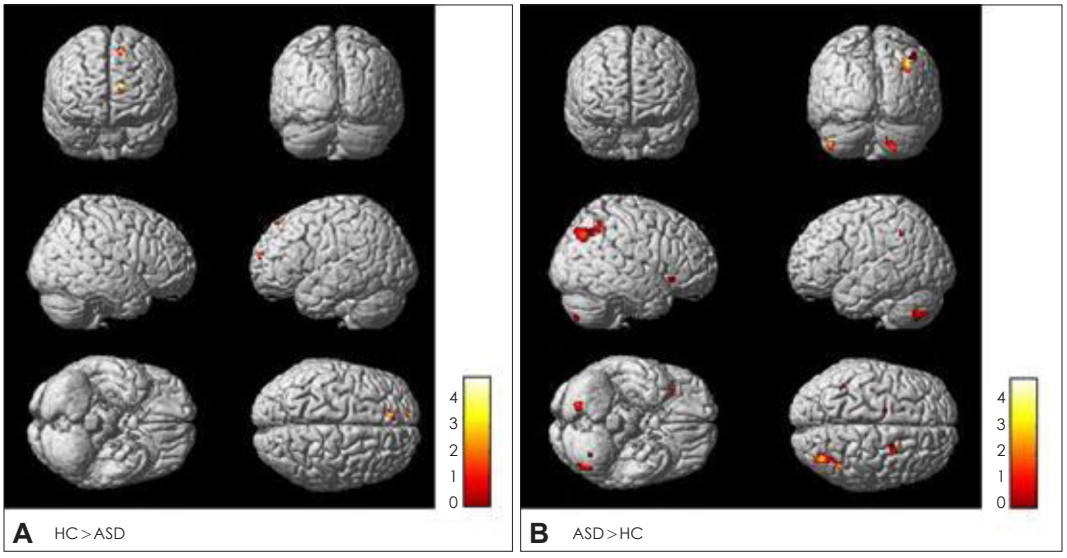

Fig. 5. Brain regions showing significant activation related on aesthetic judgement condition with aesthetic-landscape condition. A: HC (neurotypical) group exhibited relative hyperactivation in the superior frontal gyrus than non-savant ASD group. B: Non-savant ASD group showed relative hyperactivation in the parietal area, insula, posterior cingulate area, and cerebellar area than HC group. Adapted from Park et al. J Korean Acad Child Adolesc Psychiatry 2018;29:101-113. [66], under the terms of the Creative Commons Attribution Non-Commercial License (CC BY NC). ASD, autism spectrum disorder.

er degree of experience when experiencing beauty, such as evaluating their preference for artwork, than neurotypicals. Instead, these results show that relatively more diverse and broad brain regions are activated in non-savant autistic individuals than in neurotypicals when experiencing beauty. In addition, the characteristics of the activated brain regions suggest that the brains of non-savant autistic individuals "saliently" assess the beauty of landscape works and that they become more active during the visuospatial processing of landscape works.

Furthermore, Mazza et al. [67] asked non-savant autistic individuals and neurotypicals to perform objective aesthetic judgments while appreciating images of Renaissance statues with the original golden ratios maintained or modified in proportion (e.g., long torso, short legs). Simultaneously, the differences in the participants' attention to the images of the statues were analyzed using an eye tracker. The researchers classified objective aesthetic judgment as "explicit level" and the results from the eye-tracker analysis as "implicit level." Although individuals with autism had significantly lower aesthetic judgment scores for images of statues with a preserved golden ratio than did neurotypicals, eye-tracking results showed no difference in the degree to which individuals with autism and neurotypicals experienced aesthetic pleasure when making aesthetic judgments. We believe that it is crucial to consider that the stimuli used in the study by Park et al. [66] were landscape and fractal works, whereas those used by Mazza et al. [67] were images of statues and figures. In other words, the degree of evaluation of beauty may vary slightly, depending on the type of artwork. More importantly, there is no reason to assume that non-savant autistic individuals have fewer and shallower aesthetic experiences than neurotypicals when experiencing artwork. Mazza et al. [67] emphasized that the degree of aesthetic experience at the implicit level did not differ between non-savant autistic individuals and neurotypicals.

If the above studies were primarily about the aesthetic judgment of artwork, what are the results of studies on artistic performance? Masataka [68] compared the drawings of non-savant children with those of ASD and TD children aged 5–6 years. The children participated in the same picnic for the same amount of time and were asked to draw their most memorable experience from the picnic on that day. The researchers coded the drawings according to the types of objects depicted—individuals, animals, plants, foods, cars, buildings, and more—and the results showed no significant difference in the variability of the objects between the two groups. The only difference was that the ASD group tended to focus more on non-human objects than on portraits when drawing, whereas TD children tended to focus more on individuals.

As such, the results showing that non-savant autistic individuals did not differ significantly from neurotypicals in the context of aesthetic experience are not limited to the study of aesthetic experiences in visual artworks; studies on the aesthetic experience of music show similar results.

Gebauer et al. [69] made non-savant autistic individuals and neurotypicals listen to happy or sad music while scanning their brains with fMRI and then asked them to rate their level of happiness or sadness. There was no difference between the two groups in their evaluation of the happiness or sadness of the music. In addition, brain scans showed activation of the midbrain, parahippocampal gyrus, orbitofrontal gyrus, and nucleus accumbens in all participants, regardless of music type. Only the emotional assessment of happy music elicited significantly higher activation in the insular and dorsolateral prefrontal cortex in autistic individuals than in neurotypical individuals. In other words, individuals with autism felt more salient when listening to happy music and put a greater cognitive load on evaluating happy music than neurotypicals.

Lai et al. [70], using fMRI scanners, investigated differences in brain activation between non-savant autistic individuals and neurotypicals when singing songs and speaking phrases. Brain activation in the left inferior frontal area, the center for speech production, was significantly lower in individuals with autism than in neurotypicals when speaking, whereas brain activation in the same area was significantly higher in individuals with autism than in neurotypicals when singing songs. Functional connectivity between the left inferior frontal area (speech production center) and the left superior temporal area (language comprehension center) was significantly higher when singing songs than when speaking in individuals with autism. Large-scale functional connectivity analyses showed significantly higher anterior-posterior connectivity in individuals with autism when singing than when speaking. The researchers concluded that the brains of individuals with autism had characteristics better suited to singing than to producing speech. This finding by Lai et al. [70] emphasizes the importance of the "Hmmmmm" hypothesis of Mithen [36], which we have earlier discussed.

Masataka [68], who studied drawing in non-savant children with ASD, used an original method for the musical aspect [71]. The study participants were children with ASD and TD, aged 4–7 years. In the first experiment (Fig. 6A), the researcher listened to Mozart's original minuet (consonant music) and a dissonant-altered version of the same Mozart minuet. Both groups spent less time listening to dissonant music than the original minuets. In other words, both groups found the original consonant minuet more beautiful than the altered dissonant minuet. Children with ASD listened to

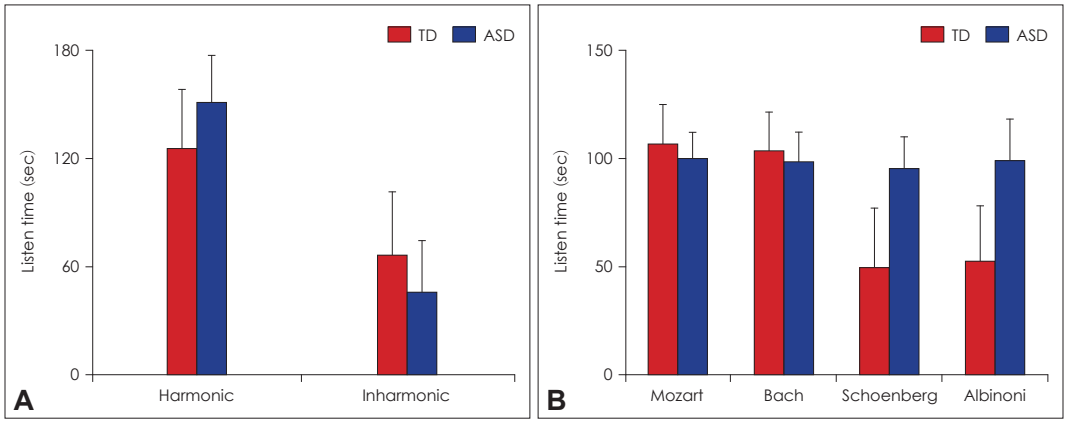

Fig. 6. Comparison of mean preference for the types of music between autism spectrum disorder (ASD) and typical developing (TD) children. A: Mean preference for an original simple harmonic minuet of Mozart (Harmonic) and its modified inharmonic version containing many dissonant intervals (Inharmoic) in children with ASD and in TD children. B: Mean preference for musical pieces of Mozart, Bach, Schoenberg, and Albinoni in children with ASD and in TD children. Adapted from Masataka. Front Psychol 2017;8:1595. [71], under the terms of the Creative Commons Attribution License (CC BY).

the original minuet for longer and the altered minuet for shorter than TD children. In the second experiment (Fig. 6B), the researcher asked the same participants to listen to Mozart's and Bach's musical works with consonant harmonic structure and Schoenberg's and Albinoni's pieces that are exceedingly harmonically dissonant. There was no significant difference in listening time between the two groups when listening to Mozart's and Bach's music. However, TD children listened to Schoenberg's and Albinoni's works for a significantly shorter amount of time, whereas the listening time of children with ASD was no different from when they listened to Mozart's and Bach's music. In the first experiment, children with ASD evaluated the dissonant versions of the original consonant music as less beautiful than did TD children, and they evaluated the composers' "intended" dissonant music as more beautiful, unlike the TD children. In the second experiment, non-savant children with ASD had better aesthetic judgment abilities than TD children. Masataka commented that these results suggest that autistic individuals possess "potentially gifted qualities."

As we have shown, non-savant individuals with autism are not less capable of aesthetic appreciation or aesthetic activity than neurotypicals; however, some studies suggest that they have a superior ability to evaluate beauty and engage in artistic activities. Of course, the weakness of the theory of mind and mentalization of non-savant autistic individuals can sometimes be a weakness in artistic experiences that require specific psychological mechanisms, such as appreciating artworks that require the discernment of the meaning behind a character's gaze or movement. However, not all aesthetic experiences necessarily require a theory of mind. Non-savant individuals with autism possess a brain system better suited to raw perception processing, and they may also potentially possess talents similar to autistic savant artists for certain aesthetic experiences or activities.

SUMMARY OF FINDINGS TO DATE

We summarized the research results on autistic savant artists as follows.

1) To date, most studies have primarily focused on autistic savants who possess one or more talents, including artistic skills. Although there are just a few studies, there has been consistent research on autistic savant artists.

2) The characteristics of "outsider art" have been noted as a trait of the aesthetic activities of autistic savant artists.

3) Paradoxical functional facilitation is gaining attention as one of the proximate causes of the emergence of autistic savant artists.

4) Many theories have been presented regarding the emergence of autistic savant artists from various disciplines and perspectives, including archeology. In particular, the superior visual perception hypothesis and the Hmmmmm hypothesis were suggested through studies on the cave art of ancient Homo sapiens and Neanderthals. Introgression of genes could occur during the coexistence of Neanderthals and early Homo sapiens, and Neanderthal genes and associated structural and functional characteristics of the brain have also been identified in some modern humans. These characteristics are most likely the ultimate cause of the emergence of ASD and autistic savant artists.

5) There are still only a small number of assessment instruments that can evaluate artistic savant traits alone, but they are continuously being developed.

6) Researchers differ on whether the increase in savant traits of autistic savants is related to reduced social commu-

nication ability or whether autistic savants are not significantly different from non-savant autistic individuals in social communication. Productive discussions on this issue can positively impact future research on autistic savant artists.

7) Although there are few psychological and cognitive studies on autistic savant artists, more results show that artistic savant traits are domain-specific. In addition, local processing dominance is necessary for artistic savant traits, but more importantly, motor control capabilities are essential for transforming local processing in the brain into works of art through one's actions.

8) Because of the importance of mentalization in some aesthetic experiences, non-savant individuals with autism may have a less rich aesthetic experience in such cases. However, non-savant autistic individuals' aesthetic experiences are not lower than those of neurotypicals in most aesthetic experiences; some studies have even suggested that the aesthetic evaluation and activity abilities of non-autistic savants are better than those of neurotypicals. Several studies have shown the potential for non-savant autistic individuals to "potentially possess" similar levels of artistic talent as autistic savant artists in terms of aesthetic experiences.

Taken together, we find that the argument of other researchers that autistic savants and non-savant autistic individuals share a common cause in psychological and biological characteristics is more realistic than the argument of Hughes et al. [54], which suggests that autistic individuals have a particular temperament and, therefore, should be viewed as a subgroup of all individuals with autism. In addition, we agree that a significant number of non-savant autistic individuals possess latent talent but disagree with the argument of Happé and Vital [57], which states that the increased savant traits of autistic savant artists are associated with decreased social and communication skills. According to our interpretation of the findings of Daniel and Menashe [60], even if autistic savant artists have low social functions in infancy and childhood, they may eventually increase social competence by enhancing their savant skills through flow and practice effects, as mentioned by Vital et al. [59]. In other words, we believe that the "social recognition" an individual obtains through artistic activities over a long period can affect the transformation of their sociability.

Some researchers may consider the possibility of "latent" artistic talent in non-savant autistic individuals to be substantial speculation with limited scientific validation. In addition, we fully acknowledge these concerns. Not all non-savant autistic individuals have these "potential" artistic talents. Nevertheless, it is necessary to consider the rTMS and tDCS results of Snyder et al. [25] and Chi et al. [28] and the claims of Snyder et al. [25] regarding these results. Some scholars

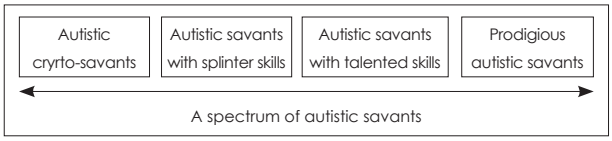

Fig. 7. Autistic Savant Spectrum Syndromic Disorder. Adapted from Camulli and Goh. Eur J Spec Educ Res 2018;3:185-204. [10], under the terms of the Creative Commons Attribution License (CC BY).

presented more systematic and compelling opinions than we did on the "latent talent" of non-savant autistic individuals and the phased classification of autistic savants.

Camulli and Goh [10] used concepts from previous studies by Chia [72] and Exkorn [73] to make new proposals about autistic savants. They proposed the concept of "autistic crypto-savants," autistic individuals with their talents in a hidden state at the lowest stage, and "prodigious autistic savants," on the other extreme, at the highest stage of talent retention. The splinters and talented skills were located in the middle stage. The aim was to use the concept of spectrum in the classification of savants, similar to the concept of spectrum in ASD. As mentioned earlier, Treffert [7] suggested such a spectrum concept and terminology. Camulli and Goh [10] proposed "Autism Savant Spectrum Syndromic Disorder (ASSSD)" as a term that encompasses these four stages (Fig. 7). The most commonly observed stage in individuals with autism is that of autistic savants with splinter skills. This is a stage of preoccupation with or memorization of what can be called trivial. Some autistic individuals' drawings or music have to be very artistic and beautiful for the individuals to be considered talented savants; in addition, they would possess a fantastic memory. A global population of autistic individuals who have reached the prodigious savant stage has been reported to comprise approximately 25 individuals [10]. For instance, Stephan Wiltshire, as mentioned above, is classified at this stage.

This proposal is, of course, a suggestion for all autistic savants, but we deem it much more appropriate to apply this proposal to autistic savant artists. Art was inseparable from the intellectual activities of ancient Homo sapiens and Neanderthals. Folgerø et al. [35] and Mithen [36] noted that artistic traits did not appear in a small number of groups but in most of the Neanderthal population. Perhaps many ancestors of modern humans were at least at the crypto-savant level.

Areas that Need Future Research

It is no exaggeration to say that increased scientific studies on autistic savant artists began only in the late 2000s. There is a very high potential for further research in this area. The scientific understanding of autistic savant artists will ultimately contribute to the acquisition of more profound knowledge of the causes of ASD and the development of various

therapeutic programs in the future. We suggest that further research in the following areas is necessary.

1) It is necessary to develop instruments that can comprehensively assess autistic savant artists. At present, there are several questionnaires for autistic savants, but it is challenging to evaluate artistic talent in detail because these questionnaires examine all eight or nine areas of talent. It is, therefore, necessary to develop instruments that can comprehensively assess various artistic talents.

2) There is a need for concepts that can more systematically define autistic savant artists in terms of the autism spectrum, or Camulli and Goh's [10] concept of ASSSD. Such a concept of the spectrum will have a significant impact on future research. For example, research focusing on autistic individuals corresponding to crypto-savants and on autistic individuals corresponding to autistic savants with splinter skills will make the object of studies clearer.

3) A longitudinal study of autistic savant artists is essential. Most of the studies published to date are cross-sectional ones. However, a cross-sectional research method is inevitable when issues such as the lack of a more accurate definition of autistic savant artists, spectral perspectives rather than a single category, and assessment tools are not resolved. When these issues are addressed, systematic longitudinal studies will be possible.

4) More systematic studies related to the Neanderthal theory of autism are warranted. Several neurobiological studies reported in the 2000s have shown that this theory could explain the functional and structural characteristics of the brains of some modern humans. It is now necessary to conduct studies targeting non-savant autistic individuals and autistic savants. Of course, the previously mentioned studies by Mozzi et al. [45] and others [47] were research attempts closer to autistic individuals and found significant results. However, no studies have directly investigated genes known to have been introgressed from Neanderthals in non-savant autistic individuals or autistic savants. Systematic studies are needed to investigate the proportion of genes introgressed from Neanderthals to Homo sapiens that are expressed in non-savant autistic individuals and autistic savants, how NeanderScore is manifested, whether the accompanying structural changes in the brain are identified, whether many results of studies on visual processing characteristics in autistic individuals [74] are related to NeanderScore, and the relationship between NeanderScore and characteristics of artistic savants.

5) It is necessary to conduct extensive studies on how active behaviors such as motor control are more important than passive cognitive processing in the artistic activities of autistic savant artists by applying the results of the study by Pring et al. [49]. Recent cognitive sciences have gone through computationalism, connectionism, and brain-centrism and are now on a paradigm shift to a science of "embodied cognition" [75]. Furthermore, the activation of embodiment-related areas in the brain while experiencing beauty and artwork is frequently reported in neuroaesthetic studies [20,76]. As such, the embodiment is considered important in aesthetic experience. We anticipate that the activation of embodiment through proactive artistic behaviors will inevitably occur, even in the development of the savant skills of autistic savant artists. In this respect, Cardinal's [17] characteristic of outsider art can be understood as the process by which savant autistic savant artists continue to embody their artistic talents. Research on the characteristics of "embodied artistic acts" by autistic savant artists is an area that must be actively studied.

6) A deeper study of the relationship between autistic savant artists and synesthesia is needed. There is a high frequency of synesthesia in individuals with autism [77]. In particular, there have been reports that the prevalence of synesthesia in autistic savants is much higher than that in non-savant autistic individuals. Hughes et al. [78] investigated the prevalence of synesthesia using self-reporting; 2.9% of non-savant autistic individuals and 10.0% of autistic savants reported having synesthesia. Cases of autistic savants with synesthesia have been continuously reported [38,39].

Therefore, it is necessary to review the artistic functions suddenly demonstrated by patients with frontotemporal dementia and primary progressive aphasia associated with the paradoxical function facilitation hypothesis [21,22]. It is worth revisiting the artistic abilities of the autistic savant artists mentioned in Wallace et al.'s [63] case report. For the most part, these artists' suddenly enhanced artistic abilities did not show an improvement in a single mode but a simultaneous improvement in several artistic categories, namely trans-modal improvement. We understand that these results were made possible by the type of synesthesia.

Our review did not focus on the synesthetic abilities of autistic savant artists. However, the topic of synesthesia must be continuously studied to better understand autistic savant artists, as this topic will also provide insight into the pathogenesis of ASD.

7) We must not lose sight of the fundamental questions, which refer to the essential question of the aesthetic feeling and emotion that autistic savant artists subjectively feel about their artistic experience, i.e., what is the "beauty" they experience? As mentioned above, the study results signify the importance of the mechanisms of the theory of mind and mentalization in the aesthetic judgment and experience of neurotypicals, which are now an established theory in

aesthetic, psychology, art, and other disciplines. However, we believe that there is no need to reiterate the lack of mechanisms of theory of mind and mentalization in the aesthetic experience of autistic savant artists who show a high-level of raw perception ability. In this regard, respect and a sense of awe for the beauty experience of autistic savant artists are essential attitudes that ordinary individuals as well as researchers should have. Furthermore, a multidisciplinary approach in which aesthetic, psychology, philosophy, neuroaesthetic, psychiatry, special education, and other related disciplines are required to understand the reality of the aesthetic experience of autistic savant artists is required.

CONCLUSION: SUPPORTING THE EXPRESSION "BEAUTIFUL *OTHERNESS*" ONCE AGAIN

Researchers must now identify, study, and understand the artistic talents and savant traits of individuals with autism. The artistic savant traits of autistic individuals are by no means "by-products" of a lengthy evolutionary process but are important traits resulting from "positive selection." A deep understanding of this characteristic will be imperative to understanding and helping individuals with autism as a whole, beyond the boundaries of savants.

In addition, we believe that the importance of understanding the savant traits of autistic individuals needs to be viewed from a broader perspective. This is the perspective of the root question, "Why did the nature of pursuing beauty appear in mankind?"

Ellen Dissanayake, an outstanding scholar in the field of art history and anthropology, stated that evolutionarily, humans had no choice but to acquire the ability to perform arts and defined the core of this artistic activity as "making something special" [79]. In addition, this "making special" ultimately emphasizes repetition, shape, pattern, elaboration, and stylization, because an individual can control a mess and gain satisfactory and good feelings. However, this process of "making special," that is, the pursuit of repetition, shape, pattern, and elaboration, is often observed in autistic savant artists and, more often, in non-savant autistic individuals. We are convinced that understanding the characteristics of the aesthetic activities of autistic savant artists will contribute significantly to understanding the valuable act of the pursuit of beauty that humanity has acquired.

In this regard, we realized once again how precise the phrase "the beautiful *Otherness* of the autistic mind" was chosen by Happé and Frith [18] more than a decade ago and believe that everyone should deeply understand the meaning of the phrase and continue the ontological reflection on savants.

Philosopher Byung-Chul Han, in his book *The Agony of Eros*, described Eros as follows: "...Eros concerns the *Other* in the strong sense, namely, what cannot be encompassed by the regime of the ego [80]." We assert that the true process of Eros is the gradual discovery and understanding of the reality of the beautiful *Otherness* of autistic savant artists.

Availability of Data and Material

Data sharing not applicable to this article as no datasets were generated or analyzed during the study.

Conflicts of Interest

Jung-Woo Son, a contributing editor of the *Journal of the Korean Academy of Child and Adolescent Psychiatry*, was not involved in the editorial evaluation or decision to publish this article. The other author has declared no conflicts of interest.

Author Contributions

Conceptualization: Jung-Woo Son. Data curation: Seungwon Chung, Jung-Woo Son. Formal analysis: Seungwon Chung, Jung-Woo Son. Investigation: Seungwon Chung, Jung-Woo Son. Methodology: Jung-Woo Son. Project administration: Seungwon Chung, Jung-Woo Son. Resources: Seungwon Chung, Jung-Woo Son. Software: Seungwon Chung. Supervision: Jung-Woo Son. Validation: Seungwon Chung, Jung-Woo Son. Visualization: Seungwon Chung. Writing—original draft: Seungwon Chung, Jung-Woo Son. Writing—review & editing: Seungwon Chung, Jung-Woo Son.

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