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Savant syndrome - Theories and Empirical findings

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Abstract

Savant syndrome is a rare condition in which some people have extraordinary talents despite some serious mental or physical disability. It is a syndrome with remarkable features, standing in stark contrast to a person's overall character. The term savant, or idiot savant, describes a person who, in spite of low intelligence, has a skill in some specific narrow area. Savants can have a specific talent in, for instance, music, art, calendar calculation or foreign language but whatever the specific talent is, it is always connected to extraordinary memory. Savant syndrome seems to be also connected to autism or autistic characteristics. In this paper I aim to give a clear description of the savant syndrome and explain its connection to autism. Further, I present how specific theories try to describe the causes of savant syndrome, and connect the theories to results of empirical research in order to give an overall view of the syndrome's appearance. I will also compare the theories and evaluate their strengths and weaknesses with respect to the discoveries and progress that has been made within the area of savant syndrome research.

Keywords: Savant syndrome, Autism, Left brain injury/Right brain compensation - theory, Weak Central Coherence - theory, Hyper-systemizing - theory

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1. Introduction

The word "savant" is derived from the French word "savoir" which means "to know" and it is not without reason that these rare and extraordinary talented persons sometimes go under the name "*an island of genius"* (Treffert, 2006). Among the first to describe the savant syndrome was Benjamin Rush who in 1789 presented the case of Thomas Fuller, nicknamed as "a lightning calculator". Rush (1789, cited in Scripture, 1891) describes how Thomas Fuller performed extraordinary calculations. When Fuller was asked how many seconds a man had lived if he was 70 years, 17 days and 12 hours old, it took him 90 seconds to give the correct answer of 2,210,500,800 seconds. Moreover, Fuller had even corrected for the 17 leap years.

The first scientific description of a savant case was published in the German psychology journal *Gnothi Sauton* in 1783 (Treffert, 2000). In the journal the case of Jedediah Buxton, who was a lightning calculator with an extraordinary memory, was presented (Scripture, 1891). Still, it took several more decades before the phenomenon of savant syndrome was more clearly described and investigated.

In 1887, Dr. J. Langdon Down (cited in Treffert & Wallace, 2004) investigated the syndrome which at that time referred to explaining "idiot savants[1]". Idiot savant was an accepted medical description of someone suffering from savant characteristics. The term was used to describe a person who had an IQ below 25 but still seemed to be a "knowledgeable person"[2] (cited in Treffert & Wallace, 2004). Later, Dr. Down described several savant cases, and he found that the syndrome was characterised by "verbal adhesion", by which he meant that some savants seemed to have memory without reckoning. Dr. Down also keenly pointed

[1] The term idiot savant was coined by Alfred Binet (1905).
[2] Today, this term is no longer in use and investigations have revealed that people with savant syndrome in most cases have an IQ between the range of 40 – 70, some having even higher than 114, so the definition of idiot savant is not only demeaning but also misleading (Treffert & Wallace, 2004).

out the fact that the savant's talent is linked to 'extraordinary memory'; as an example of this, one of his patients had memorized very long pieces from the book *Rise and Fall of the Roman Empire* (cited in Treffert, 2004).

Dr Down also found the link between the savant syndrome and autistic characteristics, although he did not recognize this connection as such. After all, autism was not a known diagnosis at that time. The people Dr. Down met who were described as savant idiots, were at that time categorized under the name 'Developmental disorder' (because their behaviour differed from ordinary mental retardation) (cited in Treffert, 2004). The characteristics among most of these people were typical autistic features according to today's norms, so even if Dr. Down did not know it back then he had found a relation between savant syndrome and autistic condition. Dr. Down himself described these patients: "Their language is one of gesture only; *living in a world of their own* they are regardless of the ordinary circumstance around them, and yield only to the counter-fascination of *music*." (Down, 1887; cited in Treffert, 2004, p. 1)

Today, there is substantial knowledge about savant syndrome, and over the last century about a hundred cases have been described in the scientific literature. What we know for sure about this syndrome, besides its amazing nature, is that there is a clear connection to autism. Regardless, there is still no theory that can fully explain why the savant syndrome occurs, under what circumstances, and what does its relation to autism signify. In addition to autism, the syndrome can occur among people with other developmental disorders (for example, Tourettes syndrome) or persons with damage to the central nervous system (CNS) (Heaton & Wallace, 2004). Lately, savant syndrome has also been discovered in some people with front temporal dementia (FTD) (Miller, Yener & Akdal, 2005). However, savant syndrome seems to be most prevalent in people with autistic spectrum disorder. About 1 in 10 persons with autism have varying degrees of savant syndrome, and 50% of all people with

savant syndrome have some form of autistic spectrum disorder while the rest may have CNS injury or disease (Hermelin, 2001; Treffert, 2000). Other research suggests an even higher rate of savants with autistic traits; in a study by Young (1995), all of her 51 participating savants showed some autistic behaviour (Young, 1995; cited in Nettelbeck & Young, 1996).

In this paper I aim to give a clear description of the savant syndrome and clarify the relation between the syndrome and autism or autistic characteristics. I will also describe few savant cases briefly in order to present examples of the different characteristics and amazing abilities of various savant individuals. Further, my aim is to review the relevant theories together with relevant empirical research that exists within this area in order to understand how savant syndrome may arise. I will also compare and evaluate the strengths and weaknesses of these theories.

2. Typical features of Savant syndrome

Approximately 10% of people with early infantile autism have some savant skill (Treffert, 2006). Comparably, about half of all people with savant syndrome have autistic spectrum disorder (Hermelin, 2001). It is therefore necessary to give a brief but clear presentation of autism, the prevalence of which is estimated to be 1 in 200 people (Baron-Cohen, 2003).

First, we need to differentiate between autism as an illness and autism as a symptom (also referred to as autistic behaviour). *Autism as an illness* refers to Early Infantile Autism which is present already at birth. It is characterized by profound withdrawal and an obsessive need for status quo. There is no real engagement in social relationships with other people and an autistic person may pay very little attention to things going on around him. Leo Kanner (1943) saw, based on his observations, that the central feature in autistic patients is an

inability to close emotional bonding with others. For instance, babies with autism tend not to stretch out their arms in order to want to be picked up and they neither tend to respond to smiles. They seem to treat other people as objects and this is connected to the fact that they have difficulties with 'reading other people's desires' (Kanner, 1943). In early infantile autism there may also be retention of intelligence in some specific areas (Treffert, 2006). On the other hand, there is *autistic behaviour*, and even though the symptoms may be the same as in early infantile autism, the cause of this behaviour may vary. It can, for example, be due to mental retardation or schizophrenia (Treffert, 2006).

Besides the connection with autism, it is also known that there is a higher prevalence of savant syndrome among men than women, approximately in a 6:1 ratio (Hermelin, 2001). A possible explanation for this significant gender difference has been offered by Geschwind and Galaburda (1987) and will be discussed in chapter 3.3. Further, most skills observed in savants seem to be of right hemispheric type. This may be due to hemispheric lateralization (differences in function between the left and right hemisphere). The right hemisphere seems to support functions that are necessary for common talents that savants possess (Treffert, 2000; 2006). This will be further discussed in section 3.3.

Savant syndrome itself always includes memory but the talent can be present within different domains. For example, there are musical, mathematical, artistic or mechanical skills and there are even skills in phenomenal memory itself. The most common area that savant syndrome seems to occur in is calendar calculating (Hermelin, 2001). One such savant will be met in the following section but before this I will describe the three categories proposed by Treffert (2000) that the wide spectrum of savant skills can be divided into.

First in this spectrum of skills are *splinter* skills. This is the most common form of savant syndrome and means that a savant has a minor talent, they may for example memorize small amounts of facts, like license plate numbers. Second, there are *talented*

savants which have impressive talents when compared to their handicap. Their general appearance is of a mentally retarded but still within some domain they can perform impressive tasks. Third, there are *prodigious savants* who have an extraordinary talent and these talents would be remarkable even if the savant was not handicapped in any way (Treffert, 2000). Prodigious savants are very rare, and probably there are only about 12-15 prodigious savants alive today (Treffert, 2006).

2.1. Some well-known Savants

In this section I will describe some well-known persons with savant syndrome. I have chosen three different kinds of savants, namely Leslie Lemke who is a musical savant, Gottfried Mind who was an artistic savant, and finally the twins George and Charles who are calendar calculators. Of course, there are further domains in which savant syndrome can appear but I have chosen these savants because they are some of the most well-known throughout history.

2.1.1. Leslie Lemke

Leslie Lemke is a blind man whose savant talent applies to music. He was born in Milwaukee, 31st of January 1952. At the age of 2½ Leslie seemed to be very distant and preoccupied but still he was able to both speak and sing clearly. A half a year later he showed spastic behaviour, had some problems with walking properly and his conversational behaviour was mostly in form of echolalia[3]. Around the age of seven he was given his first

[3] Echolalia is a form of automatic repeating of what you hear. If asked questions in a conversation you do not tend to answer them, rather you repeat what you were just asked (Treffert, 2006).

piano and by the age of 8 he could not only play the piano[4] but also bongo drums, ukulele, concertina, xylophone and accordion. A year later he also learnt to play chord organ. Leslie shows very little emotions except from when he plays his piano: then, there is real enjoyment. His favourite song is "Batman's theme song" but he also enjoys playing country and western music (Treffert, 1988; Treffert, 2006). Regardless, the enjoyment of music is unmistakably strong for Leslie. He may sit for hours listening to records or radio, and if asked to play something he has heard, he does not just play the song but he also repeats the introductive speech exactly as he has first heard it, in a true echolalia form (Treffert, 2006). Treffert (2006) has written about his first meeting with May (Leslie's mother) and Leslie and what he felt when Leslie sat down by the piano and started to play:

> "I don't recall what the song was about but I do recall what I felt - astonishment, fascination and inspiration. I still feel those three things now, many years and many tunes later, whenever I see and hear Leslie play. Here was Leslie with his triple handicap - blindness, retardation and cerebral palsy - playing, for this audience of three, a concert worthy of an audience of a thousand." (Treffert, 2006, pp.133-134)

Due to his prodigious memory Leslie can also repeat music that he has heard on a single occasion: he has been able to exactly copy a 45 minute long opera (Treffert, 2006). A new skill also later emerged: he does not only play music he has heard but he can improvise as well (Hermelin, 2001).

In 1986, Leslie had a complete neurophysiological and neuropsychological examination. These examinations indicated, in sum, moderately severe mental retardation, atonic diplegia, scoliosis, savant syndrome, echolalia, and automatic responding[5], and his overall learning-ability was at the level of a normal 7-8 year old child. The lowest level of Leslie's functioning was in independent functioning, physical development and self-direction.

[4] Leslie Lemke had never taken a single piano lesson (Treffert & Wallace, 2004).
[5] The word *all* triggered Leslie to automatically say "eh, eh, that's all folks", repeated from the ending of Bugs Bunny cartoon (Treffert, 2006).

Electroencephalogram (EEG) showed mildly abnormal electrical activity and therefore a CAT-scan (Computed Axial Tomography) was suggested. The CAT-scan showed clear left-side abnormality, especially in the frontal lobe. Moreover, the entire left frontal bone showed some deformity (Treffert, 2006).

2.1.2. Gottfried Mind

Gottfried Mind, also known as "the Cat's Raphael", was a genius of art, and maybe the most well-known artistic savant. He was described by Dr. Alfred F. Tredgold (1914; cited in Treffert, 2006) who concluded:

> "Occasionally the talent for drawing passes beyond mere picture-copying, and shows the presence of a real artistic capacity of no mean order. This was the case with the celebrated Gottfried Mind, who had such a marvellous faculty for drawing pictures of cats that he was known as "The Cats' Raphael"." (Tredgold, 1914; cited in Treffert, 2006, pp.115-116)

Gottfried was born in 1768 at Berne and his talent developed in at an early age. He could neither read nor write, had no concept of money and his hands were of a remarkable large size. The general appearance he had was of a mentally retarded but his paintings were so well-done that he won European fame; he even sold one of his pictures to King George IV. He died at the age of 46 (Tredgold, 1929).

Below, in Figure 1, you can see one of Gottfried Mind's paintings.

Figure 1: This picture “Katzen” was painted by Gottfried Mind.

2.1.3. George and Charles

The twins George and Charles are calendar calculators and they were first presented in annual meeting of American Psychiatric Association in 1964. George and Charles can tell you the name of any day in a week with a span of 80.000 years, 40.000 forward and 40.000 backwards (Treffert, 2006). For instance, with great accuracy and speed, they can tell you if your 60th birthday is on Monday or not.

George and Charles were born 3 months prematurely, in 1938. At the age of six George had turned into a calendar calculator, whereas Charles showed no interest for this until he was nine years old. Charles’s interest arose at the time when the two brothers became more closely connected. Like many other calendar calculators, neither George nor Charles can count. George and Charles have been asked to describe how they do their “calculating”. They state that they “see” the numbers in their heads, but they have also pointed out that they do not see whole sheets of calendars (Treffert, 2006).

Besides their talent for calculating calendar, they also have a very good sense of smell, and they tend to smell people they meet. They can, for example, pick out their own clothes from others' by smelling them (Treffert, 2006). Further, there is one more skill to add to their talent which is their memory of weather. Most of the days George and Charles have lived through, they remember exactly what the weather was like on a specific day with great accuracy (Treffert, 2006).

3. Theories about Savant syndrome

In order to properly present the current hypotheses, I will start with short descriptions (3.1) that rather have focused on explaining certain aspects of the syndrome instead of explaining the causes to the disorder in an overall manner. These will be followed by two theories (3.2. and 3.3.) that I find relevant because of their well-established accounts about what gives rise to this syndrome. The last three accounts (3.4., 3.5. and 3.6.) are also well-grounded theories of savant syndrome, but they additionally pay attention to autism as well as savant syndrome.

3.1. Describing aspects of Savant syndrome

Many researchers have described features or characteristics that seem to be essential in the savant syndrome, although it seems that none of these descriptions alone grasps the wide range of savant abilities or manages to explain the cause or causes of the savant syndrome. Nevertheless, each description is valuable in adding to our knowledge about the characteristics that seem to be required for savant syndrome to occur, and may even offer a partial explanation as to why the savant syndrome may arise. Next, I will discuss the role of

memory, the role of genes and the role of sensory and social deprivation in the savant syndrome.

In general, memory is an essential part of the savant syndrome and the form of the memory is often automatic, concrete and mechanical. It was previously believed that memory is co-working with intelligence but since most savants have overall low intelligence (according to standard intelligence tests) and still can possess prodigious talents, there seems to be a possibility for memory to develop separately from intelligence (Hermelin, 2001). Thus, Hermelin (2001) has concluded that there seems to be a superior memory function besides general intelligence but that the memory itself is not sufficient to fully explain savant syndrome.

There are two forms of memory that seem to be involved in savant syndrome. One form is *eidetic memory*. Normally, if you are shown an object and it is then quickly removed from your sight, the information about what the object looked like stays in your short term memory only for some seconds. In contrast, if you have good eidetic memory, an image of an object that is rapidly shown and then removed can "stay on the retina" and be seen for up to 40 seconds. Nevertheless, the retrieval of this short term memory is no better than ordinary retrieval (Abhyankar, Thatte & Doongaji, 1981; Treffert, 2006). The other form of memory relevant in savant syndrome is *photographic memory* (or visual imagination memory). This type of memory allows you to remember what you have seen, just as clearly as if you were having a photo of it in your mind. The retrieval of photographic memory is better than average (Hermelin, 2001).

Another memory-related description that applies to savant syndrome comes from Joan Goodman (1972). She has suggested that savant syndrome is not about a great ability to remember but rather that savants cannot simply forget what they have experienced. In savants, the contents of short-term memory end up stored in long-term memory, and

coincide with the inability to erase or forget any of these contents. This could explain the high amounts of trivial information that seems to be stored by some savants (for example, information such as bus schedules and license plate numbers).

While the memory-related approaches describe a particular feature required for the savant syndrome to develop, the *inherited skill approach* assumes that a genetic component is essential for a particular skill to evolve. The theory about inherited skills came as an attempt to confront behaviourism in early 1930. The behaviourists' believed that every child had the possibility of becoming just as skilled as a savant and that savants developed their skill in no different way than an ordinary healthy child did. In contrast, the inherited skill approach suggested that the savant syndrome had to be explained by genetics. Mental retardation had to do with heredity and that was also the case for the different skills that the individual savants developed. The proponents of the inherited skill approach assumed that training was not the essential ingredient for the skill to arise, rather the development of the skill was based on an innate ability (Treffert, 2006). A recent finding within the field of genetics supports the inherited skill approach. A linkage has been established between a savant's skill and chromosome 15q11-q13 (Nurmi, Dowd, Tadevosyan-Leyfer, Haines, Folstein & Sutcliffe, 2003). Nurmi et al. (2003) conclude that this chromosome may give rise to a cognitive style or pattern of cognitive impairment but the skill itself may also be due to other genetic or environmental factors.

The final descriptive approach to the savant syndrome is the idea that isolation, either social or sensory isolation, is necessary for the savant syndrome to occur. *Social isolation* can, for example, be maternal deprivation or some other lack of social engagement at an early age. *Sensory isolation*, on the other hand, can be due to defects like blindness or deafness. Both of these types of deprivations can lead to preoccupation and intense concentration (obsession) for certain things which in turn may lead to skills about trivial

knowledge (Treffert, 2006). Bernard Rimland (1990) offers empirical support for this hypothesis. Rimland has found that normally functioning people process information differently from savants, and he suggests that savants' focus stays intensely on details because they are perceptually locked upon concrete and single items (Rimland, 1990). Thus, sensory deprivation, caused by being perceptually locked from the surroundings, could be a possible factor in the development of savant skill.

3.2. Rote memory and Inability for abstract reasoning

So far, I have presented different approaches that shed light on certain aspects of the savant syndrome. Next, I will go deeper into the issue and introduce theories that try to shed light on the possible causes for the savant syndrome. The rote memory approach highlights the savant's difficulty for abstract reasoning. This inability has been investigated by Scheerer, Rothmann and Goldstein (1945; cited in Treffert, 2006), who focused their research on calendar calculators. They conclude that people with this form of savant syndrome simply do not have the function to perform abstract reasoning (Scheerer et al., 1945; cited in Treffert, 2006).

Most of the calendar calculators state that they "simply know" what day of a week a certain date is. Most of the savants cannot explain why or how they possess knowledge of dates, and as most of them do not know how to do mathematics, they cannot calculate the weekday. This type of concrete calculation performance obviously differs from the non-savants' ability to calculate (Hermelin, 2001). Moreover, Scheerer et al. (1945; cited in Treffert, 2006) assume that the savant uses the most primitive concrete procedures in calculating, that is, treating numbers like objects, for example, counting apples instead of numbers. This type of performance leads to a great use of rote (concrete) memory, which is

characterized by the sort of facts that savants tend to memorize, for example, large quantities of numbers, trivial information and whole pages of books, even in foreign languages (Treffert, 2006).

Bölte and Poutska (2004) have found supportive empirical evidence for the rote memory theory. In one study, they measured performance in the Digit span -test which is suggested to be a test of rote memory. The autistic savants showed better performance than the autistic non-savants. Thus, Bölte and Poutska (2004) believe that this finding could support the rote memory - theory.

Nettelbeck and Young (1996) have also conducted research on calendar calculators and they believe that the savant's performance depends in part on an excellent declarative rote memory. Nonetheless, they also conclude that this is not a fully sufficient explanation, as it seems that the talent is not *always* dependent upon this form of memory. Nettelbeck and Young (1996) state that there are empirical findings suggesting that some calendar savant skills are based on rules and structure. A similar conclusion has been made by O'Connor and Hermelin (1989; Hermelin, 2001). Thus, the findings that calendar calculation skills may be based on the use of specific rules do not support the rote memory theory in full (Nettelbeck & Young, 1996). (More about savant skill based on rules in section 3.5.)

3.3. Left brain injury/Right brain compensation - theory

Before exploring left brain injury/right brain compensation - theory, I will give a brief introduction to the lateralization of the brain. The left hemisphere functions are mainly developed to handle language, speech and some motor skills, although each area of function is not necessarily bound to a certain hemisphere. (For example, language-functions can be found in the right hemisphere). The left hemisphere functions are of a more *abstract* character, using

sequential, logical and symbolic methods when processing information. In contrast, the right hemisphere seems to be dedicated to spatial- and visual-constructional tasks. This hemisphere seems to have more of a *concrete* information processing character, utilizing simultaneous, intuitive and non-verbal methods (Treffert, 2006).

The left brain injury/right brain compensation - theory, supported by Treffert (2006), relies on research that has shown that most people with savant syndrome have damage in the left hemisphere, while the savant skill is mainly of a typical right hemisphere character. This suggests that when the left hemisphere is injured, the right hemisphere compensates for the loss (Treffert & Wallace, 2004). According to Treffert and Wallace (2004), research that eventually led to the left brain injury/right brain compensation - theory seems to have begun by the work of Pamela Tanguay in 1973 (cited in Treffert, 2006) who found connections between the right brain's functions and savant syndrome. In autism, a relationship between left brain dysfunction and right brain's activities was discovered in 1975: in these investigations, motor and language functions were noticed to be "taken over" by the right hemisphere. In 1980, Brink (cited in Heaton & Wallace, 2004) investigated a boy who was shot by a gun in the left hemisphere. The injury rendered him mute, deaf and paralyzed on the right half of the body. After the accident, the boy became a savant with mechanical skills, supporting the idea that the right hemisphere may compensate for the left hemisphere injuries.

Another result that speaks for this theory comes from the research of Miller, Yener, and Akdal (2005) who have found that a remarkable number of people with front-temporal dementia (FTD) have developed artistic skills. Miller et al. (2005) have speculated that this may be due to visuo-spatial functions being preserved in the brain. FTD, which often develops in the left hemisphere, has been found to be associated with visual creativity, triggered by the onset of the disease. Moreover, these patients lose symbolic thought which results in their art lacking components of symbolism and abstract character. In most cases, the

same picture is being painted over and over again, with a compulsive need that results in perfection in picture copying. In a recent SPECT (Single Photon Emission Computed Tomography) scan, conducted with a FTD patient during a painting performance, the most active region of the brain seemed to be right posterior parietal area. According to Miller et al. (2005) this may incline that left dysfunction, due to FTD, can lead to increased activity of brain function in undamaged areas of the brain.

There is also ongoing research using rTMS (repetitive Transcranial Magnetic Stimulation). In these experiments, left hemisphere's activities have been interrupted with magnetic stimulation to see if the subjects exhibit some savant-like abilities. Snyder, Bahramali, Hawker, and Mitchell (2006) have used rTMS on 12 normal subjects in order to find out if normal healthy subjects are capable of having savant abilities. The researchers asked 12 participants to guess numbers of discrete items while stimulating them with rTMS over the left anterior temporal lobe (a common defected area for people with savant syndrome in late onset FTD). Ten participants improved in their ability to perform the task when they had been stimulated with rTMS, and in eight of the subjects the performance deteriorated when stimulation was withdrawn. Snyder et al. (2006) believe that: "The probability of as many as eight out of twelve people doing best just after rTMS and not after sham stimulation by chance alone is less than one in one thousand." (p. 837).

Further supporting evidence comes from Geschwind and Galaburda (1987). Their research about lateralization has provided further information for the left brain injury/right brain compensation - theory, and helped in understanding the savant syndrome as well as autism. Geschwind and Galaburda (1987) try to explain why the syndrome is more prevalent among men. In the prenatal state, the left hemisphere completes its development later than the right one, and simultaneously in a male foetus the circulating testosterone may reach very high levels. Geschwind and Galaburda (1987) have found that if high levels of

testosterone are present during critical period, it can lead to slower growth of, and impair neural functions in, the left side of the brain. This may give rise to deficits like autism with or without savant syndrome. Furthermore, this finding may also explain why the savant syndrome is more common in males than in females (Geschwind & Galaburda, 1987).

Even though the focus of the left brain injury/right brain compensation - theory is upon the right-hemispheric character of the savant skill and left-hemispheric damage, Treffert (2006) also points out the major importance of concentration, repetition and practice in the development of a skill. Further, he makes an important distinction between prodigious savants and the splinter skilled and talented savants. Treffert (2006) and Treffert and Wallace, (2002) believe that genetic factors must partially be a cause for prodigious savants because this form of savant syndrome is a true 'genius of island', and they believe that it cannot develop without an innate, inherited component.

3.4. Waterhouse's theory

Another theory developed to explain the savant syndrome was put forward by Waterhouse in 1988, and today, the theory is still considered as a plausible explanation. The theory arose as a response to the failure of theoretical models of intelligence in explaining savants' talents. Waterhouse, Modahl and Fein (1996) believe that the savant skills are qualitatively different from ordinary peoples' skills.

The Waterhouse's theory applies to possible dysfunctions in the brain due to autism (Waterhouse et al., 1996). One of the possible dysfunctions in autism results in *a loop of abnormally extended selective attention*. This form of selective attention is due to certain abnormal neuro-developmental-processes in the parietal and temporal areas which results in primary tissue being spared or even extended. Further, this in turn leads to mal-development

of the parietal and temporal poly-sensory association cortices which results in (1) disruption of formation of complex representations and (2) increased reaction time to complex environmental stimuli (Waterhouse et al., 1996). Thus, due to the loop of abnormal extended selective attention, Waterhouse et al. (1996) postulate: "…that a small subgroup of autistic individuals with disordered temporal and parietal polysensory regions will experience supernormal high-fidelity memory for visual or auditory stimuli." (p. 464), and "Some autistic individuals with supernormal high-fidelity visual or auditory memory will be identified as autistic savants…" (p. 464) Waterhouse et al. (1996) also hypothesize that the common perseverative behaviour in autistic individuals depends on the same mechanism that supports the high-fidelity memory: "We infer that repeated intense feature processing in conjunction with a fixed stimulation reward link generated by abnormal amygdala function will combine to create a powerful force for driving and maintaining perseverative behaviour." (Waterhouse et al., 1996, p. 468).

In sum, savants have an ability of abnormal detailed memory registration. Waterhouse et al. (1996) believe that identification and memory of pattern-components are crucial for autistic savants. The finding that activity in parietal regions of the brain has been recognized during performance of savant skill, is seen as providing empirical evidence for this theory (Waterhouse et al., 1996).

3.5. Weak Central Coherence - theory

The weak central coherence - theory was proposed by Uta Frith in 1989. She claimed that weak central coherence is a common cognitive characteristic in autistic people, that is, they tend to have a special *cognitive style*. Frith (cited in Happé & Frith, 2006) noticed that adults and children without autism treat incoming information in a gestalt form with the

cost of neglecting details or single elements in the stimuli, on the other hand, autistic individuals pay attention to single details rather than grasping the whole. This feature has been discovered in a study of 'conceptual clustering', which is a test of memory. Given words like 'white, green, five, blue, black, eight, two' we tend to categorize these concepts as colours and as numbers and only recall a few of these. We also tend to recall them in an order different from how they were originally outlined like 'green, two, black'. When people with autism perform this test, there seems to be no cluster effect: they tend to repeat the words in an echolalia-form and in the exact order the words and numbers were given to them (Hermelin, 2001).

Another study by O'Riordan and Plaisted (2001) that supports the lack of categorisation in autistic people showed that autists have increased sensitivity to single features but not to shared features, which results from deficient categorisation. Yet other tests that also reveal deficient categorisation are the Block design test and the Digit Span test. In these, autistic people (with as well as without savant skills) also tend to perform better than expected (Bölte & Poutska, 2004; Hermelin 2001). These investigations do not only support weak central coherence - theory but they also seem to show that the deficit is connected to language processing, and is rather due to autism than to low intelligence. Thus, the weak central coherence - theory highlights that people suffering from savant syndrome have difficulty in grasping the whole, and because of this inability they tend to focus more intensely on the fragments (Hermelin, 2001). Hermelin (2001) concludes that; "…the 'weak central coherence' theory is the only one about autistic perception and cognition that allows not only for mental deficits, but also for certain assets that may result from such style of information processing." (p. 48).

Moreover, Hermelin (2001) has described how weak central coherence - theory may be applied to research that she and her colleagues (e.g. O'Connor) have conducted within

different domains of savant syndrome. They have investigated calendar calculators, musical talent, graphic artistic skills, linguistic talent, mathematical skills and memory. Among these studies, one was carried out on a savant named Christopher who has a talent in foreign languages. Christopher can understand, talk, read and write 16 languages despite his overall mental handicap. He also shows characteristic traits of autism (for instance, avoiding eye contact) and Asperger's syndrome, even though he has not been diagnosed with either. In this particular study, Christopher was supposed to translate texts from all the 16 languages he knows (this is a very difficult task which only a few professional linguists can accomplish) and he did this with speed and ease. An interesting observation was made when he mistranslated on some occasions: he did not notice that mistranslation had occurred, which seems to show that what he is saying during the session does not make any sense to him. He does not seem interested in the meaning of a whole sentence, he was just translating the text word by word. When he was asked to look at the whole sentence before translating it, he became distressed and he said that he could not do that (Hermelin, 2001).

Further, there are examples of calendar calculators who 'just seem to know' what a week day certain date is. The regularities and correspondence, which are characteristics of a calendar, fit together with the characteristics of autism; both have a tendency for repetition and structure (Cowan, Stainthorp, Kapnogianni & Anastasiou, 2004). Investigations in this domain of savant skills have shown that the skill cannot follow only from practice. Rather, it seems that the savants use some rule-based strategies, and with their obsessive interest in calendars, the savants may gather knowledge bit by bit in order to understand the whole calendar[6]. The savants may start by finding out that Monday was on the 1st of October, Tuesday was on the 2nd of October, and so on. Later, that information spans over weeks: if 1st is a Monday, then 8th must be, too. Eventually, the pattern may extend over

[6] This form of knowing that calendar calculators possess may not be of conscious character, it may rather be an automatic process, just like we do not think about how we constitute our language when we speak – mainly we just speak it (Hermelin, 2001).

years (Cowan, O'Connor & Samella, 2002; Hermelin, 2001). Thus, instead of understanding the whole structure of the calendar, the savants in a way introduce the calendar to themselves in fragments.

In musical savants there is a similar connection to interest for the parts which begin with savant's absolute-pitch ability[7], that is, an identification of single notes (Hermelin, 2001). This form of structural knowledge is the base from which savants can create or replay music: "…overall, within the domain where they are talented, autistic savants appear to use the strategy of taking a path from single units to a subsequent extraction of high-order patterns and structures." (Hermelin, 2001, p. 174).

Normally, we tend to recognise a holistic picture (Gestalt) which we store in memory and then reconstruct its parts from this memory. But the special *cognitive style* that savants seem to possess, according to weak central coherence - theory, changes their reconstruction process. Within the different domains that savants appear, the obsessive interest due to autistic character results in acquiring lots of information (for example, distinct dates, music pitches, words etc.) from which they can construct strategies and rules that lead them to know the outcome (Hermelin, 2001).

3.6. The Hyper-systemizing - theory

The hyper-systemizing approach is laid forward by Simon Baron-Cohen (2003) and it focuses especially on autism. As we have seen, autism has very high prevalence in people with savant syndrome, and plenty of research suggests that autistic traits are common and important for a full understanding of the savant syndrome. In the genetic field, assortative mating is a long-recognized aspect of animal behaviour which led to the conclusion that mate

[7] This has been discussed by Hermelin et al. (2001) to be a form of an 'in-built talent'.

selection is not random. Baron-Cohen (2006a) has suggested that autism depends largely on genes, and that these genes seem to be inherited from both parents who have not randomly selected to mate with each other (The Assortative-Mating theory). What lead Baron-Cohen to this conclusion was that he found four patterns among parents to autistic children; both parents tend to be super-fast on attention-tasks, there is an increased likelihood that both parents have had a father that worked with engineering, the parents also seem to have elevated scores on subtle measure of autistic traits and their brain activities tend to have a 'male-pattern' (measured with fMRI: functional Magnetic Resonance Imaging). The parents showed that they are good in systemizing: they have a drive to analyze details in order to find out how different things work[8]. *Hyper*-systemizing, on the other hand, is a feature that some of the autistic children exhibit; in this case it is not for example about checking weather reports once a day but every hour of every day (Baron-Cohen, 2003; O'Connor & Hermelin, 1989). Thus, in autistic people the systemizing mechanism is genetically set to high, and may result in hyper-systemizing. This leads to the conclusion that autists can only understand systems that have a structure (for example, calendars) and they have difficulties coping with change.

4. Discussion

Thus far I have described the savant syndrome, and presented possible explanations for, and theories about, the savant syndrome. Now, I turn to discuss what the strengths and limitations of these explanations and theories consist of. First, I will discuss the overall problems that more or less affect all the theories. Then, I will focus on the strengths and weaknesses with respect to each individual theory. Finally, I conclude the discussion with my own thoughts.

[8] Examples of systemizing works are engineering, lawyer, mathematician, astronomer, chemist, and musician, among others (Baron-Cohen, 2006b).

4.1. Revisiting the Theories

The problem with conducting research on savant syndrome is that there is a low prevalence of subjects. Especially, the occurrence of prodigious savants is extremely rare, and the overall number of people with *any* form of savant syndrome is rather low, too. Together with this low prevalence of savants, there are inaccurate or vague descriptions of the syndrome; for instance, the three categories (splinter skilled, talented, and prodigious savants) proposed by Treffert (2006). These categories are just guidelines, developed to distinguish between the extent of the savant talents, but it is not a good definition of the syndrome's wide characteristics. Further, there is a lack of standardized assessment procedures; different researchers mostly use different tests for investigating the skills of savants (Bölte & Poutska, 2004).

Many of the theories on savant syndrome face difficulties in describing the syndrome in such a way that the theory applies to the wide range of skills, such as sensory deprivation approach, rote memory - theory and left brain injury/right brain compensation - theory. Some of the theories also neglect the importance of autistic traits, for example, inherited approach and left brain injury/right brain compensation - theory. Autism needs to be accounted for, not only because many people with savant syndrome have autism but because savant syndrome can appear together with other deficits that have autistic traits (for example, repetitive and obsessive-compulsive behaviour, as in Tourette's syndrome, FTD, manic-depressive disorder, etc. (Heaton & Wallace, 2004)). A theory should at least account for the meaning of the high prevalence of autism among savants. These are the most difficult problems for every theory to overcome, but individual theories face even further problems. Therefore, I shall now revisit each description and theory separately.

4.1.1. Descriptions of Savant syndrome

In section 3.1., I described the role of memory, genes, and sensory deprivation in the savant syndrome. They are all important in describing some aspect of the syndrome, but none of them is sufficient alone to account for the condition. Memory is, of course, essential in understanding savant syndrome because it is present in every talent. What seems to be the problem is that extraordinary memory cannot alone explain the skills present in the savant syndrome. For example, there are calendar calculators who are blind, thus, their talent cannot be due to photographic or eidetic memory (Hermelin, 2001). Empirical investigations also suggest that, besides memory, other factors can be involved too, for example genes. Further, the brain areas involved in savant syndrome suggest that memory is not the only possible explanation. For instance, Waterhouse et al. (1996) discuss a possible dysfunction that gives rise to a loop of abnormally extended selective attention which evolves in the parietal and temporal areas of the brain. This form of selective attention is also a possible explanation, therefore memory alone seems to be insufficient as the only explanation.

The view that savants' have an inability to forget is an interesting point which could be a part of an explanation for savant skills. It also has received some valid empirical support. Remember Leslie Lemke: at his concerts he remembers every song anyone asks him to play during a session, and if the time runs out he continues the repertoire at home until he has played every song (Treffert, 2006).

Next, the "genetic contribution to savant syndrome" - approach has important features but it is widely held that an explanation for savant syndrome contains more than genes, even though we shall not set aside the fact that genes may be important as one aspect of the explanation. Today, the generally accepted view is that genes do play some part in savant syndrome, and most researchers suggest that genes are required especially for

prodigious savant skills. Some empirical findings suggest that great calendar calculator skills require innate talent together with interest and practice to develop (Nettelbeck & Young, 1996; Hermelin, 2001; Baron-Cohen, 2003; Treffert, 2006).

Finally, the problem with sensory deprivation - approach is simply the fact that many savants have not been sensory deprived (Treffert, 2006). Thus, neither does this approach seem to be the final answer to savant syndrome's explanation. Rather, it deals with just another aspect of the phenomenon, and may only apply to specific cases. The overall important thing to remember here is that even though none of these descriptive approaches is sufficient in explaining the savant syndrome *on their own*, they contribute empirical findings that are closely connected to a full description of the syndrome.

4.1.2. Theoretical accounts of Savant syndrome

In sections 3.2. and 3.3., I presented theories that provide explanations for how the savant syndrome may occur: the rote memory and an inability for abstract reasoning - theory and the left brain injury/right brain compensation - theory. The theory about rote memory and the inability for abstract reasoning proposes that a great use of rote memory could explain why savants tend to remember trivial information. Some empirical evidence that supports this account was found in Bölte and Putska's (2004) and Nettelbeck and Young's (1996) studies, but Nettelbeck and Young (1996) concluded that it seems that the syndrome cannot always depend upon rote memory, and therefore this theory may not be the final explanation. Previously, also O'Connor and Hermelin (1989) and Hermelin (2001) came to the same conclusion. Rote memory is still relevant and useful in some aspects or for certain talents under certain circumstances, but the theory needs more empirical investigation.

Another theory described in section 3. was Treffert's left brain injury/right brain compensation - theory. This theory is well underpinned by empirical findings; in most cases the damage to the brain seems to be localized in the left hemisphere and the talent is mostly due to the right hemisphere characteristics. Geschwind and Galaburda's research (1987) gives a possible answer to the question about the higher prevalence of savant syndrome among men than women, and presents a possible explanation for the left hemisphere damage. The left brain injury/right brain compensation - theory also accounts for the varieties of diseases (for instance, front temporal dementia) that can give rise to the savant syndrome as long as the damage can be localized on the left side of the brain. Further, Treffert (2006) also mentions the role of genetics; he believes that hereditary component is necessary at least in prodigious savant skills.

The left brain injury/right brain compensation - theory has some major strengths but, on the other hand, Treffert does not account for left hemispheric talents. Remember Christopher, Hermelin's patient who had a talent in form of knowing 16 foreign languages, usually considered to be a left hemisphere talent (still, it is possible that Christopher's talent is due to the right hemisphere). As a response, Treffert has stated that his theory may apply as well to the opposite; that right hemisphere damage could lead to left hemisphere compensation (Treffert, 2006). Regardless, empirical support and investigations about this is lacking. Another problem for the left brain injury/right brain compensation - theory is the lack of detailed discussion concerning the meaning of autistic traits. Treffert (2006) does state that the characters of savants are mainly obsession, preoccupation and likewise but he does not really show in his theory why this is the case. His focus stays on savant syndrome which is both an advantage and a disadvantage. He clearly describes a possible theory for explaining savant syndrome but autism and autistic characteristics should not be neglected in a full-descriptive theory, and neither should left-hemispheric talents.

4.1.3. Theoretical accounts of Savant syndrome in connection to Autism

The sections 3.4., 3.5. and 3.6. dealt with theories that pay attention to autistic traits that seem to be common for many people with savant syndrome. An overall attack from Treffert against this position, and especially against weak central coherence - theory, is that these theories focus too much on autism (Treffert, 2000). He refers to the fact that only 50% of people with savant syndrome have autism. Nonetheless, what Treffert seems to be mistaken about is that these accounts do not just discuss autism as an illness but autism as a symptom. Many other deficits than early infantile autism may cause autistic-like behaviours, for example, front temporal dementia (FTD) described by Miller et al. (2005). FTD-patients also show obsession and intensive focus during their artwork which is a typical autistic characteristic even though these people are not diagnosed with autism. Another example from a study by Young (1995; cited in Nettelbeck & Young, 1996) reveals that all 51 savants participating in her study had some autistic traits (e.g. social withdrawal, preoccupation). According to Treffert (2004) himself, even early findings by Dr. Down suggest that some of his patients would today have been identified with the autistic disorder. Thus, there are many descriptions of savant syndrome which mention the presence of autistic behaviour, even if the patient is not suffering from early infantile autism in particular; in the end, the criticism from Treffert seems unfair.

Next, I shall turn separately to each theory accounting for both savant syndrome and autism. I will start with the theory put forward by Waterhouse (1989). Waterhouse's theory is well-developed and provides many strong suggestions that have received empirical support. Firstly, the theory generally accounts for autism, and savant syndrome is seen as a possible outcome resulting from certain brain dysfunction due to autism. The theory manages to explain why autistic savants have difficulties with complex representations, and it also

accounts for the presence of memory (high-fidelity visual or auditory). Moreover, the two suggested brain areas involved (parietal and temporal area) have been shown to be active during savant skill performance. These empirical results render the theory very interesting and it should be further investigated and considered as a possible explanation for savant syndrome.

The weak central coherence - theory is a favoured position among many researchers because it seems that the information processing mechanism necessary for the performance of savant abilities is spared in autistic people: they still have the ability to manipulate information which is highly organised and domain-specific. The typical *cognitive style* that autistic people tend to possess seems to be the best explanation for the overrepresentation of savants with autism (Heaton & Wallace, 2004). Even though Nettelbeck and Young's (1996) research about rote memory (described in section 3.2.) disagrees with O'Connor and Hermelin's (1989) conclusions, it has been empirically proven that rote memory is not a sufficient explanation for savant syndrome alone (with which Nettelbeck and Young agree). Nettelbeck and Young's (1996) research, supporting rote memory, does not account for savants whose span of dates is limited. In these cases O'Connor and Hermelin (1989) found that rules about the structure of the calendar were well developed. This suggests that weak central coherence - theory provides a possible explanation for savant syndrome (Hermelin, 2001; Nettelbeck & Young, 1996).

Further, the hyper-systemizing - theory also has strengths. When compared to weak central coherence - theory, Baron-Cohen (2006b) believes that the hyper-systemizing - theory has great advantages. The theory differs from weak central coherence - theory in that it pays attention to the social features of autism. Baron-Cohen claims that evidence from the Block Design - test, given that it is a test of lawful systems, is just as much evidence for hyper-systemizing - theory as for weak central coherence - theory, because the test reveals

that the subjects' talent may depend on hyper-systemizing as well as weak central coherence (Baron-Cohen, 2006b). There is also empirical evidence showing that autistic people (with and without savant syndrome) have difficulties when performing contextual processing (in, for example, Wisconsin Card Sorting task in which rules are constantly changing, (Baron-Cohen, 2006b)), and according to Baron-Cohen this needs not to be due to executive functioning. The subjects' perseveration may just prove how good at systemizing they are; they simply just do not want to abandon a rule they have figured out, instead, they keep testing the rule and ignore the investigator's demand of change (Baron-Cohen, 2006b).

Moreover, Baron-Cohen's theory has been viewed as an antithesis to weak central coherence - theory because empirical findings suggest that autistic persons have good ability to master a system. Regardless, defenders of weak central coherence - theory propose a possibility of local coherence – that savants can learn simple if-then rules and connect them to understand a system. Still, weak central coherence - theory can not meet one important aspect which hyper-systemizing - theory can, namely the autistic individuals' desire for collecting and connecting information within a particular area of interest (Happé & Frith, 2006).

The three previously discussed theories, Waterhouse's theory, weak central coherence - theory and hyper-systemizing - theory all stand strong, and they have major strength in that they provide explanations for the autistic character of savants. They are all supported by empirical findings but obviously there is a need for more empirical investigation and development of standard tests that can help to find out which areas of function are relevant for savant syndrome and how they work.

4.2. A unifying view?

All descriptions and theories presented in this essay contribute at least a partial explanation to savant syndrome. Moreover, it seems that several of these explanations are possible to unite. There are six features or elements of savant syndrome that are consistently mentioned by different researchers, and which I find interesting for my unifying view of savant syndrome, these are: testosterone, systemizing skill, heredity, extraordinary memory, interest and practice.

Autism or autistic characters which are present in savant syndrome seem to be linked to high levels of testosterone in fetuses during critical pre-natal periods which might lead to left hemisphere injury or at least left brain malfunction (Geschwind and Galaburda, 1987). This can give rise to a typical male pattern brain (Baron-Cohen, 2003) which is revealed through a well-developed ability to acquire and store high amounts of detailed information (weak central coherence - theory), and as systemizing skills which are typical right hemispheric characters (Baron-Cohen, 2003). According to the Assortative-Mating theory, two persons who are alike, choose to mate with each other. Baron-Cohen (2003) proposes the possibility that if two individuals, both having typical male pattern brains[9] and well-developed systemizing skills, mate with each other, the offspring can become an individual with hyper-systemizing skills which is a typical feature present in savant syndrome (Baron-Cohen, 2003). Regardless, inheritance is not enough for savant skills to emerge, but interest, practice and extraordinary memory are also required characteristics. Several researchers (e.g. Hermelin (2001), Treffert & Wallace (2002), Nurmi et al. (2003)) believe, and have found empirical support for, that these components are necessary for the possibility of becoming a prodigious savant.

[9] Male pattern is possible for females too, for example, in the syndrome Congenital Adrenal Hyperplasia (CAH), a testosterone-like androgen reaches high levels in the pre-natal state which causes female offspring to end up more genetically male. According to Baron-Cohen (2003), these women have enhanced spatial systemizing skills.

With this unifying view, I have managed to connect Geschwind and Galaburda's (1987) findings about the role of testosterone to the role of genes supported by Nurmi et al. (2003), among others. Further connections can be made to left brain injury or malfunction - theories, supported by Treffert (2006), Miller et al. (2005), Baron-Cohen (2003) and Geschwind and Galaburda (1987), who state that left brain malfunction leads to activation in the right hemisphere. My unifying view also includes connections to weak central coherence - theory, and its focus on detailed information processing, as well as to the hyper-systemizing - theory. Unfortunately, even though my unifying view connects many theories, it does not connect *every* theory, for example, Waterhouse's theory. Still, I believe it is an interesting reflection that several of the so far well acknowledged theories are possible to connect. On the other hand, I also believe that we deal with a syndrome in which conclusions should be made to each talent separately. We may not only need an overall explanation of the syndrome, but also some general conclusions for every single talent that a savant can possess.

4.3. Conclusion

My aim in this paper was to clarify what the savant syndrome is, how it relates to autism, and present possible explanations for its existence. We now know that people with savant syndrome are true islands of geniuses. We also know that the relation to autism or autistic traits exists, and that this should be accounted for in an overall explaining theory. As to the specific theories put forth to explain the savant syndrome, it seems to me that they all provide empirically supported explanations, but it also seems that preference is dependent upon what one believes about the strength of the relation between savant syndrome and autism. What I remain to be concerned about is that the variation in empirical evidence seems to point to different directions: thus, there is a need for more research. At least, and so far,

there are some things that we do know about savant syndrome; *we just do not know how to apply them into the wide range of variations*.

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