



Autism Spectrum Disorder and Savant Syndrome: A Systematic Literature Review

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Objectives: This study aimed to analyze research trends in autism spectrum disorder (ASD) and savant syndrome and their cognitive characteristics through a systematic literature review. The objectives of this study were to establish an overview of research trends in ASD and savant syndrome, analyze the overall characteristics of individuals with ASD and savant syndrome, and examine their cognitive characteristics.

Methods: For the systematic literature review, three criteria were used to select review articles: 1) literature from peer-reviewed journals, published in the past 15 years, from 2008 to 2022; 2) subjects with ASD and savant syndrome; 3) study objectives focused on the basic phenomenon and cognitive characteristics of ASD and savant syndrome. Finally, based on the selection criteria, a total of 40 articles were included.

Results: Five themes and nine subthemes were derived from the analysis of 40 studies. The five main themes were as follows: 1) What is savant syndrome? 2) Demographic characteristics of savant syndrome; 3) Spectra of savant syndrome; 4) Savant syndrome and ASD; and 5) Cognitive characteristics of ASD with savant syndrome. The subthemes of the cognitive characteristics were weak central coherence, detail-focused cognitive processing, enhanced perceptual functioning, and hyper-systemizing.

Conclusion: Several studies have been conducted to understand ASD and savant syndrome; however, no single theory can specify the cognitive characteristics of people with ASD and savant syndrome. Therefore, further systematic and multi-layered research on ASD and savant syndrome are required for more comprehensive results.

Keywords: Autism spectrum disorder; Savant syndrome; Cognitive characteristics; Enhanced perceptual functioning; Detail focused cognitive processor; Hyper-systemizing.

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INTRODUCTION

Savant syndrome refers to a condition in which an individual displays a special talent in one or more areas. The individual must exhibit exceptional abilities in one or more areas that are inconsistent with their overall level of functioning [1-3]. The most frequently used adjectives to define savant syndrome are “rare” and “remarkable,” indicating that this is a very rare condition characterized by remarkable talent.

There are two conditions that are essential for defining or diagnosing savant syndrome: “exceptional abilities” and “intellectual abilities.” “Exceptional ability” means that an individual shows extraordinary achievement in one or more areas. In other words, the individual demonstrates a special talent despite having a disability, even when compared to the gen-

eral population. The second condition is intellectual ability. Previous studies have defined savant syndrome as a condition in which a special talent is demonstrated by a person with an intellectual disability. However, subsequent cases and studies have shown occurrences of savant syndrome even among individuals without any intellectual disability and other neurological disabilities as well as among the general population [2-5]. Howlin et al. [6] reported that the savant group displayed a higher level of overall cognitive function than the non-savant group and that their average non-verbal intelligence quotient (IQ) was approximately 80, with none of the individuals showing a non-verbal IQ below 50. These findings suggest that savant syndrome was observed even in groups without intellectual disabilities.

Savant syndrome should be differentiated from the following terms that have similar meanings: exceptional ability, giftedness, and twice-exceptional [7]. Exceptional ability refers to skills that are exceptional compared to one’s overall cognitive

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functioning or even when compared to the general population, and this expression can have similar meanings to “exceptional skills” or “savant skills.” Giftedness refers to displaying a high level of performance compared to the same age group or a group with similar experiences. Twice-exceptional refers to an individual having two special traits: autism spectrum disorder (ASD) and enhanced perceptual functioning (EPF) in a particular area [7]. Displaying exceptional abilities in a particular area can also be explained by the concept of intraindividual variation, which has often been used as a diagnostic criterion for learning disabilities [2].

The current literature indicates that the characteristics of savant syndrome, ASD and savant syndrome, and cognitive features of people with ASD and savant syndrome have been studied extensively worldwide; however, there is a limited number of studies in Korea, with the only available studies being the clinical study by Kim et al. [8] and parent interviews conducted by Park [1]. Despite the scarcity of academic research on this topic in Korea, the illustration of savant syndrome by the mass media has raised awareness among the general population and sparked academic interest among relevant experts. The recently aired TV drama *Extraordinary Attorney Woo* [9] and film *Nocturne* [10] adequately directed the attention of the general population and relevant experts toward people with ASD and savant syndrome. Despite the growing popularity and interest in savant syndrome, there is a dearth of basic research on the specific characteristics of savant skills, the overall cognitive characteristics of individuals with ASD who possess these skills, and the understanding of having these skills among individuals themselves. Parents of children with ASD and savant syndrome have experienced various challenges and confusion in navigating the unfamiliar territory between ASD and savant syndrome, and have voiced the need for more systematic research on savant syndrome [1].

As documented in several studies, savant syndrome is more prevalent in individuals with ASD compared to other clinical populations, and for this reason, studies have continued to investigate which traits of ASD contribute to the onset of savant syndrome [6]. One hypothesis posits that savant skills may be related to the restricted repetitive behaviors (RRBs), special interests, and obsessive-compulsive traits, the second diagnostic criterion for ASD, while another theory proposes that the development of savant skills may stem from the difficulties in social cognitive skills, that is, difficulties in understanding others' mind [11-13]. In addition, another hypothesis based on several study findings explains that the special cognitive features of individuals with ASD may contribute to the higher prevalence of savant skills [14-17]. Indeed, there is no single theory that explains the high prevalence of savant syndrome in individuals with ASD. Thus, it is impor-

tant to conduct a systematic review of the existing literature to examine the research trends for people with ASD and savant syndrome and to explore the directions of subsequent research.

The present study was conducted to address the following objectives: 1) to analyze the research trends in individuals with ASD and savant syndrome over the past 15 years; 2) to examine the main characteristics of savant syndrome and the general characteristics of individuals with ASD and savant syndrome; and 3) to identify the cognitive characteristics of individuals with autism and savant skills.

METHODS

Selection criteria

This study analyzed studies published over the past 15 years to examine research trends in individuals with ASD and savant syndrome. Studies were included if they had been published over the past 15 years (2008–2022) in peer-reviewed journals, and were journal-published articles investigating the cognitive characteristics of individuals with ASD and savant syndrome.

Studies were excluded based on the following: studies that examined savant syndrome only in the general population; studies that examined other complex disabilities; studies examining biological factors, such as biochemistry, genetics, and molecular biology; studies dealing with other disabilities, such as epilepsy; and publications that were not peer reviewed, such as books, editorials, communications, conference presentations, and degree dissertations.

Literature search

To ensure systematic literature analysis, the preferred reporting items for the systematic review method and procedure were followed [18]. The search strategy and process are described below.

An initial search was conducted by entering a combination of search words into the search database selected for the literature search. The keyword and a combination of keywords used for the literature search was “savant syndrome,” “ASD,” “savanna,” “autism,” and “cognition.” The following databases were searched: Scopus, Science Direct, PubMed, ISI Web, CINAHL Plus with Full Text (EBSCOhost), ERIC (ProQuest), Google Scholar, DBpia, and RISS.

Next, for a thorough data search, an initial search was performed for each database, and duplicates were removed. The titles and abstracts of the remaining articles (n=137) were then reviewed to exclude ineligible articles according to the purpose of the study and the inclusion and exclusion criteria.

Third, the remaining articles (n=86) were analyzed based

on the variables selected for analysis, and articles that met the exclusion criteria were excluded. The basic exclusion criteria were studies conducted on individuals with neurological disabilities other than ASD, studies conducted only on the general population, and studies that mainly examined cranial and biological factors. Additionally, while reviewing the articles, studies without clearly defined methods or procedures or non-peer reviewed studies, such as editorials, were excluded.

Finally, 43 studies were identified through this process. Subsequently, additional eligible studies were identified through the references, and studies that met the exclusion criteria, such as neuroimaging or cranial nerve-related studies, were excluded. Consequently, 40 studies were included in this review.

Literature analysis

The aim of this study was to analyze the research trends regarding people with ASD and savant syndrome and their cognitive features. The studies were analyzed based on the variables selected from previous studies and for the purpose of the present study—publication year, study methodology, study objectives, study population, measurements, and study outcomes [19-22].

The included studies were analyzed according to the study methodology, and divided into literature reviews and surveys and different variables were used for the two types of study methodologies. In the literature review, the study objectives, topics, and results were analyzed. Survey studies were analyzed according to their purpose, participants, measurement and investigation methods, and results. Survey research was categorized into case studies, experimental studies, and questionnaire studies according to the research execution methods; one study that performed a qualitative interview was also included.

RESULTS

Overview of research trend

Research trends by publication year and methodology

In this study, a total of 40 articles were analyzed by research methods and publication year. A review according to the re-

search method showed 20 literature reviews and 20 survey studies. Two studies were published in Korea and 38 were published in an English-speaking country. Table 1 lists the studies according to the publication year and methods. In terms of quantitative changes in studies on the cognitive characteristics of individuals with ASD and savant syndrome by year, the highest number of studies was published in 2009, with eight literature reviews and three survey studies, while related studies are being conducted to date. The reason for the highest volume of research in 2009 appears to be because of the coverage of ASD and savant syndrome in Volume 364, Issue 1522 of *Philosophical Transactions: Biological Sciences*, which inspired academic research on this topic.

Overview of literature reviews

Themes and subthemes of literature reviews

Over the past 15 years, 20 studies have explored theories pertinent to the overall and cognitive characteristics of individuals with ASD exhibiting savant syndrome. These 20 exploratory studies were analyzed for overall trends based on the study themes. As shown in Table 2, five themes and seven subthemes were derived.

Table 3 presents the overall outline of the literature reviews. The main themes of this study are as follows: 1) basic theories about savant syndrome and its association with ASD [3,5,23-25]; 2) incidence of savant syndrome, sex differences, and their relationship with overall cognitive functioning [5,26]; 3) type and extent of savant skills [5,26]; 4) the relationship between ASD and savant syndrome [23,25-30]; and 5) the cognitive characteristics of individuals with ASD who display savant syndrome. The studies conducted on the cognitive characteristics primarily examined weak central coherence (WCC) and detail-focused cognitive processing [13,25-28,31], rule-based pattern recognition, hyper-systemizing, enhanced perceptual abilities and synesthesia, deficits in theory of mind, RRBs, and attentional issues [25-27,32-39] (Table 3).

Overview of survey research

Table 4 presents the overall survey research trends. Twenty survey research studies were categorized into six case studies (including a questionnaire survey of 125 parents) (23.8%),

Table 1. Publication year and research method

Methods	Year (2008–2022)														Total	
	08	09	10	11	12	13	14	15	16	17	18	19	20	21		22
Literature review & Position Paper	2	8	2	0	0	2	1	0	0	0	1	0	2	1	1	20
Experimental study & Survey, in-depth interview	0	3	2	3	2	0	2	2	1	1	1	0	1	1	1	20
Total	2	11	4	3	2	2	3	2	1	1	2	0	3	2	2	40

Table 2. Research themes and subthemes

Main theme	Subtheme	Study	
		Literature review & Position Paper	Experimental study & Survey
Definition and characteristics of savant syndrome	Definition and characteristics of savant syndrome	Treffert [3] (2014) Treffert [5] (2009) Happé and Frith [23] (2009) Gyarmathy [24] (2018) Dawson et al. [25] (2008)	
	Diagnosis of savant syndrome	Gyarmathy [24] (2018)	Bennett and Heaton [42] (2012)
Demographic information	Prevalence	Treffert [5] (2009) Wallace [26] (2008)	Howlin et al. [6] (2009) Bal et al. [52] (2022)
	Differences in prevalence by gender		Howlin et al. [6] (2009) Treffert and Rebedew [41] (2015)
	Cognitive ability and savant syndrome		Howlin et al. [6] (2009) Kim et al. [8] (2011) Vital et al. [13] (2009) Pring et al. [40] (2012) Bölte et al. [46] (2011)
A spectrum of savant skills		Treffert [5] (2009) Wallace [26] (2008)	Park [1] (2021) Kim et al. [8] (2011) Hughes et al. [12] (2018) Treffert and Rebedew [41] (2015) Dubischar-Krivec et al. [48] (2009) Bal et al. [52] (2022)
Savant syndrome and autism spectrum disorder (ASD)		Happé and Frith [23] (2009) Wallace [26] (2008) Baron-Cohen et al. [27] (2009) Happé and Vital [28] (2009) Snyder [29] (2009) Plaisted Grant and Davis [30] (2009)	Park [1] (2021) Howlin et al. [6] (2009) Kim et al. [8] (2011) Daniel and Menashe [11] (2020) Hughes et al. [12] (2018)
	Cognitive characteristics of ASD and savant syndrome	Vital et al. [13] (2009) Dawson et al. [25] (2008) Wallace [26] (2008) Happé and Vital [28] (2009) Boso et al. [31] (2010)	Benett and Heaton [42] (2012)
	Enhanced perceptual function and hypersystemizing	Wallace [26] (2008) Baron-Cohen et al. [27] (2009) Baron-Cohen and Lombardo [32] (2017) Bokkon et al. [33] (2013) Motttron et al. [34] (2009) Motttron et al. [35] (2013) Motttron et al. [36] (2021) Murray [37] (2010) van der Zee and Derksen [38] (2021) van Leeuwen et al. [39] (2020)	Hughes et al. [12] (2018) Crane et al. [15] (2011) De Marco et al. [16] (2016) Pring et al. [17] (2010) Bennett and Heaton [42] (2012) Bennett and Heaton [43] (2017) Finocchiaro et al. [44] (2015) Bouvet et al. [45] (2014) Soulières et al. [47] (2010) Dubischar-Krivec et al. [49] (2014)

nine experimental studies (47.6%), five questionnaire studies (one study included three cases and was considered a duplicate case) (23.8%), and one qualitative interview study (4.8%).

Study participants

Regarding number of study participants, there were six

case studies (28.6%) with a small number of participants of ≤ 10 (one of these studies conducted in-depth interviews with parents), five questionnaire studies with a relatively small sample of ≤ 50 (23.8%) (one study included three cases and was considered duplicate cases), six studies conducted on 51–200 participants (28.6%), and four larger studies conducted on a

Table 3. Overview of literature review and position paper

Number	Study	Purpose	Results
1	Dawson et al. [25] (2008)	Review of autistic learning, covering accounts of learning in the autism intervention research and in the cognitive and savant literatures	<ul style="list-style-type: none"> • Learning in autism is characterized both by spontaneous—sometimes exceptional—mastering of complex material and an apparent resistance to learning in conventional ways. • Learning that appears to be implicit seems to be important in autism, but autistics' implicit learning may not map directly onto non-autistics' implicit learning or be governed by the same constraints.
2	Wallace [26] (2008)	Explores some of savant skills and derives implications for the study of giftedness	<ul style="list-style-type: none"> • Savant skills are inextricably linked to autism spectrum disorder. • Neuropsychological models of autism spectrum disorder (ASD) may help to explain the raised incidence of savant skills in ASD. • Neuropsychological research into savant skills may have direct implications for better understanding the neuroscience of giftedness.
3	Baron-Cohen et al. [27] (2009)	The relationship between talent in autism and hyper-systemizing, hyper-attention to detail and sensory hypersensitivity	<ul style="list-style-type: none"> • The hyper-systemizing theory argues that the excellent attention to detail. • Law-based pattern recognition systems can produce talent in systemizable domains. • The excellent attention to detail in ASC is itself a consequence of sensory hypersensitivity. • The origins of the association between autism and talent begin at the sensory level, include excellent attention to detail and end with hypersystemizing.
4	Happé and Frith [23] (2009)	Exploring the basic theories of autism and savant, talent, creativity	<ul style="list-style-type: none"> • Special skills are associated with autistic disorder, but not everyone with talent is autistic, and not every person with ASD shows savant skills. • Savant skill and practice. • The importance of fostering talent.
5	Happé and Vital [28] (2009)	Explore why are striking special skills so much more common in autism spectrum conditions (ASC)	<ul style="list-style-type: none"> • Detail-focused processing bias ("weak coherence," "enhanced perceptual functioning") appears to be the most promising predisposing characteristic, or "starting engine," for talent development. • ASC-like traits, and specifically "restricted and repetitive behaviours and interests" related to detail focus, were more pronounced in children reported to have talents.
6	Mottron et al. [34] (2009)	Enhanced perception in savant syndrome: patterns, structure and creativity	<ul style="list-style-type: none"> • Autistics' enhanced perception and their possible contribution to the creativity evident in savant performance, are explored.
7	Plaisted Grant and Davis [30] (2009)	The qualitative differences in perceptual processing between individuals with and without ASCs	<ul style="list-style-type: none"> • Savant abilities are relatively rare, but the skills observed in individuals with ASCs are common. • These skills need as much training and encouragement as is given to any individual with talent in detailed processing.
8	Snyder [29] (2009)	Explaining and inducing savant skills: privileged access to lower level, less-processed information	<ul style="list-style-type: none"> • Savants have privileged access to lower level, less-processed information. • Owing to a failure in top-down inhibition, they can tap into information that exists in all of our brains but is normally beyond conscious awareness. • A strategy of building from the parts to the whole could form the basis for the so-called autistic genius.
9	Treffert [5] (2009)	A brief review of the savant skills	<ul style="list-style-type: none"> • The phenomenology of savant skills, the history of the concept and implications for education and future research.

Table 3. Overview of literature review and position paper (continued)

Number	Study	Purpose	Results
10	Vital et al. [13] (2009)	Investigate the association between special abilities and ASD-like traits	<ul style="list-style-type: none"> • Children with special abilities showed significantly more ASD-like traits than those without such abilities. • General intelligence did not mediate this relationship: intelligence quotient (IQ) was found to be positively associated with ability, but negatively associated with ASD-like traits. Special abilities were more strongly associated with restricted/repetitive characteristics than with social or communication traits.
11	Boso et al. [31] (2010)	The relationship of autism and genius	<ul style="list-style-type: none"> • Analyze the eccentricity the major functional hypotheses on autistic hyperfunctioning, advancing proposals for functional testing. • The potential involvement of rhythm-entrained systems and cerebro-cerebellar loops opens new perspectives for the investigation of autistic disorders and brain hyperfunctioning.
12	Murray [37] (2010)	To explain savant skills with synaesthesia and concrete representations	<ul style="list-style-type: none"> • The reification of abstract concepts and synaesthesia can explain savant skill. • Two main strands about synaesthesia are 1) There are many anecdotes about recognizing abstract concepts as concrete concepts. 2) synaesthetes who possess these structures experience cognitive benefits in the same domain.
13	Bokkon et al. [33] (2013)	Essential role of picture representation in ASD and that extraordinary savant-like skills	<ul style="list-style-type: none"> • Savant abilities can emerge through transcranial magnetic stimulation and top-down cortical inhibition in the left frontotemporal lobe. • In people with autism, there is improved visual function. • The visual cortex influences the processing of visual cues, mathematical thinking, and auditory cues. • ASD is better at visual representation than verbal representation.
14	Mottron et al. [35] (2013)	Elaborate veridical mapping as a specific mechanism which can explain the higher incidence of savant abilities	<ul style="list-style-type: none"> • Veridical mapping and savant syndrome. • Prevalence and specificity of domain-specific abilities in autism. • The atypical neural connectivity characteristics of ASD are consistent with the developmental predisposition to veridical mapping, and as a result, the appearance of servant ability, absolute pitch, and synesthesia is high.
15	Treffert [3] (2014)	Sorts out realities from myths and misconceptions about both savant syndrome and ASD	<ul style="list-style-type: none"> • The reality is that low IQ is not necessarily an accompaniment of savant syndrome; in some cases, IQ can be superior. • Savants can be creative, and the skills increase over time on a continuum from duplication to improvisation to creation. • Emphasizes the critical importance of separating 'autistic-like' symptoms from ASD.
16	Gyarmathy [24] (2018)	Examines the savant syndrome and its connection to other syndromes and the talent development.	<ul style="list-style-type: none"> • The savant syndrome, autism and talent development lead to some mutual developmental and neurological characteristics. • A savant is not a talent automatically, but many talents can possess savant abilities. • The relationship between talent and the savant syndrome indicates that the savant syndrome might be a special form of talent, a neurological predisposition arising, like any other congenital potential, as a function of environmental influences in the form of different-from-normal behavior.

Table 3. Overview of literature review and position paper (continued)

Number	Study	Purpose	Results
17	van Leeuwen et al. [39] (2020)	Review the association between synaesthesia and autism	<ul style="list-style-type: none"> • The overlap between synaesthesia and autism is established most convincingly at the level of alterations in sensory sensitivity and perception, with synaesthetes showing autism-like profiles of sensory sensitivity and a bias towards details in perception. • Autism and synaesthesia co-occur in the same individual, the chance of developing heightened cognitive and memory abilities is increased.
18	van der Zee and Derksen [38] (2020)	Provides an overview of the current state of research regarding the systemizing concept	<ul style="list-style-type: none"> • High systemizing abilities are characteristic and specific in autism and as a result, three non-social features of autism are seen: restricted and repetitive behavior, obsessional interests, and savant skills. • In order to identify autism in clinical practice, the use of an instrument which is specialized in measuring one's systemizing abilities is required.
19	Mottron et al. [36] (2021)	Prototypical autism, the genetic ability to learn language is triggered by structured information	<ul style="list-style-type: none"> • Autistic learning of complex structures: the veridical mapping model as a structure acquisition device. • Recognizing the human genetic nature of autistic language learning changes our strategy for intervention.
20	Baron-Cohen and Lombardo [32] (2017)	The cognitive and neural basis of systemizing of ASD and savant syndrome	<ul style="list-style-type: none"> • People with autism are on average hypersystemizers, scoring higher than average on the systemizing quotient and on performance tests of systemizing. • Consider the neural basis behind the systemizing mechanism.

sample of ≥200 (19.0%).

In one questionnaire survey conducted with more than 100 parents, data were collected using existing data in the database.

The ages of the participants varied widely from children to adults. The youngest patient was 7 years old, and the oldest was 90 years old. However, most studies examined participants in their late teens up to approximately 40 years of age.

Objective

The objectives of the included studies were primarily to compare individuals with ASD and savant syndrome and those with ASD without savant syndrome or to compare individuals with ASD and savant syndrome with the general population to examine the differences in cognitive processing, cognitive traits, and clinical features in individuals with ASD who display savant syndrome. More specifically, the present study aimed to examine the relationship between enhanced perception, execution functions, exceptional talent, and autistic tendencies, and to compare individuals with ASD who possess savant skills and those who do not possess savant skills to identify the cognitive factors that contribute to savant skills.

Themes of survey research

Five themes and eight subthemes were identified in the survey studies (Tables 2 and 4). The main results of the analysis

are as follows. First, there were studies that analyzed the demographic characteristics of individuals with ASD who displayed savant syndrome. These studies showed that the incidence of savant syndrome in the ASD population was higher than that in the general population or in other patient populations with neurodevelopmental disabilities. However, the incidence of savant syndrome was inconsistent, ranging from 10% to 50%. The prevalence of savant syndrome was higher in men than in women [6,8]. Second, intellectual ability was significantly higher in the group with savant syndrome than in the group without savant syndrome [6,8,13,17,40]. Third, the most common types of savant skills were memorization, music, art, reading, spatiotemporal, mathematics, and calendar calculations, and many individuals showed two or more savant skills [8,12,41]. Fourth, studies have investigated the differences in social communication and RRBs, the core diagnostic criteria for ASD, to analyze the relationship between savant syndrome and ASD. The results showed that the two groups did not clearly show variances in the social communication area but did show differences in RRBs. Thus, the savant syndrome group tends to exhibit more RRBs than the non-savant syndrome group [6,8,11,12]. Daniel and Menashe [11] suggested that a group with savant syndrome exhibited fewer deficits in social responsiveness than a group without savant syndrome. These results are in line with findings suggesting that those with savant syndrome have a higher over-

Table 4. Overview of experimental study and survey

Number	Study	Participants	Purpose	Measure	Results
1	Dubischar-Krivec et al. [48] (2009)	Savant calendar calculators with autism, n=3, age 9–36 yr Healthy calendar calculators, n=3 Non-savant subjects with autism, n=6 healthy calendar calculator layman, n=18	Identify the cognitive processes that distinguish calendar calculation in savant individuals from healthy calendar calculators.	Calculated dates of the present (current month), calculated dates of the past and future 50 years	<ul style="list-style-type: none"> Savant calendar calculators with autism (ACC) showed shorter reaction times and fewer errors than healthy calendar calculators (HCC) and non-savant subjects with autism, and significantly fewer errors than healthy calendar calculator laymen when calculating dates of the present. ACC performed faster and more accurate than HCC regarding past dates. However, no differences between ACC and HCC were detected for future date calculation. Distinct calendar calculation strategies in ACC and HCC, with HCC relying on calendar regularities for all types of dates and an involvement of (rote) memory in ACC. Thirty-nine participants (28.5%) met criteria for either a savant skill or an exceptional cognitive skill. One-third of males showed some form of outstanding ability compared with 19 per cent of females. No individual with a non-verbal intelligence quotient (IQ) below 50 met criteria for a savant skill. The association between special abilities and ASD-like traits and expand it to traits in the general population. The type of nonsocial traits most strongly associated with special abilities suggests a link to featural information processing style, or 'weak central coherence.' There were no significant differences between the meaningful and abstract versions of the EFT, in any of the groups. The savant artists performed above the level of the ASD and MLD groups on the block-design test, but not the EFT. Although an enhanced local processing style is an important aspect of savant artistic talent, motor control also appears to be a necessary skill.
2	Howlin et al. [6] (2009)	n=137 (average age 24 yr)	To investigate the nature and frequency of savant skills in a large sample of individuals with autism	Diagnostic and cognitive assessments Savant skills: parent report (n=23)	<ul style="list-style-type: none"> Thirty-nine participants (28.5%) met criteria for either a savant skill or an exceptional cognitive skill. One-third of males showed some form of outstanding ability compared with 19 per cent of females. No individual with a non-verbal intelligence quotient (IQ) below 50 met criteria for a savant skill. The association between special abilities and ASD-like traits and expand it to traits in the general population. The type of nonsocial traits most strongly associated with special abilities suggests a link to featural information processing style, or 'weak central coherence.' There were no significant differences between the meaningful and abstract versions of the EFT, in any of the groups.
3	Vital et al. [13] (2009)	6426 8-year-olds with and without parent-reported special abilities	To investigate the association between special abilities and autism spectrum disorder (ASD)-like traits	A screening questionnaire for ASD-like traits IQ, sex, and socioeconomic status (SES)	<ul style="list-style-type: none"> The association between special abilities and ASD-like traits and expand it to traits in the general population. The type of nonsocial traits most strongly associated with special abilities suggests a link to featural information processing style, or 'weak central coherence.' There were no significant differences between the meaningful and abstract versions of the EFT, in any of the groups.
4	Pring et al. [17] (2010)	ASD savant artist, n=9, age 23–43 yr ASD adult, n=9, age 22–42 yr Mild/moderate learning difficulties (MLD), n=9, age 16–18 yr Art students, n=9, age 17–20 yr Psychology students, n=9, age 17–20 yr	Explore the nature of local and global processing in savant artists with ASD	Block Design & embedded figures test (EFT)	<ul style="list-style-type: none"> The savant artists performed above the level of the ASD and MLD groups on the block-design test, but not the EFT. Although an enhanced local processing style is an important aspect of savant artistic talent, motor control also appears to be a necessary skill.
5	Soulières et al. [47] (2010)	ASD savants, n=2, nonsavants, n=6	Understanding the superior estimation abilities through a case study	Computerized and noncomputerized tasks	<ul style="list-style-type: none"> Certain autistic spectrum individuals may develop superior and highly specialized abilities in estimation. These findings in relation to the role of "veridical mapping" in the development of special ability.

Table 4. Overview of experimental study and survey (continued)

Number	Study	Participants	Purpose	Measure	Results
6	Bölte et al. [46] (2011)	High functioning ASD, males, n= 35 High functioning ASD females, n= 21 Unaffected sibling controls (23 males and 35 females)	<ul style="list-style-type: none"> To identify gender differences and clinical correlations in the cognitive domain Functional comparison of visual attention to detail and executive function 	Autism Diagnostic Observation Schedule (ADOS), intelligence tests, Child Behavior Checklist (CBCL)/Young Adult Behavior Checklist (YABCL), Autism Diagnostic Interview-Revised (ADI-R), visual attention to detail (AITD) & selected executive functions (EF)	<ul style="list-style-type: none"> Females with ASD outperformed males on EF as assessed by the Trail Making Test B-A. Males with ASD showed superior performance for ATTD as measured by the Block Design Test (BD) clinically meaningful cognitive sex differences in ASD. Particularly an association between EF and stereotypic behaviours and interests. ATTD as a potential basis for specific cognitive strengths (e.g., scientific/savant skills) might be more pronounced in males with ASD. The savant artists performed better than the ASD comparison group on the fluency and monitoring, but not perseveration, aspects of the design fluency task. No significant differences were observed between the savant, ASD and MLD groups on the card sort task. In the domain of their talent, savant artists have enhanced executive abilities, relative to their non-talented counterparts.
7	Crane et al. [15] (2011)	Savant group, n=9, age 23–43 Autism, n=5 Asperger syndrome, n= 3 Atypical autism, n=1 Control group Non savant ASD, n=9 Mild Learning Disabilities, n=8	To assess executive abilities (specifically, fluency, perseveration and monitoring) in savant artists with ASD, relative to non-talented individuals with ASD or MLD	Three facets of executive ability (fluency, perseveration and monitoring) assessed.	<ul style="list-style-type: none"> The savant artists performed better than the ASD comparison group on the fluency and monitoring, but not perseveration, aspects of the design fluency task. No significant differences were observed between the savant, ASD and MLD groups on the card sort task. In the domain of their talent, savant artists have enhanced executive abilities, relative to their non-talented counterparts.
8	Kim et al. [8] (2011)	Savant autism, n=60 Nonsavant autism, n= 81	Relationship between Savant Skills and Autistic Symptoms in Korean Patients with Autism Spectrum Disorder	The domain scores and total scores of the Korean version ADI-R, Korean versions of Asperger Syndrome Diagnostic Scale (K-ASDS), and Korean translated versions of Social Responsiveness Scale (K-SRS)	<ul style="list-style-type: none"> Memory (n=47) was the most prevalent savant skill in the savant ASD group (n=60). The savant ASD group had a statistically higher mean age and IQ score than did the nonsavant ASD group. The savant ASD group showed high IQ profile, a higher RRB and higher language and cognitive scores than did the nonsavant ASD group.
9	Bennett and Heaton [42] (2012)	Study 1. Parents of 125 children, adolescents and young adults with autism spectrum disorders Study 2. Three individuals with exceptional skills for music, art and mathematic	<ol style="list-style-type: none"> To develop and pilot a new screening questionnaire Validating the screening instrument 	Special Skills in Autism Questionnaire+case study	<ul style="list-style-type: none"> 42% of respondents had children with one or more skills that were outstanding given their child's functional skills. Special skills are associated with superior working memory and highly focused attention that is not associated with increased obsessiveness. Although intellectual impairment and a local bias have been widely associated with special skills in the savant literature, neither the screening nor case studies provided strong evidence for such associations.

Table 4. Overview of experimental study and survey (continued)

Number	Study	Participants	Purpose	Measure	Results
10	Pring et al. [40] (2012)	Savant artists with ASD, n=9 Non-artistically talented individuals with ASD n=9 Mild/moderate learning difficulties (MLD), n=9 Talented art students, n=9	To explore savant artists with autism and their creativity	1) TTCT (Torrance Test of Creative Thinking) Task 2) Figural synthesis task (FST)	<ul style="list-style-type: none"> The savants did produce more elaborative responses than the ASD and MLD groups, no differences were observed on the other indices of creativity. Elaboration is a key skill in savant artistic talent. On the non-drawing construction task, the savant group produced more original (but not more fluent) outputs. The co-occurrence of abilities, which share the same structure, suggest the importance of veridical mapping in the atypical range and nature of abilities displayed by autistic people.
11	Bouvet et al. [45] (2014)	Savant autism (n=1, age 21 yr): several savant abilities: absolute pitch and synesthesia-like associations	To examine the relationship of enhanced perception, veridical mapping, and savant ability	Case study (developmental history, self-report, test)	<ul style="list-style-type: none"> ASD people perform better in accurate responses. In terms of speed, it was not. During calendar calculation, calendar calculators with ASD and typically developing calendar calculators both showed maxima at frontal and left superior temporal sites as well as bilateral insulae. This is in accordance with verbal fact retrieval and working memory as well as monitoring and coordination processes.
12	Dubischar-Krivec et al. [49] (2014)	Savant calendar calculators with autism, n=3 Typically developing calendar calculators, n=3	Neural mechanisms of savant calendar calculating in autism Neural mechanisms of savant calendar calculating in autism	126 calendar tasks with dates of the present, past, and future	<ul style="list-style-type: none"> ASD people perform better in accurate responses. In terms of speed, it was not. During calendar calculation, calendar calculators with ASD and typically developing calendar calculators both showed maxima at frontal and left superior temporal sites as well as bilateral insulae. This is in accordance with verbal fact retrieval and working memory as well as monitoring and coordination processes.
13	Finocchiaro et al. [44] (2015)	A child with savant and ASD (age 7 yr)	A case study of a child with ASD and savant abilities	A protocol of academic skills: Measures of cognitive, academic, adaptive skills, Calculation skills	<ul style="list-style-type: none"> Performances in number elaboration showed an adequate access to semantic and verbal number information. In the written and mental calculation task and in fact retrieval, implicating calculation strategies and information retrieval, processes were automatized. 79% male, 21% female. 90% are congenital savants, 10% are acquired savants. Among the individuals with congenital savant syndrome, the most common underlying disability was ASD (75%); in the other 25%. Fifty-five percent possessed a single special skill, while 45% had multiple skills. Music was the most frequent principal skill followed by art, memory, mathematics, calendar calculating, language, visual-spatial/mechanical, athletic, computer, extrasensory perception, and other skill.
14	Treffert and Rebedew [41] (2015)	Savnannt autism, n=319	To identify the demographic characteristics of Savant Syndrome	Subjects were chosen based upon existing mail and e-mail	<ul style="list-style-type: none"> 79% male, 21% female. 90% are congenital savants, 10% are acquired savants. Among the individuals with congenital savant syndrome, the most common underlying disability was ASD (75%); in the other 25%. Fifty-five percent possessed a single special skill, while 45% had multiple skills. Music was the most frequent principal skill followed by art, memory, mathematics, calendar calculating, language, visual-spatial/mechanical, athletic, computer, extrasensory perception, and other skill.

Table 4. Overview of experimental study and survey (continued)

Number	Study	Participants	Purpose	Measure	Results
15	De Marco et al. [16] (2016)	24-year-old male (Asperger syndrome)	Observation of special ability	Calendar calculation skills, priming effect, The "Easter Test" Investigation of autobiographical memories	<ul style="list-style-type: none"> Responded with 98.2% accuracy to 492 day-date correspondences covering a period of 40 years. Such accurate performance on future-date trials relies on knowledge and use of calendrical regularities.
16	Bennett and Heaton [43] (2017)	Savant ASD group, n=17 (age 8–13 yr) Nonsavant autism group, n=19 (age 8–13 yr) Typically developing, n=17, (age 8–13 yr)	To compare clinical and cognitive profiles of child savants and non-savants with ASD	<ol style="list-style-type: none"> Skill validation assessment Clinical assessment: symptom severity (Social Communication Questionnaire, ADOS, short sensory profile), Obsessionality Cognitive ability Assessments 	<ul style="list-style-type: none"> Striking differences between savant and non-savant groups emerged on measures of cognitive ability. Children with savant skills exhibited highly superior working memory and their scores on tests of analytic skills were also superior to those of non-savants.
17	Hughes et al. [12] (2018)	Savant and ASD, n=44 Nonsavant ASD, n=36 Typical control, n=31	Investigate a psychological profile in autism and savant syndrome	Investigated the cognitive and behavioural profiles. Investigate a novel savant skill—calendar calculation	<ul style="list-style-type: none"> Heightened sensory sensitivity, obsessional behaviours, technical/spatial abilities, and systemising were all key aspects in defining the savant profile distinct from autism alone, along with a different approach to task learning. A unique cognitive and behavioural profile in autistic adults with savant syndrome that is distinct from autistic adults without a savant skill.
18	Daniel and Menashe [11] (2020)	Savant, n=712 Nonsavant, n=2032	Exploring the familial role of social responsiveness differences between savant and non-savant children with autism	<ul style="list-style-type: none"> Demographic features and primary ASD diagnosis measures Compare the SRS scores between the savant and non-savant groups. 	<ul style="list-style-type: none"> Savant children had significantly lower SRS scores (less deficiencies) compared to non-savant children ($p < 0.05$). Intra-familial analyses revealed weak pairwise-correlations between SRS scores of parents and their children. The less severe autistic traits among savant children with ASD compared to other people with ASD is not likely to be a familial trait.
19	Park [1] (2021)	9 mothers of ASD and savant syndrome	Explore the parenting experience of mothers who has young adult child with ASD and savant syndrome	In depth interview	<ul style="list-style-type: none"> Parents have been confused with their child's abilities. There are still many difficulties that those parents encounter, therefore, they expect more systematic support. Parents were hoped to their child to live as healthy members of the society.
20	Bal et al. [52] (2022)	n=1470	Examining the relationship between parent-reported talents and strengths and performance on standardized cognitive tests	Parent report ADI-R, Differential Ability Scales, 2nd edition	<ul style="list-style-type: none"> Almost half (46%) had at least one parent-reported talent and an additional 23% without extraordinary talents had at least one personal strength. Children with these parent-reported skills had different patterns of performance on these standardized tests than children without skills in that area (i.e., visuospatial, drawing, computation, reading, and memory). These results emphasize the importance of considering strengths separately by area.

all intellectual ability. However, Bennett and Rebedew [42] stated that exceptional talent may be linked to exceptional attention to detail rather than RRBs, including obsessive-compulsive tendencies. Fifth, cognitive traits that contribute to savant syndrome among individuals with ASD have been proposed to employ cognitive processing modalities, such as excellent working memory [42-44], enhanced executive functioning [15], EPF, synesthesia [45-47], mechanical memorization, and systemizing [15,17,48]. Lastly, their unique cognitive approaches have been observed to result in swifter and more sophisticated task performance [12,17,48], more rule-based task performance [16,27,31], and consequently higher response accuracy [16,49].

Savant syndrome and ASD

What is savant syndrome?

Providing an accurate depiction of the characteristics of savant syndrome can be challenging, given the vast array of areas and extent of savant skills. Nevertheless, various studies have elucidated the common characteristics of this condition.

First, savant syndrome is a rare condition; however, the exceptional capabilities displayed by individuals with savant syndrome are remarkable. Savant syndrome can be found in all populations with neurological deficits, including ASD and intellectual disabilities, as well as in the general population. The prevalence of savant syndrome is the highest in the ASD population, with approximately 50% of all individuals with savant syndrome having ASD [50]. Additionally, there is a higher incidence of savant syndrome among males, with a reported male to female ratio of 6:1 [5] or 4:1 [32,41]. It has been suggested that this male predominance may be attributed to left-hemisphere sensitivity and the influence of the male sex hormone testosterone [14,51].

According to the results of our literature analysis, few studies have reported the incidence of savant syndrome and sex ratios for the incidence rate; however, these data remain unclear. This may be attributable to the lack of diagnostic criteria or systems for savant syndrome and the difficulty in developing screening or diagnostic tools focused on a particular area of talent, as the areas and degrees of skill in savant syndrome vary widely [24].

Second, individuals with savant syndrome often display exceptional talent in two or more areas. They tend to show extraordinary memory in addition to the exceptional talents in other major areas [5,8]. Although memorization is extraordinary, it may seem automatic and unconscious. Often, expressions such as “verbal adhesion,” “automatic,” and “exaggerated form of memory” are used to describe this unique memory skill [8]. In other words, the memory skill of indi-

viduals with ASD who display savant syndrome may pertain more to automatic memory, that is, implicit memory than “meaning” [27].

Third, although savant syndrome is mostly congenital, cases of acquired savant syndrome as a result of brain injury have also been reported [24,26]. The notion that savant syndrome is congenital is based on cases in which individuals exhibit exceptional talent despite a lack of special education or experience. Even this congenital condition may advance further through practice and training beyond a certain age. According to a Korean study, nine mothers of children with savant syndrome recalled that their children were born with savant skills but that the skills became more advanced through education [1]. In contrast, there are also rare cases of acquired savant skills after an accident or disease that injures a specific part of the brain, such as the left parietal lobe [24]. These individuals developed savant skills that they did not possess prior to the brain injury; hence, the term acquired savant skills.

Fourth, savant skills tend to be advanced and not diminished or lost [5]. However, similar to the well-known case of Nadia, there are cases in which savant skills are suddenly lost. Nadia exhibited a prodigious talent for drawing in early childhood, which vanished after intensive learning of the language. This account has prompted discussions on the phenomenon of special talent diminishing or disappearing following the acquisition of a language or education. Nonetheless, such instances are exceedingly rare, and numerous studies have reported that savant skills are more constructively advanced as children grow [5,26]. A study conducted in Korea reported that parents observed that their children’s exceptional abilities became more pronounced as they grew older. However, there were also parents who said that their children with ASD who showed savant syndrome experienced a temporary decline in their artistic talent as their social skills improved, while their social interaction deteriorated once they immersed themselves in drawing again [1]. In summary, while savant skills may not diminish or disappear, increased opportunities for social interaction with others could reduce the time spent practicing these skills, which can be considered as a temporary regression of talent.

Savant syndrome should be recognized as a spectrum

Savant syndrome is not a uniform phenomenon. It is a multifaceted condition with varying areas and extent of skills involved; thus, it should be viewed as a spectrum. These skills are most commonly observed in areas such as music, art, calendar calculations, mathematics, visuospatial, memory, linguistic abilities, and sensory sensitivity but may also be observed in other areas [3,6,12]. While savant skills can manifest in a single domain, they can also be observed across multi-

ple domains, and those with two or more savant skills often show extraordinary memory [41]. Bal et al. [52] indicated that 46% of individuals with ASD and savant syndrome possess two or more savant skills. Similarly, Korean studies have reported that individuals with ASD who demonstrate savant skills often exhibit these skills across multiple domains [1,8].

Further, savant skills should be understood as a spectrum because the extent of savant skills varies significantly. While many people perceive savant skills as exceptional and remarkable, limited splinter skills fall under the category of savant skills among individuals with ASD. For example, a splinter skill such as the ability to memorize all subway stations may also be considered savant. Individuals with savant skills can be classified into three types based on their degree of exceptionality [3,5]: 1) prodigious savants, a rare group of savants who demonstrate phenomenal talent, even among the general population; 2) talented savants who demonstrate marked talent in a particular area, such as music and art, compared to their overall abilities; and 3) some individuals demonstrate splinter skills such as remembering license plates, maps, historical events, or particular songs as standalone memories.

Diagnosis of savant syndrome

As discussed thus far, despite the fact that savant syndrome has been defined and evidence has been accumulated in the literature, specific and systematic definitions and diagnostic criteria for savant syndrome are still lacking. In particular, the lack of official diagnostic criteria or any relevant information on savant syndrome in the Diagnostic and Statistical Manual of Mental Disorder (DSM) or International Classification of Diseases (ICD) shows that savant syndrome is not recognized as a specific clinical domain [24].

Several screening tools have been developed to treat savant syndrome. For example, Hughes et al. [12] developed the Sussex Cognitive Style Questionnaire to assess areas of savant skills, and Bennett and Heaton [42] developed a questionnaire to screen special skills among individuals with ASD. Although the use of such screening tools is relatively promising, there are still limitations, in that there are no validated and standardized instruments. Amid such challenges in the diagnosis of savant syndrome, items 88–93 of the Autism Diagnostic Interview-Revised (ADI-R), the gold standard for ASD diagnosis, are commonly used to understand savant skills [53].

Cognitive phenotype of individuals with ASD who exhibit savant syndrome

WCC and detail-focused cognitive processors

Central coherence refers to the capacity to establish meaningful connections holistically and assimilate information

from the external environment. Research has shown that individuals with ASD exhibit weaker central coherence than those without ASD. In other words, while people with ASD demonstrate an exceptional capacity for processing localized and detailed information, they frequently encounter challenges in integrating individual details or establishing meaningful connections between information pertaining to a broader context, owing to their reduced central coherence [54]. The concept of central coherence explains how individuals process cognition and is based on field theory, which was previously employed in the context of learning cognition. Field theory categorizes learners as field-dependent and field-independent based on their cognitive characteristics. Field-dependent learners tend to perceive external input as a whole and excel in identifying and synthesizing the flow and gist of the given information. In contrast, field-independent learners tend to have difficulty actively utilizing social context or surrounding factors when processing information. As a result, they tend to focus on the individual parts and details of the given information [54].

There is extensive evidence to indicate that individuals with ASD have WCC [23,54]. Such individuals find it challenging to select the necessary information from complex informational sources, meaningfully integrate and utilize the information, and process intricate information. In addition, people with ASD often have difficulty summarizing, selecting, and remembering key points from various messages and pieces of information that they need to learn. As a result, while they have no issues remembering particular aspects of the given information, they have difficulty comprehending the main themes or the overarching narrative of the story. Moreover, individuals with ASD may struggle to comprehend and systematically analyze various types of information.

The WCC theory, which has been understood as a cognitive deficiency, has been utilized to explain the occurrence of savant syndrome in individuals with ASD. According to this theory, individuals with ASD tend to engage in analytical thinking when processing external information, resulting in a focus on specific details, and enabling them to develop cognitive styles that allow them to excel in more detailed areas [23]. In other words, individuals with ASD who have savant syndrome exhibit remarkable abilities in particular areas, and this theory attributes this to WCC or a detail-focused cognitive processing style [30]. The primary areas of exceptional talent associated with detail-focused cognitive processing are mathematics, music, and the art [55,56]. Because of this detail-focused cognitive processing, individuals with ASD tend to concentrate on specific details in areas such as music, technology, and mathematics and, as a result, can acquire special abilities that exceed those of the general population [23,57].

Bennett and Heaton [43] examined 17 patients with ASD, 19 non-savants with ASD, and 17 individuals without ASD or savant syndrome, to determine the cognitive phenotypes of savants with ASD. Specifically, they investigated whether savant syndrome is associated with autistic tendencies, namely, special cognitive styles such as detail-focused cognitive processing and systemizing. Their results indicated that savants scored higher on working memory and analytic skills than non-savants [25,43]. In fact, detail-focused cognitive processors exhibit two-fold more exceptional talent than their counterparts [13]. In essence, the cognitive phenotypes observed among individuals with ASD who display savant syndrome, namely obsessive tendencies, excellent working memory, analytic skills, and detail-focused cognitive processing styles, may be involved in the development of savant skills.

Therefore, the special abilities of individuals with ASD are believed to be linked to detail-focused cognitive processing. Individuals with ASD can focus more on details or special areas or domains than the general population, which drives them to demonstrate extraordinary talent in relevant areas [54,56]. Thus, cognitive processing can be understood in terms of detail-focused processing, which pertains to strength, as opposed to WCC, which pertains to weakness.

EPF and hyper-systemizing

EPF is a useful theory for explaining the exceptional capabilities of students with ASD, beyond other theories that explained the cognitive phenotypes of students with ASD based on WCC [31,54,55]. The EPF model stresses that automatic perception and enhanced roles as the major cognitive features of individuals with ASD [26,36,56]. Individuals with ASD who display savant syndrome automatic and enhanced cognitive processes during perceptual information processing, which contribute to the development of exceptional abilities. For example, savant skills, such as synesthesia, perfect pitch, and hyperlexia, share similar neural structures that can be understood as EPF.

As shown in the literature, EPF is one of the most frequently discussed theories in explaining the cognitive traits of individuals with ASD who display savant syndrome [15,17,34,35]. Although EPF may be in line with WCC theory in that it also features detail-focused perceptual traits, WCC theory posits the inability to view a concept as a whole as a deficit, whereas the EPF model understands the presence of low-level perceptual operations as a factor of exceptionality [54].

According to previous studies on the visual and auditory perceptions of individuals with ASD, these individuals demonstrate better performance in low-level cognitive operations such as discrimination. In other words, individuals with ASD excel in visual and auditory perceptual processes compared

to sociality and higher-level cognitive processing, and such cognitive pattern is believed to be attributed to the hyper-activation of the parts of the brain related to primary perceptual functions [34,35,57]. The co-occurrence of target detection tasks, such as mnemonic, attentional, or visuospatial operations, and remarkable discrimination and co-occurrence of perfect pitch and excellent auditory memory among individuals with ASD may constitute examples of EPF [58].

Pring et al. [17] administered a block design test and an embedded figure test to test the hypothesis that EPF is a common characteristic in individuals with ASD and savant syndrome. Their results indicated that the savant and control groups did not differ in the embedded figure test, but the savant group performed better in the block design test than the other groups. The block design test involves constructional tasks, and these results support the notion that EPF is involved. Although several studies have presented evidence supporting the theory that EPF is a common feature of individuals with ASD and savant skills, the extent to which EPF is involved in the development of savant skills remains unknown.

Mottron et al. [34] stated that various mediating factors such as age and level of experience in the area could affect exceptional visual and auditory perception among individuals with ASD. In other words, enhanced visual discrimination advances spatiotemporal abilities, whereas enhanced auditory discrimination contributes to remarkable musical talent. Although the EPF model explains the exceptional visual and auditory processing styles among individuals with ASD to some degree, "enhanced pattern perception" better explains savant skills [34].

A comparison of savants with ASD, non-savants with ASD, and the normal control group revealed that the group with ASD and savant syndrome had higher sensory sensitivity, tended to be more obsessive, engaged in hypersystemizing, and employed a locally oriented cognitive style [43]. These characteristics may contribute to the development of savant skills. Individuals with ASD who exhibit savant syndrome pay attention to details and tend to hypersystematize. For instance, their ability to recognize rules such as "q" follows "p" is augmented, and such ability contributes to the development of exceptional talents [12,14]. As previously mentioned, high sensory sensitivity, obsessive-compulsive behaviors, a locally oriented cognitive style, exceptional working memory, and analytic skills stimulate vertical mapping and pattern recognition, ultimately contributing to the development of savant skills [43].

CONCLUSION AND RECOMMENDATIONS

This study examined the research trends regarding indi-

viduals with ASD and savant syndrome over the past 15 years and explored the main characteristics of savant syndrome as well as the major phenomena and cognitive phenotypes of individuals with ASD who possess savant skills. Our findings indicate that there has been continued research on individuals with ASD and savant syndrome over the past 15 years, and the study methodology can be broadly divided into literature reviews and survey research studies. Five main themes and nine subthemes were identified. The five main themes were: 1) definition and characteristics of savant syndrome, 2) demographic characteristics of savants, 3) types and extent of savant skills, 4) savant syndrome and ASD, and 5) cognitive profiles of individuals with ASD and savant syndrome.

Based on these findings, we present the following points for further discussion. First, most theoretical exploratory studies have focused on establishing fundamental theoretical grounds such as the concept of savant syndrome and the characteristics of individuals with savant syndrome. These results reflect the lack of theoretical consensus on ASD and savant syndrome. Furthermore, the fact that all relevant studies were either theoretical explorations or surveys calls for further studies with diverse methodologies. In other words, studies should investigate whether savant skills can be advanced through education, or whether the cognitive functions of individuals with ASD who display savant syndrome can be improved through education or external support. Although this study limited the subject of the literature for research purposes, an initial overview of the basic data prior to the literature analysis showed that there were insufficient studies that conducted interventions or treatments on savant skills and examined their effectiveness. These results suggest that comprehensive research on ASD and savant syndrome has not yet been conducted.

Second, as suggested by our results, the types and extent of savant syndrome are diverse and multifaceted to the extent that it may be construed as a spectrum. Thus, there is no single criterion for diagnosing savant syndrome nor has it been included in a reliable diagnostic framework [59,60]. These findings underscore the need to establish a diagnostic system that accounts for the definition of savant syndrome and the type and severity of savant skills [61].

Third, survey research studies either had a small sample size, including case series, or had a large sample size, which analyzed data from a database. In terms of age, most studies included all age groups, from children to adults, as opposed to specifying a particular age group. This means that the participant characteristics were not controlled for, which may suggest that savant syndrome is a relatively rare condition. Although savant syndrome is more prevalent in the ASD population than in other populations, there is still difficulty in sampling enough participants to conduct a well-controlled study.

Fourth, studies have explained the cognitive phenotypes of individuals with ASD who display savant syndrome in terms of EPF, detail-focused cognitive processing style, hypersystemizing, or pattern recognition [27]. Several different theories have been used to explain the cognitive features of individuals with ASD and savant syndrome; however, these theories influence one another or share common characteristics in significant ways, as opposed to being mutually exclusive.

In conclusion, the characteristics of individuals with ASD who exhibit savant syndrome can be explained by various factors. However, as noted by Treffert and Rebedew [41], there is no single theory that can account for savant syndrome, nor is there a single theory that can specify the cognitive phenotypes of individuals with ASD and savant syndrome. Therefore, further systematic and multidimensional research is needed on individuals with ASD and savant syndrome [62].

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

The author has no potential conflicts of interest to disclose.

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