Geniuses, Prodigies & Savants

CENTRE FOR THE MIND

Extraordinary people – What makes them tick

6-7 December, 1999
WP Young Room
University of Sydney

This event was conceived and organised by the Centre for the Mind, Joint Venture - Australian National University & University of Sydney

www.centreforthemind.com

The Centre for the Mind gratefully acknowledges all those who contributed to this event, in particular David Helfgott, the Tao family and the many speakers who presented such inspirational material. We would also like to acknowledge the support of *New Scientist*.

Contents

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FOR THE
MIND

Professor Allan Snyder recently completed filming of a BBC documentary and a radio documentary on the Centre for the Mind's research into Geniuses, Prodigies and Savants. Professor Snyder is the Director of the Centre.

Foreword

Professor Allan Snyder, FRS

Director, Centre for the Mind

One of the enduring mysteries of the mind is that so much is done unconsciously. Great ideas seem to pop up from nowhere.

Clearly, a world of unconscious information is sifted through, by mechanisms of which we are totally unaware, to arrive at our perception and judgements.

One way to get insight into the fascinating workings of the unconscious is to understand unusual minds. These minds seem to have privileged access to the unconscious, as I discuss in the last two articles of this book.

Art, music and mathematics are often presumed to be the supreme expression of human achievement. Yet, they are mysteriously the very skills that seem to appear effortlessly in the case of child prodigies or even spontaneously in the case of individuals who suffer from rare forms of brain damage. We are compelled to understand this phenomon.

Two days in December 1999 marked an historic occasion in

Perhaps what stands foremost in my mind is the depth of compassion and understanding by everyone in their reaching out to understand unusual minds.

Reading about the feats of extraordinary minds and scientific research at the frontier of knowledge is in itself exciting. But, nothing can equal the exhilaration of witnessing these breathtaking minds in action right before our eyes.

The occasion was one of a continuous high. Many of the moments were captured by unprecedented media interest including TV coverage from the BBC, the ABC and all major print media, and extensive radio coverage. A number of radio and TV documentaries are now in preparation. And, the event in its entirety was filmed by a visual anthropologist.

This collection of summaries encapsulates the main concepts discussed at the event. I will not attempt to precis them further.

The impetus for this unique occasion originated with research that Professor John Mitchell and I published in the *Proceedings of the Royal Society* of London on the mind's secret arithmetic. The global debate resulting from this research inspired the event.

We concluded that the extraordinary skills of savants, such

Event Programme

CENTRE FOR THE MIND

Monday 6th December 1999

Opening Address
Phillip Adams — 9:00-9:10

First Impressions – Snapshots
Phillip Adams, Dr Glenison Alsop, Professor Bruce Miller, Professor Jack Pettigrew, Robyn Williams, Dr Robyn Young — 9:10-10:30

Morning Tea — 10:30-11:20

Unveiling the Savant Mind
Dr Robyn Young — 11:20-11:40

'Normal' Potential – What is it?
Dr Glenison Alsop — 11:40-12:00

Insight – Creative Genius
Fiona Hall, Visual Artist — 12:00-12:20

Lunch — 12:20-1:30

Visual Feast – Short Film
1:30-1:45

Event Programme

C E N T R E F O R T H E M I N D

Monday 6th December 1999

What Do Unusual Minds Tell Us About Ourselves
Dr Robyn Young, Professor Allan Snyder, Dr Mike Anderson — 1:45-3:00

Insight – The Savant Mind
Dr Joan Curtis — 3:00-3:15

Afternoon Tea — 3:15-3:45

Insight – Family Perspective
Dr Billy Tao — 3:45-4:00

Transition From Prodigy & Savant to Adulthood
Dr Joan Curtis, Gillian Helfgott, Dr Billy Tao, Terence Tao, Nigel Tao, Trevor Tao, Simon Tedeschi, Dr Robyn Young — 4:00-5:00

Insight – Personal Viewpoint
Gillian Helfgott — 5:00-5:20

Close — 5:30

Lounge – Refreshments — 5:30-7:00

Concert – David Helfgott — 7:00-8:00

Event Programme

C E N T R E F O R T H E M I N D

Tuesday 7th December 1999

Welcome
Professor Allan Snyder — 9:00-9:10

Wired to Create: Geniuses, Prodigies & Savants – The Brain
Professor Bruce Miller, Professor Michael O'Boyle — 9:10-10:30

Morning Tea — 10:30-11:20

How Do They Do it ? – Savants
Dr Mike Anderson, Professor Allan Snyder, Professor John Mitchell — 11:20-12:30

Performance – Trevor Tao — 12:30-1:00

Lunch — 1:00-2:00

Child's Play – Hypothetical with Kids
Lynne Kelly — 2:00-2:30

Education: Its Role – Help or Hindrance
Dr Glenison Alsop, Lynne Kelly, Trevor Clark, Dr Robyn Young, Dr Mike Anderson — 2:30-3:45

Afternoon Tea — 3:45-4:15

Genius + Madness: Is There a Connection? — 4:15-5:30

Background on Speakers

Phillip Adams

Writer and compere of the influential Australian Broadcasting Corporation Radio National program *Late Night Live*. Phillip was the foundation chairman of the Commission for the Future, Chairman of the Australian Film Commission, the Australian Film Institute, the National Australia Day Council and President of the Victorian Council for the Arts. His most recent books include *Retreat from Tolerance*, *Talk Back* and *A Billion Voices*.

Dr Glenison Alsop

A recognised authority on profoundly gifted children. Glenison is a member of the CHIP Foundation which was created to develop children with high intellectual potential, and is currently writing a book *Demonstrating where Development and Social Psychology leads*.

Dr Mike Anderson

Trevor Clark

Acting Director of Services at the Autism Association of New South Wales, and the Principal for the Vern-Barnett School of Children with Autism. Trevor is the winner of the 1995 Hollingworth International Research Award. He is a community member of the NSW Association for Gifted and Talented Children, the Gifted Learning Disabled Support Group and the Australian Special Education Association.

Dr Joan Curtis

Founder of the Mansfield Autistic Centre and the Mansfield Adult Autistic Services in Victoria. The Mansfield Autistic Centre provides travelling teachers who can visit families with autistic children living at home, full-time remedial training and education and adult residence for autistic men to promote independence. Joan has now retired as Director of Services at Mansfield Autistic Centre but continues as Co-ordinator of MACCRO.

Fiona Hall

A remarkable South Australian visual artist, creative genius and winner of the inaugural Contempora Award.

Lynne Kelly

Principal, Virtual School for the Gifted, a school which has no physical location and offers over 25 courses to gifted students all over the world. Lynne is also the Co-ordinator of the Gifted and Talented Program at the Methodist Ladies College which is a prestigious girls' school. Lynne has a Masters in Education, a Graduate Diploma in Computing, a Diploma of Education and a Bachelor of Engineering. Lynne is the author of eight education texts and a CD-ROM.

Professor Bruce Miller

Bruce Miller is an AW Clausen Professor of Neurology at the University of California, San Francisco Medical School. Bruce discovered that a form of dementia triggered amazing artistic prowess in patients who previously had no interest or ability in art.

Professor John Mitchell

John is a mathematical genius who has been involved in various aspects of physics and biology for much of his early career. His current work at the Centre focuses on unravelling the phenomenon behind our innate mathematical abilities. He is a founding member of the Centre and is the co-author of the internationally acclaimed paper 'The Mind's Secret Arithmetic'.

researcher on how intellectual ability is mediated by the structure and circuitry of the human brain. His area of expertise is Cognitive Neuropsychology. He has won various awards including the 'Outstanding Educator Award', The National Honor Society, Iowa State University.

Professor Jack Pettigrew

Professor of Physiology and Director at the Vision, Touch and Hearing Research Centre at the University of Queensland. Jack is a fiercely original researcher who has generated immense international interest on his break-through work on bipolar disorder and its links to creativity. He has 159 publications in refereed journals and collectively receives over 300 citations a year. Jack is the only Fellow of the Royal Society in Queensland and is in high demand to speak at international conferences. Jack won the first Commonwealth Special Research Centre award in 1988 at the University of Queensland.

Professor Allan W Snyder

Director, Centre for the Mind, a joint venture of the Australian National University and the University of Sydney. Allan's discovery with John Mitchell that savant skills are within us all received world-wide attention. He was awarded the International Australia Prize from the Prime Minister in 1997 and was featured as one of Australia's 10 most creative minds in the *Bulletin/Newsweek* magazine in 1998. Allan holds the 150th anniversary chair of Science and the Mind at the University of Sydney and the Peter Karmel Chair of Science and the Mind at the Australian National University. He is a fellow of the Royal Society of London.

The Tao Family

Billy Tao is a Paediatrician. His wife Grace taught high school mathematics. Their three remarkable children, Nigel, Terry and Trevor, are now young adults. Terry was a child prodigy who became a UCLA Assistant Professor of Mathematics at age twenty. Terry made front-page news when he started high school (doing Year 11 Mathematics and Physics) at age seven. Trevor was diagnosed autistic when he was two but went on to win many prizes in music, chess and mathematics competitions. Nigel is now a Science/Economics student and tutor at the Australian National University.

Simon Tedeschi

Simon Tedeschi was born a musical prodigy and is the 1998 Young Performer of the Year. Simon is a musical genius.

Dr Darold Treffert

Darold Treffert is celebrated internationally for his work with autistic savants and is the author of *Extraordinary People*.

Robyn Williams

Author and host of the popular ABC Radio National Science Show, Robyn is the President of the Australian Science Communicators and is a visiting Professor at the University of New South Wales. Robyn has won various awards including the Michael Daley Award of Science in 1996 and the Individual Award, Centre for Australian Cultural Studies

in 1996. Robyn has published many books including *Here Comes the Philistines* and *And Now for Something Completely Different*.

Introduction*

Phillip Adams, AO

Recent election outcomes have intensified the hate part of my love/hate relationship with Australia. Add to this the glass ceiling that presses down on fellow broadcasters like Robyn Williams who have discovered that the size of audiences is inversely proportional to the quality of the broadcast, I've come to the conclusion that my old impression that Australia is an anti-intellectual realm is correct. I used to see Australia as looking at a great pair of buttocks squatting in the South Pacific with Sydney and Perth at the hips and Adelaide approximately at the sphincter. This image was echoed in the iconography of the coat of arms because here are two creatures which are huge of bum and small of head.

The Centre for the Mind is such a big idea, it is too big for any one university, so it is shared by the Australian National University and the University of Sydney.

How did this come about? While many of you were attending university, I was reading comics. It was only through comics that I educated myself and I discovered that when the planet

we realise the dream by investing in groundbreaking research which shatters mindsets by stage-managing spectacular initiatives which challenge and inspire and by acting as a nexus for the great minds of our world".

The Centre is a nexus for neurons, a safe house for synapses and right from day one, it has been provocative and fascinating. We only have to look at the calibre of people the Centre has bought to this country, the likes of Oliver Sacks and Daniel Dennett.

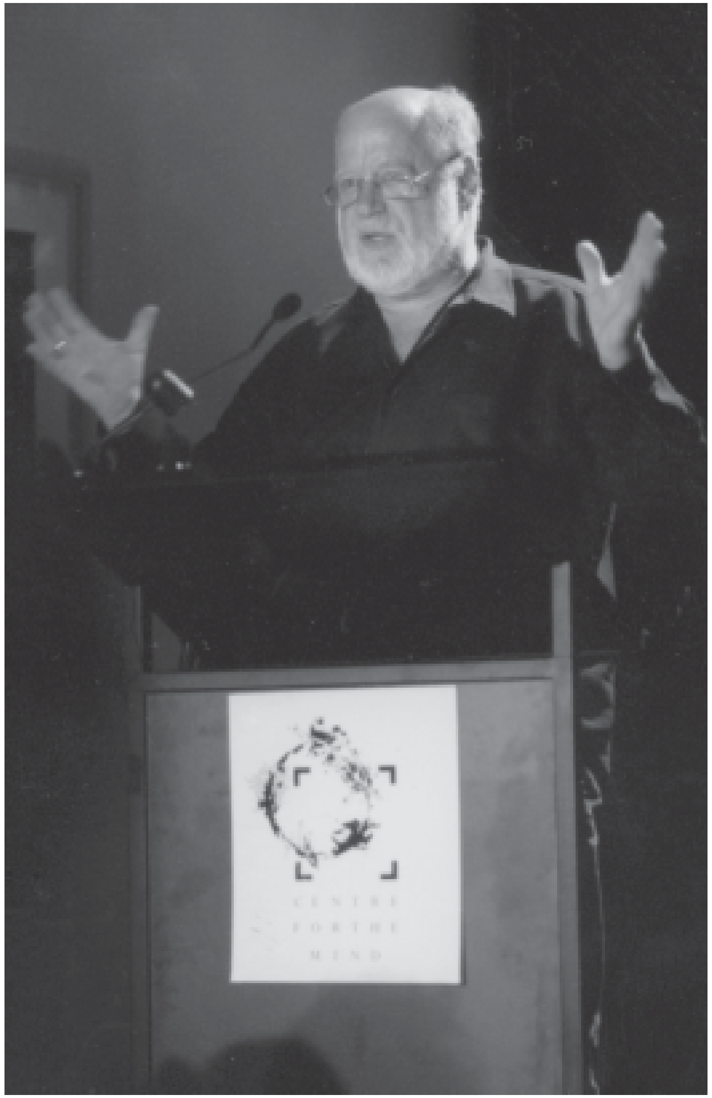
Typical of the Centre, we are focusing on the greatest mystery of all, the greatest mystery of creation, which is the strange mollusc we have between our ears. The snail-like creature beneath the calipash of the skull.

Night after night, I sit in the radio studio listening to people talking about this organ and disputing its significance or its nature. The study of consciousness is probably the hottest of all; not only among scientists, but amongst philosophers and those who study artificial intelligence. There is no more fascinating or awesome task than the study of what makes the human mind tick, and that is the purpose of the event that follows.

with him. I'm always astonished at what happens between his ears. He's not actually interested in scenery unless there's a ruin in it so he finds himself being bounced around my property in a four wheel drive tightly disinterested in it, but I was fascinated by his first encounter with a farm gate. Now it is an Australian tradition that if you're sitting in the front with the driver, you've got to open the gates. So we stop at the first gate. This is a gate that cows can open, they come over with their big wet noses and push the wire off the post and the gate swings open. My seven-year-old could open it. Barry couldn't. He spent about 15 minutes tugging at the wire and looking at it at various angles, trying to conceive the wire holistically. Finally he opened the gate. I said "Barry, we have a problem, you're on the wrong side".

Now I was telling this story in the middle of the desert to Professor Paul Davies with whom I was making a television series called 'The Big Questions' and for some reason the producers decided to put this English academic into RM Williams clobber, so he was being dressed up as a cowboy. He looked exceedingly odd. He was in the process of dressing himself when I was telling him the Barry Jones story. He laughed and I noticed he couldn't do his belt up. He had one of those belts with two loops through which you snake the leather and it completely defeated him and I found great comfort in this; that two of the most intelligent people I knew couldn't do their trousers up or open gates. I think this sets up the theme we are looking at because the human brain is a profoundly odd organ.

* The previous three pages are a transcript from the event and not written specifically for this publication.



Phillip Adams - a national treasure.

First Impressions – Snapshots*

Robyn Williams

When I was 15 or 16, I was going to a special concert at the Royal Festival Hall in London and it was completely packed. I raced up the wrong staircase with my Australian friend and we blundered straight into the royal box where your Queen sits on special occasions and there was Bertrand Russell, with the head of his family the Duke of Bedford. Bertrand Russell had been a hero of mine for many years, for as long as I can remember. He revolutionised maths, he wrote the Second Principia at the turn of the century, he revolutionised philosophy. He won a Nobel Prize for Literature and he was an amazingly radical protestor. This was in fact his 90th birthday concert, only a few months after and a few months before he was actually being arrested by the police in Trafalgar Square.

I went up to this man in the box and noticed a pimple on his nose. This genius has a pimple and the most extraordinary thing is that I have found that if ever I come across someone who is supposed to be a genius or a prodigy, my meeting them can in some way devalue them because they turn out to be human beings. I noted that practically every genius and hero through history has in some ways been deconstructed.

I love them being human and that's why Bertrand Russell grew in stature in my eyes. But you can see that people write off Mozart because a lot of people say that Mozart's work is 80% predictable. When he was young he was writing amazing music, but it was music for young people, unlike Mendelssohn who was writing grown-up music. And so people get

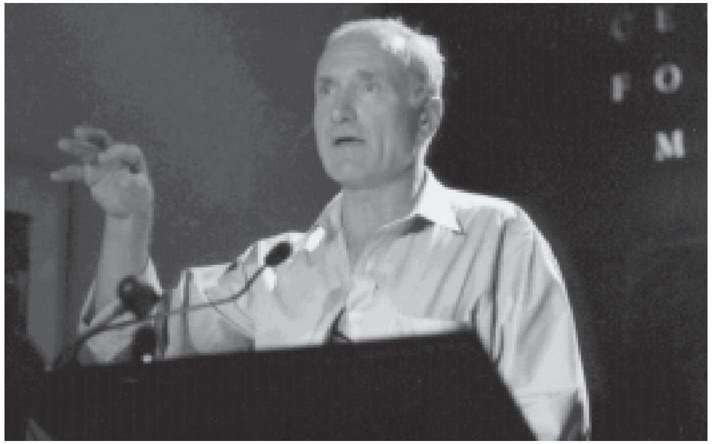
deconstructive; I think you can turn that on its head and show that their capacities are in fact very human ones.

I have broadcast a number of programmes recently about aspects of the brain which show how extraordinarily developed ideas show how little you know. The other day, I was interviewing Tim Crowe. Tim is a Professor of Psychiatry at Oxford. He describes schizophrenia as not a straightforward disease - but the price you pay for having language, and many of the symptoms - like voices and the strange bits of information that flow through, are in fact, he suggests, the way that language has gone somewhat out of control.

Then there's Sarah Blakemore who is doing research on tickling. The reason she is doing this is to find out whether the brain's understanding of self is different in certain people, indeed against schizophrenics. In fact, you find if they put them in one of those big machines you can tell where the chemical work is going on, that people who have symptoms turn out to be rather like self ticklers which go to different parts of the brain. It is awareness of self.

John Bradshaw, who is a Professor at Monash, talked about synaethesia where you actually see colours associated with words and he described that growing up is involved in the paring away of function. We become more and more efficient at things, you have an immense capacity of doing things at the beginning, things are too linked and he likens it to a statue being a huge block of stone. You remove the excess stone and end up with material in your brain that you can actually use effectively, except it doesn't happen completely in some people. So you get various folk who say the words "John Howard" which to them represent a dirty brown colour. I wonder what colour Jeff Kennett would be.

I suggest that what this Centre has done has shown very effectively that genius is a matter of supreme concentration and it is also a matter of learning randomlessly. Jack Pettigrew is interested in the way the mind can run free. Well when I arrived, I started talking in German to Allan Snyder, for no reason. My mother had a very free brain and people couldn't understand what the hell she was talking about because when she was making a joke, she missed out the middle two lines and quite often you do that. Spike Milligan has just been on the radio talking about bipolar disorder which is why he is devoted to lithium and Milligan is a quintessential guy. Half the time his randomness and jokes really worked, the other half, we had no idea what he was talking about. He looked mad and in some ways he was mad. It seems to me there are ways in which human beings can in fact catch up with



Robyn Williams - the familiar voice of the ABC Science show.

Unveiling the Savant Mind

Dr Robyn Young

A savant is an individual demonstrating exceptional skills despite an overall low level of general functioning. Savant Syndrome refers to observable behavioural characteristics rather than to a diagnostic classification and the term therefore incorporates all types of intellectual disability or mental retardation including autism.

There are three types based on level of skill:
1. Prodigious savant - skills not only remarkable in contrast to their low general level of functioning, but also to levels beyond the accomplishments of most people in the general population.
2. Talented savant - skills are beyond the range predicted by a generally low level of intelligence, but are not exceptional in the 'prodigious' sense because they might be expected to occur at similar levels among non-disabled persons.
3. Splinter skills - levels of interest and competence appreciably above the general level of functioning and which are far more common among the autistic population.

Despite the range of abilities available to all humans, savant-type skills fall into a discrete range of skills:

- musical precocity

- highly developed sensory discriminations
- artistic ability
- mechanical dexterity
- memory for facts.

I conducted three main studies:

Study 1 – The Examination of a Musical Savant and his Family.

Findings:
- musical ability among available members of the savant's family
- perfect pitch in all musical savants and some family members
- memory for music was well organised and structurally based
- some cognitive functions may be independent from a general capacity.

Study 2 – Calendar Calculation

Findings:
- savants were aware of the 14 calendar

Study 3 – Psychometric Evaluation

Findings:

- Significant correlations between skill level and IQ suggest that the extent to which the ability is developed reflects more sophisticated cognitive processes and is IQ dependent
- Mean IQ of immediate family members supports the predisposition of savants toward higher levels of intelligence
- Presence of 'similar' skills in family members
- Presence of as many as nine skills (M=4.4, SD=2.2) – suggesting that the same underlying processes may be involved in the development of subsequent skills.

It is suggested here that savant skills are suited to the individuals who develop them because

(i) they are highly dependent on some preserved neurological ability (perhaps declarative memory)
(ii) they require little higher order manipulation of cognitive stimuli
(iii) they can occur in the absence of a high general level of intellectual functioning
(iv) the processes involved can be developed further with practice.

The existence of savants is consistent with a theory that some skills are based on relatively well-differentiated neurological capacities; the skills developed by savants are generally rule-based, rigid and highly structured, lacking critical aspects of creativity and cognitive flexibility – abilities generally considered to reflect intelligence.

In summary, my studies suggest that a savant is a neurologically impaired individual with idiosyncratic and divergent profiles of intellectual ability and language and intellectual impairments consistent with autism, who has an intense interest and preoccupation with a particular area of skill. These circumstance, together with the necessary preserved neurological capacity to process information in a manner relevant to their skill (probably sequential), a well-developed memory (probably declarative), a familial predisposition toward high achievement (possibly innate), and adequate support, encouragement and reinforcement, provide the necessary climate for savant skills to develop.

Coffee break at the art display during the *Geniuses, Prodigies and Savants* event.

‘Normal’ Potential – What Is It?
Dr Glenison Alsop

In the quest to better understand the most extraordinary, we are left to wonder about the source from whence they come. In other words, is there something about ‘normal’ intellectual potential which can in any way predict extraordinary potential – that associated with genius, prodigy, savant – and the realisation of that potential into extraordinary achievement.

Extraordinary intelligence certainly has its place in the emergence of the genius and the prodigy. Like the prodigy, the savant too is a performer. But unlike the inclusive creativity of the genius, the savant is characteristically rigid and exclusive. That is, savantism is associated with an unusual form of behaviour or with its unusual expression in a highly particularised domain.

Although we recognise consistencies in the way all three function in their personal attributes, and the source of their achievements, we cannot as yet replicate the conditions where we can predict one will emerge from among us. Very high intelligence is a pre-condition of the prodigy and the genius, but both also rely on other aptitudes and personal traits.

We do have a very good understanding of the conditions which nurture extraordinary intellectual potential – we know them, but as a society we do little to respond to them. Yet social values are critical to how children of high intellectual potential (CHIP) learn to manage and respond to their achievement. Arguably self-knowledge is a necessary determinant of achievement. Without appropriate social support and

validation of the highest learning children, the most important experiences on which their adaptive behaviour and self-learning is based will be attenuated.

It becomes possible to hypothesise therefore that there is a link between the experience of learning and brain function. The question becomes: could learning behaviour become a variable that shapes brain function, mediated by the individual’s understanding of his or her level of competence?

Should this be the case, as a society we will need to change our values if we wish exceptional intelligence to be a determinant in the future.

Dr Glenison Alsop, Professor Bruce Miller and Professor Jack Pettigrew.

Insight

Fiona Hall, Visual Artist

Through the layering of ideas in my work, I try to show the multifaceted nature of environmental issues and the interconnectedness of concepts and materials that might at first appear quite alien to each other.

At the very early stages of thinking about a work, I have on the one hand an idea about the subject I intend to work with and on the other hand, an emotional response to that subject, and also a strong attraction to a material which I may incorporate into the work. At first the subject matter and the material generally appear quite disparate even to me, and it's a struggle to amalgamate the two, but I usually find that the disparity pays higher dividends in the final work than if I started with materials and subject matter that seemed much more appropriate to each other, but would in the end be too predictable.

I have learned to trust my peripheral mind and to bring quick or fleeting perceptions more sharply into focus. If I sit in a chair and try concertedly to come up with a good idea, nothing very exciting will happen. I think it's important to have an awareness of the territory which interests you, but to avoid the potential constraints inherent in this kind of focus.

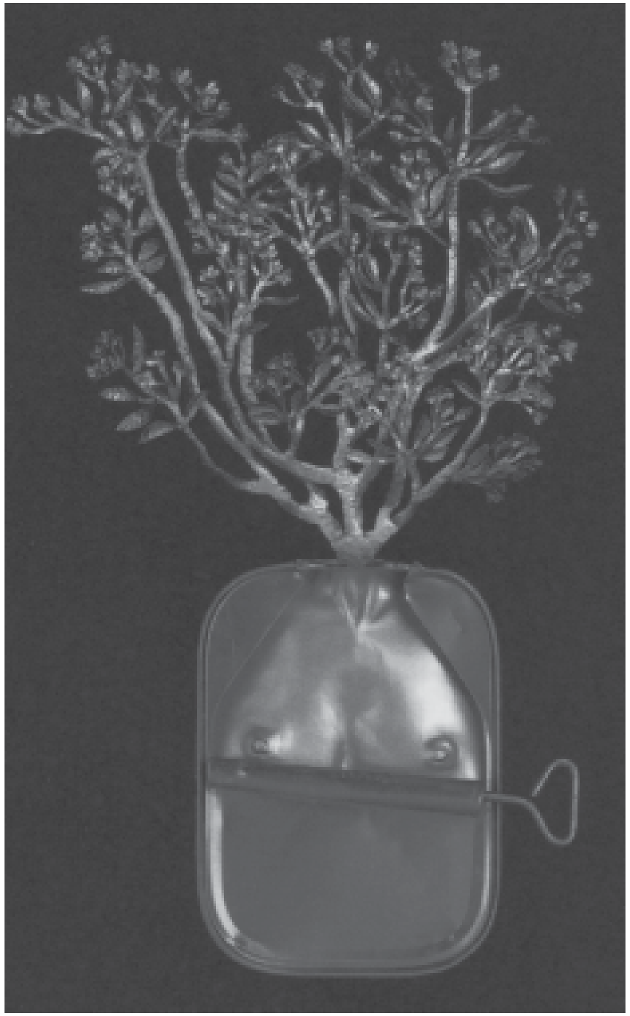
My work generally necessitates an intense amount of labour in its production. I've now become accustomed to the idea that a work may take several months to complete. At times this does seem a bit too arduous, but I do derive much pleasure and satisfaction from the process. In the process of making,

the mind might be in the future, enabling it to wander quite freely over a variety of issues related to other works. I find myself working on a number of projects simultaneously, each requiring different mediums and different kinds of problem solving.

Recently I have been working on a couple of landscape architecture commissions which have even further extended and challenged the materials and scale I work with. I now find that I am working simultaneously on very small intricate things and on work of landscape proportions both of which may be closely aligned conceptually.

For example, the work *Paradisis Terrestris Entitled* (sardine can sculptures of Australian native plants which are titled with Aboriginal language names of these species) has close ties with the garden commission at the National Gallery of Australia, where all of the surviving Aboriginal names of the plants species used in the garden are written in the pathways.

What might be seen as distinctly different methodologies actually come from the same conceptual base. More and more it is the multifaceted rendering of a concept into several vastly different mediums and modes of practice that interests me. The work is enriched by these different permutations, that then come back in altered forms.



Plumeria acutisolia: frangipani; araliya; malliya poo, 1999
aluminium and tin by Fiona Hall.

The Centre for the Mind would like to thank Fiona Hall for allowing the use of her art work in this publication.

A Visual Feast
Dr Darold Treffert

(During the *Geniuses, Prodigies and Savant* event videos of Dr Treffert's autistic patients and their art works were screened. He describes these here.)

To merely describe Leslie's music or Alonzo's sculptures is to do justice to neither. The spectacular expertise of the prodigious savant must be seen and heard to fully appreciate the rarity and uniqueness of this astonishing juxtaposition of ability and disability – the islands of genius – in these remarkable people. These videos demonstrate the nature and scope of the extraordinary abilities in four prodigious savants, and explore as well the vast implications that savant syndrome has for understanding brain function over-all, and hidden potential, perhaps, in each of us.

Alonzo

Alonzo now lives in a condominium in Boulder, Colorado and has a part-time job at the local YMCA. His remarkable sculpting ability has been his conduit toward normalisation and greater independence. Alonzo sculpts animals magnificently, using crystalline clay as his medium. Horses are his favourites but any animal can be copied exactly from just a brief glimpse at a two-dimensional picture or from a stroll through the zoo. He can complete such a horse or any other animal in about forty-five minutes. He has also done life-size pieces, some of which have sold for as much as $45,000. His work is sought and appreciated around the world.

The film illustrates Alonzo's remarkable, innate talent as a sculptor. He has never had an art lesson in his life. His case is even more rare because he is what is called an 'acquired savant', that is, a person whose savant skill emerged following a CNS injury or illness. It was following a fall as an infant that Alonzo's incredible sculpting talent appeared. As with other savants, Alonzo's family has been a loving and powerful force in 'training the talent' through encouragement and reinforcement. Their unconditional acceptance of Alonzo, and their focus on ability rather than the disability, has been instrumental as well in furthering his art – which is his language – and in so doing furthering Alonzo's social and daily living skills as well.

In the 'acquired savant' particularly there is evidence that damage to the left hemisphere of the brain results in right hemisphere compensation producing then, the right brain skills – art, music, lightning calculating and other mathematical skills, calendar calculating and spatial and mechanical skills – so typical and characteristic of savants overall. These right brain skills are always coupled with prodigious memory – exceedingly narrow but exceptionally deep – probably because of corresponding damage to higher level cognitive memory circuitry permitting access to, but also the limitation of, lower level habit memory circuitry. The combination of right brain skills linked to habit memory is savant syndrome. In the male foetus circulating testosterone can be one source of neuronal damage to the later developing left hemisphere, with subsequent right hemisphere compensation, which may account for the approximately 6:1 male:female ratio in savant syndrome.

In the prodigious savant, such as Alonzo, repetition and practice alone would not be sufficient to account for the innate access that these remarkable people have to what have been called the 'rules' – the vast syntax – of art, mathematics or

music. Instead some genetic or inherited factors – so called 'ancestral memory' – must additionally be present to account for this vast, inborn store of knowledge, talent and skills. This film explores that possibility suggesting such buried potential may well reside within all of us. Our task now is to learn how to tap such buried potential. Meanwhile Alonzo continues to sculpt, to create, to enjoy and to grow toward even more independence in his infectiously mellow manner. His is a most inspirational story.

Tony

Tony is an autistic savant (approximately 50% of savants are autistic; the other 50% have some other form of developmental disability or brain injury). Tony is blind. And Tony is a musical genius. This film documents that prodigious musical skill. I first met Tony in 1989 when he was awarded a summer scholarship at the prestigious Berklee College of Music in Boston, Massachusetts. Tony so impressed the staff at Berklee with his astounding musical talent that summer, that he was admitted there as a full time student and graduated magna cum laude in 1996. That is a striking achievement for someone both blind and autistic. Tony is a tremendous jazz musician and improvises freely and impressively.

Tony's spectacular jazz ability extends to other musical styles as well, ranging from country to classics. He plays fourteen musical instruments, twelve of them proficiently. Like many other musical savants, his ability surfaced at an astounding level when his mother, Janice, bought him a chord organ at a sale. Tony was two years old at the time. On the film his mother recounts Tony's remarkable progress since then, including his repertoire of over 7000 songs even "before we stopped counting 8 years ago". The film shows Tony receiving his diploma from Berklee, a highlight in his life and a tribute again to the usefulness of 'training the talent'. There has been no dreaded trade-off of musical skills for language acquisition and growth in social skills. Quite the contrary, those skills have provided, again, a conduit toward normalisation, an impressive transition indeed. Tony maintains a web site at www.ccmw.org/deblois/.

Richard

Richard is an autistic savant who has continued to excel as an artist of international renown. He uses the unique medium of Swiss oil crayons and concentrates on landscape scenes done with breathtaking fidelity and rich, deep colours. His preoccupation with, and phenomenal skill at depicting light remains striking and amazing. As his repertoire has grown however, so have his language and social skills, again with no dreaded trade-off of special abilities. This film is a brief glimpse at some of his work, and a brief introduction to him as a person. The best way to describe Richard and his phenomenal talent though, is to view his art, which can be accessed at http://wawro.org. His art speaks for itself and requires no elaboration.

Leslie

When Dustin Hoffman watched Leslie play the piano on a 1983 *60 Minutes* program he was "moved to tears". That program inspired Dustin Hoffman to play the part of the savant when the script for the movie *Rainman* came to Hollywood in 1986. That movie made autistic savant a household word. Leslie's story of his incredible talent, nurtured by the untiring effort, faith and belief of his foster-mother, May, continues to inspire still wherever Leslie plays. That story was told in yet another movie – *The Woman Who Willed a Miracle* – which depicts so vividly the remarkable moment in which Leslie at

age 14, played flawlessly from beginning to end Tchaikovsky's *Piano Concerto No. 1*, having heard it for the first time as a theme song to a television movie that evening. Leslie is blind, mentally handicapped and has cerebral palsy, yet his music is magnificent. His repertoire seems bottomless as well and professional musicians marvel at his innate grasp of the 'rules' of music. He has never had a music lesson in his life. Imaging studies have documented the type of left hemisphere brain damage cited above. Music is Leslie's language. And it has been his conduit toward normalisation as well and this film amply documents that progress and growth as with the other savants. His story, like so many savants, is better seen than told and these brief film clips, I hope, exemplify that.

The real significance of the savant is our ability to understand him or her, yet no model of brain function will be complete until it can fully incorporate and explain this amazing circumstance of incredible islands of ability existing in a sea of disability. My thoughts to better understand that circumstance, and to better appreciate the vast implications savant syndrome has for understanding and eventually tapping hidden potential that I am convinced resides in each of us, are contained in much greater detail in my book, *Extraordinary People: Understanding Savant Syndrome*, which will be re-released soon with an epilogue update. Newer information about Savant Syndrome, incorporating some of those recent research advances, can also be found on my savant syndrome website at http://wismed.com/foundation/savant.htm. There is a recent article entitled 'The Savant Syndrome and Autistic Disorder' in *CSN Spectrums: The International Journal of Neuropsychiatric Medicine*, volume 4, no. 12, pp. 57-60, 1999.

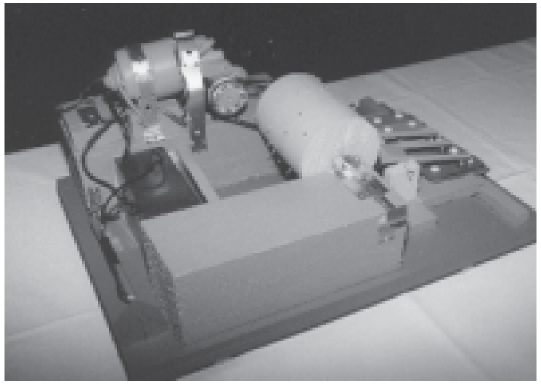
Insights from a Savant Calculator

Dr Joan Curtis

I am presenting 3 examples of autistic prodigies.

1. An exhibition of 30 paintings by six autistic young men.

2. Two electrical models invented by an autistic young man who has no literacy or numeracy skills, and no training in electricity.



An electronic dog and music box invented and constructed by autistic savant Guy Burton.

3. An autistic young man whose memory for names and dates is phenomenal.

Tim Mallows, an autistic savant, and Dr Joan Curtis.

While the unusual talents of some autistic people are so dramatic that they catch everyone's attention, it is important to realise that even low functioning autistic people have 'islands of ability' and if we search for them some remarkable gifts come to light.

Living with Exceptional Children

Dr Billy Tao

BACKGROUND:

I shall begin by saying something about the background of my family. I am a paediatrician and my wife Grace was a high school mathematics teacher. We have three children: Terry, Trevor and Nigel, all born in Adelaide.

Terry is now 24. He started school at five, but by seven he was studying part-time in primary school and part-time in a nearby high school, doing Year 11 and 12 Pure Math and Year 11 Physics. He did his matriculation exams in Math I and II when he was eight, and was allowed to study as a part-time student in first and second year Mathematical courses at Flinders University when he was nine. He won a bronze medal in the International Mathematical Olympiad Competition when he was 10, a silver medal in the following year, and a gold medal the year after. At eight he scored 760 out of 800 in the American University entrance SAT-Math test. At 17 he completed his Masters degree at Flinders University, and at 20 his Ph.D. at Princeton University. He has been an Assistant Professor in Mathematics at UCLA since 1996, and earlier this year he was the recipient of a Sloan Fellowship, one of the most prestigious post-doctoral awards in America. He is currently a visiting Fellow at the University of NSW.

Trevor is 22. He was diagnosed autistic when he was two. He started to show his musical ability at an early age, and has won prizes or medals in many piano performance and music

composition competitions. He was also interested in chess, and at 14 he was the Australian Junior Chess Champion. In the following year he won the (Australian) National Chess Player of the Year award. He was one of the six members in the Australian Men's team in the International Chess Olympiad held in Moscow in 1994. His ability in the mathematical field actually came as a surprise. When he was in primary and junior high school he was doing OK in state-based mathematical competitions, getting distinctions and credits and so forth, but then from 1994 onwards he started to win a series of prizes in national mathematical competitions.

The wins were slightly unexpected because unlike Terry and Nigel he had not been reading mathematical books or attending special tutorial lessons. We thought he already had too much on his plate, in music, chess, and normal school activities, and because of his autism we were not confident about his writing and presentation skills.

The ultimate surprise came in 1995, when he won a Westpac Medal and then a place (together with Nigel) in the Australian team for the International Mathematical Olympiad, which was held in Toronto. He won a bronze medal on that occasion. He matriculated with five merits, earning him an Australian Students Prize for Excellence, and entered the University of Adelaide in 1996 studying two degrees concurrently, in Mathematical Science and Music. He was also the first student allowed to major in both Music Performance and Composition at the Elder Conservatorium. He was awarded the University of Adelaide's Dean's Certificate of Merit for both Level I and Level II math subjects. He is currently doing Level III subjects.

His mathematical insight was quite unusual for an autistic savant, and I sometimes wondered if he should still be labelled as a savant or something else. So too was his creativity in music composition, for he was not just copying or memorising other composer's works. His pieces were often quite original, with his own distinctive style.

He has been winning prizes in composition since he was in primary school, and one of his earliest winning pieces, a String Quartet, was played by the Australian String Quartet in a music workshop held in Adelaide in 1991, and broadcast on 5UV, an Adelaide-based classical music radio station. Last year his quintet entitled *Abstractions* was chosen for performance in the Elder Conservatorium Centenary Concert, and has received good reviews from music critics in both *The Australian* and *The Advertiser* newspapers. He currently holds a performance scholarship at the Elder Conservatorium, and is the winner of the Conservatorium composition prize two years in a row.

Nigel is 20 and is more of an all-rounder. He skipped one grade in primary school, and then won a high school scholarship. He continued to win prizes in many state and national science and mathematics competitions, and competed in the International Mathematical Olympiad at age 14 and 15, winning bronze medals on both occasions. He won a 1994 and a 1995 Australian Students Prize for Excellence, and a national undergraduate scholarship in 1996 to study for a combined degree in Science and Economics at the Australian National University. In addition to Math, Computer and Economics subjects, he has also taken Psychology, Biology, Politics and Law courses at ANU in the past two years. He

plays four musical instruments and has been active in several different sports at ANU. His latest award in sports was a best-and-fairest trophy in netball. He is also a tutor in residence at his university dorm. Despite his diverse interests and busy social life he still managed to win two major prizes in final year Economics earlier this year.

REFLECTIONS ON THEIR EDUCATIONAL MODELS:

I would now like to spend some time on their educational models, which were slightly different from each other, because the three of them had different personalities, interests and strengths, and in Trevor's case, the effect of autism. The same can be said for other gifted children and their education in general.

At the time when Terry and Trevor were discovered to be unusual students it was almost 20 years ago, and special educational programs for either gifted or high-functioning autistic children were not in place as they are today. There were no set models for us to follow, so we had to improvise from the start. Ironically it was a good thing, because had we not had the same degree of freedom to experiment, the outcome could well have been quite different.

Terry's model could best be described as one of radical acceleration, starting high school at seven, university at nine, and becoming an Assistant Professor at 20. For it to succeed, we had to have several pre-conditions. Firstly, we must not have a failed precedent, which would certainly mean the end of any proposal to put a seven-year-old student in high school at that time. Secondly, we must have open-minded school teachers and university staff who were willing to try the unknown and take up the challenge. Thirdly, the primary and high schools and the university must be fairly close to each other so that travelling from one place to another was still practical between lessons. Lastly, there must not be any premature and adverse publicity at the start of the programme, or else some egalitarian bureaucrat from the Education Department could easily become alarmed and want to "nip the whole thing in the bud". Fortunately for Terry, by the time his story appeared on the front page of the local newspaper it was already *fait accompli*, so no one intervened, even though the general policy at that time was against accelerated education.

Trevor's model was one of early intervention, which meant finding out the diagnosis early, and getting professional help early. Again at that time it was relatively uncharted territory in teaching high functioning autistic children, and there was not much experience from either the Education Department or the Autism Association of South Australia. So the Association assigned a special-Ed teacher by the name of Jean Bryant to work with us, and explore how best to educate him and integrate him into a normal school. Nowadays integration of autistic children into normal schools is commonplace, but in those days we had to find a school which was prepared to try it first.

We did find a nearby school which seemed to suit Trevor perfectly. It was a small school with little more than one hundred students, and the principal was not daunted by the idea of having an autistic child among his pupils. At about

the same time we had also discovered his savant abilities in music and chess, and arranged lessons for him with several music teachers and chess players. Jean Bryant has since written a book on her teaching experience with Trevor, which is called *The Opening Door*.

Nigel's model was a more traditional one, which was that of a broad-based high-quality education with emphasis more on diversity and lateral extension rather than vertical acceleration. Even his university education followed the same mode. For example, he has completed many of his university subjects ahead of time and could have finished his combined degree in three years, but instead of graduating early he has chosen to spend another year studying 'non-core' subjects such as Psychology, Politics, Biology and Law. The choices of his university subjects were all made by himself, but even at an early age we were convinced that this model suited him better. If we had implemented Terry's model onto him purely because "it has worked well for Terry", we probably would have a mismatch and a different outcome for Nigel.

One important aspect about Nigel's education is also worth mentioning. Being the youngest in the family and less well known than either Terry or Trevor, he was somewhat overshadowed by his two elder brothers, although by all accounts he was a tremendously gifted child with an I.Q. greater than 180. We sensed that he was not at his best when he was living with us, and was probably held back because of self-doubt and lack of motivation. Then an opportunity came when he finished high school, and we actively encouraged him to leave Adelaide to study at the Australian National University. It proved to be a good move and had a very positive effect on him. He has emerged from the shadow of his brothers and become a wonderfully helpful and considerate person. He started to achieve his full academic potential, and has become a very popular person at his dorm. Again, I want to emphasise that the same approach for Nigel may not suit somebody else, who may not like the idea of leaving home and venturing into a totally new and unfamiliar environment.

My description of Terry's educational model as one of acceleration and Nigel's model as one of extension was made deliberately to highlight their differences. In reality, the two were just two slightly different versions of a universal model of gifted education, which is best visualised as a pyramid. The breadth of the pyramid is the extension part, and the height of the pyramid is the acceleration part. The ultimate shape of the pyramid, whether it is 'tall' or 'squat', depends very much on the characteristics of the child's ability and personality.

In Terry's case, the extension part of the model was provided by allowing him to study in different grades on different subjects at high school. So between the age of seven and 13, while still attending university part-time in Math and Physics, he was allowed to complete high school education in subjects such as Chemistry, English, Latin, and Geography. In Nigel's case, acceleration was provided by allowing him to study high school math when he was in primary school, and attending math and physics lessons several grades ahead of his home class when he was in high school. He finished his matriculation Math I and II and Physics exams at age 13 and 14 respectively. However, unlike Terry he did not attend university part-time when he was still in high school. Instead

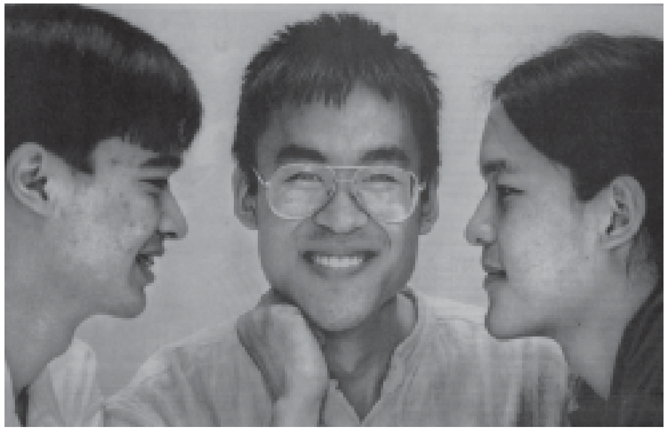
he took up Music and Japanese, and spent more time in extracurricular activities such as chess and school band.

I believe the major advantage of a pyramid model is the stability factor. A purely vertical acceleration model is like a column, which becomes more and more unstable as the height increases. As bright children make the transition into adulthood, it is important that they have a broad knowledge base, and are emotionally mature to be able to withstand the shocks of reality.

A CAUTIONARY NOTE ON THE POSSIBLE OVERUSE OF THE WORD 'GENIUS':

Before I finish, I would like to make a plea to everyone here not to overuse the word 'Genius'. Genius is the highest level of attainment in any particular field of human endeavour. When compared with prodigies, geniuses imply much greater depth and calibre in knowledge, wisdom, creativity, experience, personalities, maturity of thought, and a host of other valued human qualities and dimensions. Not only do they have overwhelming talents and abilities, their greatness and achievements must also pass the test of time. In contrast the achievements of prodigies can often be described as superficial – dazzling speed of learning or high levels of technical skills etc. They are often relatively young people and still inexperienced in life. Like apprentices trying to become masters, prodigies have a long way to go before they can be called geniuses. In history, only a handful of geniuses were ex-prodigies (e.g. Mozart), while many were little known during childhood (e.g. Einstein).

It is human nature to overstate a person's ability or weakness, particularly from people with a bias, such as admirers or critics. We often call someone a genius or idiot more than the person deserves. We have a tendency to call above-average children 'bright', bright children 'gifted', gifted children 'prodigies', and prodigies 'geniuses', without realising that this can put severe pressure on them and actually hinder their progress. The word genius is a very big hat to wear, and has to be handed out cautiously. Just ask the Nobel Prize winners of our time: how many of them will feel comfortable if they are called geniuses, which may evoke the thought of a Shakespeare or Einstein? Yet they are all very bright and successful people, the highest achievers in their fields. Some of them may well have been prodigies when they were young. The fact that they may not like to be called geniuses does not mean that they see themselves as failures. So I think we should refrain from overusing the word 'genius' on prodigies, and avoid over-expectation on these very bright people.



Terrence Tao, Trevor Tao and Nigel Tao.

Transition of the Prodigy and Savant

Simon Tedeschi

I was always 'different' both as a baby and young child (according to my mother) but, unlike other gifted people, I showed no signs of prodigious ability until around five or six years old, before which my life was quite normal.

Once I heard a piano my life was irrevocably altered. It became a vehicle for my emotions, my intellect, my drive and my spirit. My need to make beautiful music was overwhelming. It took the place of normal childhood pursuits and when I was very young, I didn't really feel the sacrifice.

Only now as an adult I can look back and understand that to devote myself to music, other aspects of life, usually so integral to normal development, were omitted. I spent very little time in the classroom, although nominally I attended school. A lot of that time was spent in the school hall with my best mate, the piano. Thus, my being 'different' was cultivated. In the afternoons instead of games or sport or homework, I practised while others played soccer and cricket. I was already, from the age of eight or nine, up on a concert platform with all its associated challenges.

Adolescence somehow didn't have time to emerge – childhood merged into adulthood without the normal experiences and rebellions of teenage angst. The gaining of maturity was unusually rapid, driven by overseas tours (alone from the age of 14), by earnings, tax returns, an agent and signing contracts – heady stuff for a teen.

It has not been easy, but if I had my time again, I suspect history would repeat itself.

A panel session of *Geniuses*, *Prodigies & Savants* ('Transition from Prodigy & Savant to Adulthood', 4-5pm Monday).

Living with David

Gillian Helfgott

The topic of my comments today is 'Living With David Helfgott'. I wonder how many of you have seen the movie *Shine*. The film, whilst never setting out to be a documentary, was inspired by David's life and gave a wonderful insight into his personality. Whilst some scenes were dramatised and certain characters had to be combined, the director Scott Hicks made a film that is not only one of great integrity but also truly inspirational.

David was born into a Jewish/Polish family, who had little prosperity. In 1947 and by the age of five David was showing a great interest in the piano and by nine performing major works by Chopin and Liszt. By the age of 12 he was declared a prodigy, and the ensuing publicity kept his name to the fore in Western Australia. He won the ABC Concerto Competition in that State six times and had a great ambition to study overseas.

In direct contrast to Dr and Mrs Tao, who appear to have so wisely guided their three outstanding children in their education, David, whose father had a leaning more to communism than capitalism, sent David to the local State schools. He did not even attend the special music school in Perth and did not apply for any scholarships to colleges or music schools. When he was forced to leave home by his father in his late teens, he then applied for the Royal College of Music in London and gained acceptance and a scholarship. The years in London he found very fruitful, until ill health intervened in his last year at the College and he returned to Australia and over a decade in and out of mental institutions.

After twelve years away from the professional concert platform, David returned to performing in 1984 – an outstanding achievement considering his traumatic past.

I met David when he just started playing in the Wine Bar in Perth in 1983. The impression he made on me was immediate, overwhelming and lasting. His hyperactivity was very apparent, but the warmth of his personality and desire for acceptance were extremely appealing. I guess I fell in love with him on the spot. The next day he saw me and asked me to marry him and I nearly said yes! Why?

David is an exceptional person. Whilst he has many mannerisms and certain nervous anxiety at times, he is full of love. He wants everyone to be kind as indeed he is. He does not know meanness, jealousy, resentment, sustained anger or bitterness. And this is despite twelve years on and off in mental institutions – and that was in the seventies which was not the most enlightened time in mental health treatment. Shock therapy was given, heavy medication, he was denied access to a piano in the first instance and unfortunately there was not a great deal of empathy between him and his psychiatrist, until he was fortunate enough to meet Dr Wyn Warren in 1988. She helped him open new doors of confidence, personal love and a sense of peace about his very troubled relationship with his late father. I attended sessions with David, at Dr Warren's request, and this strengthened even further our bond of love and respect.

Challenging, funny, exciting, frustrating, loving and exhausting are all words describing my experience of life with David. But never boring! When we met he was drinking

25 cups of coffee a day, about 500 grams of sugar, smoking 125 cigarettes a day, taking about quarter of a bottle of aspirin and chewing gum! One does not need to have a vivid imagination to guess the level of hyperactivity from that consumption. His medication was *Serance*, which he had been on since 1970.

For those who have been in a mental wilderness, love and support in a personal sense seems so important. I was able to devote 24 hours a day to David – and at times it felt like 48 hours in one day. But I was there by choice, unlike parents and families. But soon the results started to manifest. With the decrease in coffee, cigarettes, etc., a greater calm descended and taking David swimming for an hour twice daily (this of course helped cut down the cigarette intake) his physical health started to improve dramatically. His untidiness, as the scenes in *Shine* show, was evident every day. It was not until we built our own home in 1991 that he realised that the property was his, and his attitude changed. He then took great care not to litter the house, and indeed now helps daily, and with such amazing willingness. I don't think I have ever asked him to do anything and he has hesitated – even getting me a glass of water in the middle of the night!

In my book *Love You to Bits and Pieces, Life with David Helfgott*, I describe in detail our life together – the blending of his creative abilities and my practicality. We make a good team – complete opposites, but that has its benefits as we both have our own interests – he practices and I do some astrology and deal with all the business, and yet we share our love of books, nature, travel and friendships.

One of the things I found sad when I went to live with David was the lack of public awareness to mental illness and the fear of it. As about 20% of the population will require some therapy at sometime in their lives, it is essential that we gain a great tolerance to those who appear different, and, an understanding of the need for medication at certain times in a person's life. Why do we not feel a diabetic is failing if they need insulin, and yet anyone on medication for a psychiatric disorder is deemed a failure by many and this can result in the person withdrawing their medication, sometimes with disastrous results. I also deal with this matter in my book.

The years away from performing did not dim David's passion for his music and his comeback in 1984 revealed that his great virtuoso ability had not left him – it had been dimmed, but never died. His music fills his life, his head, his soul. He is indeed blessed that he can earn his living now from his obsession and passion – few have that opportunity. His suffering has added a new dimension to his music – his Liszt performances of the *Dante* and *Sonata in B Minor* reflect his journey through life and speak more eloquently than words.

For those with exceptional talent, to use it is paramount to their fulfillment. As David says "away from the stage I am a mouse, but when I walk on to the stage and play the piano I become a leaping lion".

David Helfgott, Professor Allan Snyder and Gillian Helfgott.

Emerging Genius at the Onset of Dementia

Professor Bruce L. Miller

Art burst forth on the planet earth approximately 40,000 years ago. Remarkably, it appeared in both Australia and Europe at the same historical moment, produced in different climates and habitats by peoples separated culturally and physically. Not crude scribblings, these works were breathtakingly beautiful and their production required advanced technical skills. Beyond demonstrating abilities never previously evident on this planet, the art mirrored a culture with spiritual ideas and musical passions. These sculptures, cave-paintings and petroglyphs still serve as a window into the cognitive processing and brain capacity of the humans who lived in these ancient societies. The capacity, perhaps even necessity, to produce art suggested that a profound change had occurred in the human brain. Soon after the appearance of art, pictorial and then symbolic language emerged and a written record began to complement the visual history left from pictures and sculptures. Like the "language organ" elegantly described by Chomsky, humans had evolved an "art organ" pre-wired genetically and ready to express visual images of the external and internal world. The study of patients with focal brain lesions offers valuable insights into what parts of the brain are required to produce art. Ultimately, it tells us about the brain regions that evolved to allow the presence of art and language.

The ability to precisely copy internal images, objects or drawings is profoundly altered by injury to the right parietal lobe. Realistic reproduction is lost with right parietal injury,

even in previously accomplished artists. This loss is due to a variety of factors relating to spatial cognition. Neglect of the contralateral visual space will lead to drawings where the left half of the space is unused, or only sketchily drawn. Additionally, the simple process of copying or putting together two three-dimensional structures is impaired. The right hemisphere, but in particular, the right posterior parietal lobe, is required for the art that was produced for the first time 40,000 years ago. Clearly, right posterior parietal cortex is required for realistic reproduction. Less is known regarding the function of the left hemisphere in the production of art and it is possible to suffer a left hemisphere infarct and continue to produce precise copies of objects or paintings. However, there does appear to be an important left hemisphere contribution to art, and in one report, a conceptual artist who suffered a left frontotemporal stroke lost the ability to produce symbolic paintings. In contrast, this man continued to produce beautiful realistic reproductions. The left hemisphere remains important for the conceptual and verbal aspects of visual art.

Two degenerative dementias, Alzheimer's disease and frontotemporal dementia, reveal contrasting ways through which focal brain injury can influence artistic expression. With Alzheimer's disease there is a relentless loss of visuoconstructive ability. Drawings become distorted with diminished accuracy and spatial perspective. These losses coincide with dysfunction in the right parietal lobe. In frontotemporal dementia the ability to copy is relatively preserved. Even though creativity disappears in most patients with frontotemporal dementia, the ability to draw remains late into the course of the illness. This suggests that evolution of the frontal lobes, by itself, is unlikely to explain the production of art in prehistoric times. Furthermore, in one anatomical subtype of frontotemporal dementia, patients with left anterior temporal degeneration, visual creativity remains or develops. The art in these individuals is reminiscent of the non-symbolic reproductions of the conceptual artist who lost the ability to produce symbolic art with left hemisphere stroke. Yet, despite the absence of symbolism, the work is visually appealing and successful. We have hypothesised that both visual perception and visual interest is enhanced by injury to the left anterior temporal lobe, the brain region responsible for access to semantic information.

Clearly, various brain regions contribute to visual creativity. The right parietal lobe is dominant for the ability to actively reproduce images while the left anterior temporal and frontal lobes contribute to the conceptual component of art. Most artistic productivity uses both the left and right hemispheres although autistic savants and patients with semantic dementia produce an art that is primarily visual and non-conceptual. The appearance of art 40,000 years ago reflects a change in the human brain. The likely site of this change is posterior parietal cortex.

Professor Bruce Miller - discoverer of artistic genius at the onset of a form of Alzheimer's disease.

Do The Brains of Extraordinary People Differ From Normal People

Professor Michael W O'Boyle

By way of introduction, my name is Professor Michael W. O'Boyle and I have recently been appointed Morgan Chair in Psychology and Director of the Morgan Centre for the Study of High Intellectual Potential at the University of Melbourne. The following is a very brief overview of past work and future directions in my ongoing investigation of intellectual giftedness.

The expressed goal of the newly formed Morgan Centre is to conduct empirical research into the biological, cognitive and developmental mechanisms that underlie gifted intellectual ability, and in particular, the investigation of prodigious mathematical talent (i.e., those who are 12-15 years of age and classified in the top 5% of performers based upon standardised tests of math abilities). While much has been said and done with regard to psychometrically identifying individuals who are (or are not) mathematically gifted, very little has been done in developing a scientific model of how such prodigious talent has arisen, seemingly in the absence of any formal training or instruction.

Over the last decade, my work has focused on the functional organisation of the gifted brain and how it is qualitatively (not just quantitatively) different from those of their average ability cohorts (O'Boyle, Benbow, & Alexander, 1995). In particular, using a variety of neuropsychological methods, I have demonstrated that enhanced development of the right cerebral hemisphere and an unusual reliance upon it when processing information for the purposes of learning, are key

characteristics of the mathematically gifted brain. In addition, the ability to switch (and adjust) activation levels in an orchestrated and coordinated manner between the left and right hemispheres when processing new information, may be a unique characteristic of gifted brain functioning. Interestingly, in a recent *Nature* paper, Canadian researchers (Witelson, et al., 1999) have examined the brain of Albert Einstein and found that his brain was characterised by enhanced development of the parietal lobes, particularly in the right cerebral hemisphere. This, by the way, is the very area that has been implicated in my research as being related to mathematical precocity in these gifted adolescents.

Supporting evidence for such theorising has come primarily from electrophysiological data collected in my lab via the electroencephalogram (EEG). The latter is used to monitor brain wave activity in gifted subjects when performing a variety of mental tasks (e.g., mental rotation, chimeric face processing, visually matching circles to arcs, etc.). My future projects, however, will investigate underlying brain morphology and functional organisation in the mathematically gifted using far more sophisticated and state-of-the-art brain imaging techniques. Specifically, these studies will involve the use of functional magnetic imaging (FMRI) and positron emission tomography (PET) technology to investigate how brain structure and functional organisation relate to prodigious mathematical talent.

Dr Billy Tao and Professor Michael O'Boyle.

How Do They Do It? – Savants
A Savant Prime Number Calculator

Dr Mike Anderson

Prime numbers have a mystical quality that has intrigued us since at least the beginning of Greek Philosophy. Perhaps this makes it even more astonishing that a young man (Michael) with a very low measured IQ, and who can barely communicate, can recognise a prime number when he sees one.

How he recognises whether a number is, or is not, prime is certainly not through any mystical process. We have conducted a series of experiments that demonstrate that he recognises a prime number using a method first described by Eratosthenes – an astronomer in ancient Greece.

By comparing Michael's response times with those of mathematics students and using computer simulations we discovered that he divides a target number by every integer up to the square root of that number. If none of the integers divide leaving no remainder then he knows that the target number is prime. What we do not know is how he came to discover this method.

Many have wondered whether prime numbers have a transcendent quality that derives from the very physical structure of the universe itself, or on the contrary whether they are merely constructions of the human brain. Maybe this isn't an either or. Maybe both human brains and prime numbers reflect fundamental principles of the physical universe. And maybe this can be seen most clearly in this extraordinary case.

Education – Help or Hindrance? Perspectives from a Psychological Theory of Intelligence

Dr Mike Anderson

In my presentation I will argue that a viable theory of human intelligence provides some hypotheses about whether geniuses and prodigies are born or made and what role, if any, education should have in the fostering of talent.

What we know about the likely cause of savant skills indicates the central role of general intelligence in fostering genius, for there are no savant geniuses. True genius probably requires an inborn talent that arises largely through a rare assortment of genes. Eminence on the other hand is likely to be a product of an interaction between high intelligence, personality and circumstance. Real genius is likely to be relatively immune from educational intervention. The development of talent, on the other hand, may be best accomplished when children are taught alongside peers of similar abilities.

How Do They Do It? – Savants

Professor John Mitchell

Professor Snyder and I have a theory. How do we come to such a strange theory when there are probably more obvious theories suggested by mainstream psychology? We came at it from an unusual angle, we didn't come at it from studying savants, we came at it from the vision side of things. We were interested in how the visual system worked. We were interested in such questions as why do we have colour vision, why do we have optical illusions and so forth.

And so for us the interesting question was not why a mentally retarded three-year-old could draw like Leonardo Da Vinci but why the rest of us couldn't. And the conclusion that we came to was that we are not normally interested in the details of the pictures we see. We're interested in identifying objects and deciding how to respond to them. We had a pixel map of what's out there in our brain and if we were conscious of it, we should have little trouble drawing out that pixel map on a piece of paper but we don't do that for the reasons just outlined. For example, if you see your friend, you recognise him straight away. You don't look and say "he's got grey hair, blue eyes, big nose and moustache, that must be John", you just recognise him straight away.

Then it came as a bit of a surprise to find that a supposedly mentally retarded three-year-old girl could draw so well. But of course, we learned that she was autistic and this meant that she is somehow conceptually deficient.

She didn't think in terms of concepts like we do so maybe she can get access to these details and reproduce them readily.

So this led us to put forward this bold hypothesis that maybe all savant abilities came about in this particular way. I think we do tend to have a bit of a distorted idea as to what is genius. We thought for a long time that being able to play chess like a grand master was genius but we all know now that chess doesn't require intelligence. But we do not consider walking across a room without falling over to be genius because anyone can do that and we don't consider being able to recognise voices or to be able to understand language as genius. But these are extraordinary abilities, we're all walking geniuses. I don't think it is far fetched to say that perhaps, there are hidden facilities that don't normally manifest themselves because we are not really interested in identifying primes or multiplying numbers together. We are not normally interested in doing mathematics and we are not normally interested in drawing. We evolved for the purpose of identifying what's out there and responding – should we run away from it – should we chase after it. That's the way our brains evolved.

It seems to us that the simplest hypothesis for someone like Nadia was to simply suggest that for some reason, she has lost the ability or the desire or the interest in conceptualising and this somehow opens up access to other parts of the brain. There doesn't seem to be any reason until proven otherwise to suggest that she has some other part of the brain that is different to the rest of us.

Geniuses, Prodigies and Savants – A Teacher's Perspective

Lynne Kelly

The normal school, by definition and statistics, has mostly pretty normal ability children racing around its corridors. They will not meet a savant, but may, very occasionally, come across a prodigy or genius. Both are poorly defined terms, and we teachers can't sit around until the debate is done about what they are and what they need. So we can only do what we can with the information we have available today, and programme accordingly.

We use the term 'gifted' and acknowledge varying degrees of giftedness – the further from the norm being the profoundly gifted child – probably what is best described as genius. There is no homogeneous group of gifted children, and the idea that they can be grouped together for a single special program is outdated now. There is just too much variation between them. The key to dealing with such variation is recognising the abilities may not be consistent over subject domains. A profoundly gifted mathematician may be average in language skills. A gifted artistic child may not be so far ahead in mathematics. So they need to be placed according to their ability level in the different domains. This requires flexibility within the school timetable, so a child based in year 6, say, can do year 9 maths, but be in enriched year 6 for the rest.

Research, such as that by Prof. Michael O'Boyle and others, is indicating a different brain behaviour for prodigious mathematics students. This probably moves across all domains. They think and learn differently. This matches many of the instincts of teachers dealing with these kids. It is essential we move beyond just doing things faster into doing it faster and adding things which are different – curriculum material which enables them to use the different thinking patterns. For example, in mathematics, many children can calculate well and get the answers to problems they "know how to do" quickly. It is those who can visualise approaches to problems they don't "know how to do" who are the true mathematicians. It is those who pose further problems, to whom getting the right answer is only the first step in playing with the numbers, who challenge us to make sure there is work which encourages this skill.

While talking about skill, can I mention my other pet hate. The expression of superiority when the child "knows more than the teacher". Little Johnny (this poor kid has a lot to answer for) might be able to name every dinosaur since the Big Bang, but that is not what modern education is about. This is the information age – information is available at the touch of a finger or two to the keyboard. We teach the higher level skills (according to Benjamin Bloom); comprehension, application, analysis, synthesis and evaluation. The more able the child, the higher the proportion of the latter level skills. An individual program is needed, slotting in and out of the regular program as required, with the ability to move faster and to access material designated to these higher levels, problem posing, individualising, but with a framework. I believe trained educators are needed to develop such frameworks, knowing the future needs of the student in upper secondary and tertiary level.

But that takes time. Teachers have very little and expectations

on them are continually increasing. Very few schools can provide such specialisation yet, although the trend towards such provisions is definitely clear. I am very fortunate to have such a position at Methodist Ladies College in Melbourne, where programming for gifted students is my sole task. I work there part-time, and the rest is spent as Principal of the Virtual School for the Gifted, which provides such specialist courses into the normal school via the Internet. These children are different to the normal student and need different educational provisions. The bad news is, they are very different to each other, and the more gifted they are, the more individual their program needs to be.

Education: Help or Hindrance?

Trevor Clark

Among the underserved minority of gifted children with disabilities are a group of children referred to as autistic savants. These gifted children, despite suffering from often incapacitating disturbances in communication, social skills and intellectual development, often display remarkable gifts or splinter skills in one or several domains. They are possibly the least recognised, and potentially productive group of gifted underachievers.

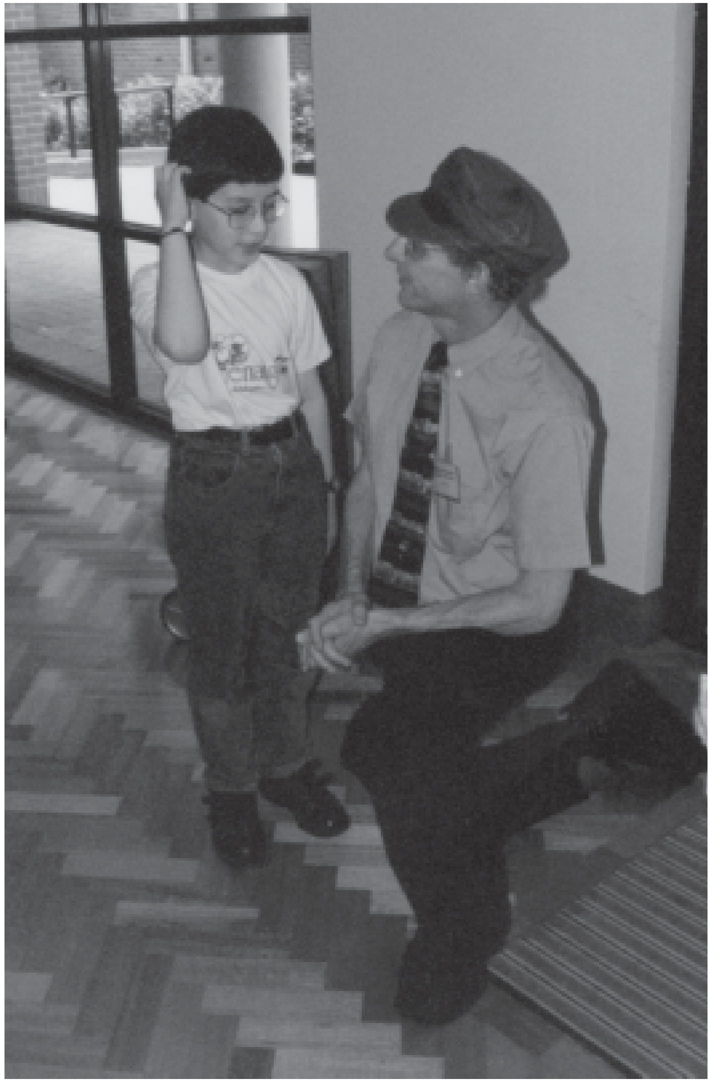
Savant gifts or splinter skills may be exhibited in the following skill areas or domains; memory, hyperlexia, art, music, mechanical or spatial skill, calendar calculation, mathematical calculation, sensory sensitivity, athletic performance, and computer ability. These skills may be remarkable in contrast with the disability of autism (Savant 1), or may be in fact prodigious when viewed in relation to the non-disabled person (Savant 2).

The often prodigious gifts or talents of the majority of autistic savants are exhibited in *obsessive or unproductive behaviours.* These skills appear to have *little meaning or functional application* and are often referred to as *anomalous talents or skills.* It is my view that education can assist the autistic savant to use his or her often anomalous savant skills to lead a more independent and functional life.

Under the supervision of Professor Miraca Gross, at the University of New South Wales, I am currently involved in a research project entitled, *The Application of Savant/Splinter*

Skills In The Autistic Population Through Curriculum Design. The project aims to *apply the often unproductive but prodigious savant skills in a functional and meaningful manner,* through the design and implementation of an educational curriculum. The curriculum incorporates several programme models currently in use in the education of both the gifted and the autistic child. The curriculum is based upon the savant skills or gifts, on the strength and interests of the students, and not on their deficits. The intrinsic motivation displayed by the savant whilst engaged in their areas of savant interests, is in essence being *borrowed* to help teach functional living skills.

Although it is important to increase our understanding and knowledge of savant syndrome, and how it is they are able to engage in often prodigious performances in certain skill domains, it is now time to assist the savant to make use of their savant skills, to increase their chances of leading more functional and rewarding lives. By doing so, we may in fact be able to reduce the impact of autism on the lives of these students with autism, who also display savant skills or gifts.



Genius + Madness: Is There a Connection?

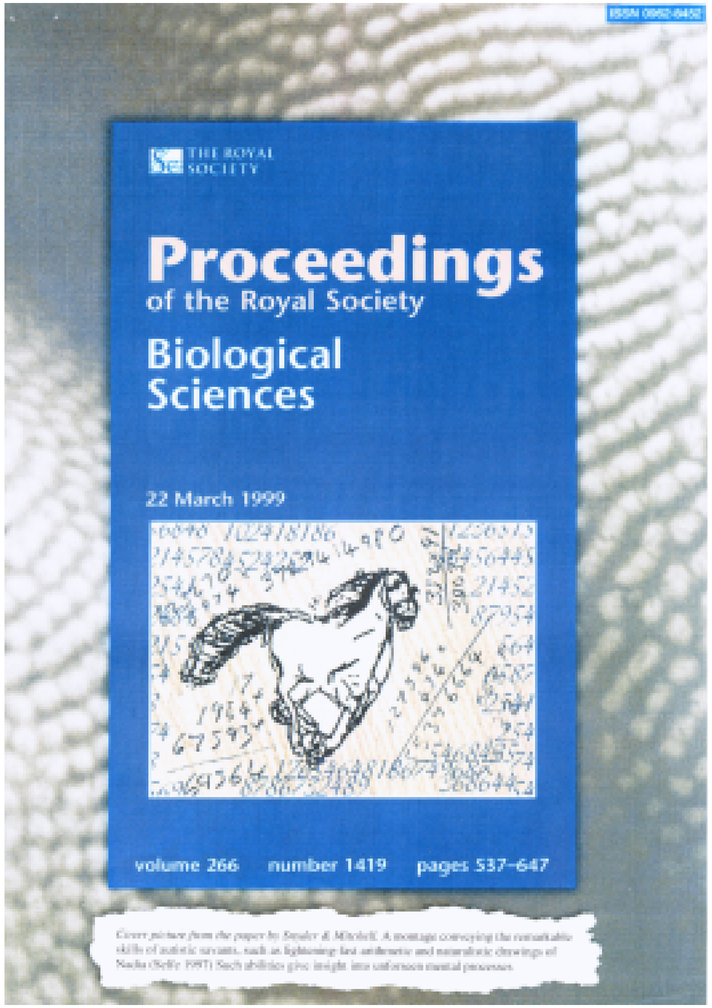
Professor Jack Pettigrew

The link between human creativity and bipolar disorder is well recognised, despite two symmetrical difficulties:- 1. measuring creativity in the present, when the bipolar diagnosis is more secure; 2. the difficulties of diagnosis in an historical genius whose creativity has stood the test of time. I would like to try to go beyond the obvious link between creative output and the hypomanic state to suggest a role for two other universal mental traits that seem to be quantitatively altered in bipolar subjects:- neural clocks that govern switch rates and intraneuronal signalling pathways. One neural rhythm, interhemispheric switch rate, varies by two orders of magnitude in the general population but is slower in bipolar subjects.

Slower interhemispheric switching would provide greater divergence in the complementary 'points of view' adopted successively by each hemisphere and therefore a greater creative clash when they 'meet' (note that I think that both hemispheres are involved in the creative process, not just the right as popular writings have it).

Intracellular signalling pathways have greater amplification in bipolar brains. While there is no available data on a possible link between clock rate and intraneuronal signal amplification, I predict a correlation based on the likelihood that gene products used to make the clock (e.g. ion channels) will also be used elsewhere in other parts of the brain. Sensitivity to external stimuli of all kinds is of obvious relevance to creativity, since creation of new thought patterns has to precede their selection and execution.

Professor Jack Pettigrew - speaking of his personal journey and scientific enquiry about bi-polar disorder.



The following text is the cover story from the prestigious scientific journal, *Proceedings of the Royal Society*, London. Professors Snyder and Mitchell's paper created enormous interest world-wide on the mind's secret powers. Media coverage ranged from *The Times* of London to the Russian popular press, plus radio, TV and documentaries. This research was also the impetus for the *Geniuses, Prodigies and Savants* conference.

Is Integer Arithmetic Fundamental to Mental Processing?: The Mind's Secret Arithmetic

Professor Allan Snyder and Professor John Mitchell

Unlike the ability to acquire our native language, we struggle to learn multiplication and division. It may then come as a surprise that the mental machinery for performing lightning fast integer arithmetic calculations could be within us all even though it can not be readily accessed, nor do we have any idea of its primary function. We are led to this provocative hypothesis by analysing the extraordinary skills of autistic savants. In our view such individuals have privileged access to lower levels of information not normally available through introspection.

1. Introduction

We are largely unaware of the ways in which our brains process information. For example, we are not conscious that shape is computed from object shading or that perspective is derived (among various ways) by the gradient of texture (Hemholtz 1910, Snyder and Barlow 1988). And why should we be? It is the 'object' itself that is of ultimate interest rather than the manner in which we derive its label. Indeed, this specific example explains why it is so difficult to draw naturally occurring scenes, as has been elaborated elsewhere (Snyder and Barlow 1988, Snyder and Thomas 1997). Analogously, the foundations of our most fundamental beliefs, our mindsets, are not normally available for introspection. We are highly concept driven (Bartlett 1932; Snyder 1998). Presumably, this confers advantage by allowing us to operate

automatically. Essentially, a world of unconscious information is sifted through, by mechanisms of which we are unaware, to arrive at our final judgements. We might therefore be in for some genuine surprises if we had access to the mental processes used to construct our mindsets.

To gain insight into this fundamental problem we turn to a rare group of individuals, savants with early infantile autism, because they appear significantly less concept driven than normal individuals. Furthermore, this group has been a subject of scrutiny, so we can borrow from comprehensive empirical studies and much theoretical discussion (Kanner 1943; Asperger 1944; Frith 1989; Treffert 1989; Baron-Cohen 1994) in order to build a framework from which predictions can be made about unconscious mental processes. This leads to our hypothesis that the mental machinery for performing lightning fast integer arithmetic (lengthy multiplication, division, factorization and prime identification) is within us all, although it can not normally be accessed, nor do we know what primary function it serves.

2. Savants - minds with privileged access to lower levels of information?

Building on the pioneering work of Kanner 1943, Asperger 1944, Frith 1989, O'Connor 1989 and Hermelin and O'Connor 1990, we surmise that children with early infantile autism give insight into a mind with limited mindsets, a mind that is not concept driven (Snyder and Thomas 1997; Snyder 1998). In our view such a mind can tap into lower level details not readily available to introspection by normal individuals. This is consistent with the constellation of traits associated with early infantile autism, especially those of savants (Hill 1978;

Treffert 1989; O'Connor 1989; Howe 1989; Nettlebeck and Young in press) who seem to be aware of information in some raw or interim state prior to it being formed into the 'ultimate picture'. For example, it explains (Snyder and Thomas 1997) how it is that Nadia (Selfe 1977), a mentally retarded three and a half year old, can draw natural scenes like that of Fig. 1 from memory, with astonishing life-like perspective and to do so 'spontaneously' without any training or without even passing through the usual scribble stage.

Now, it is a surprising fact that normal individuals cannot draw naturalistic scenes unless they are taught the tricks and schema to do so (Gombrich 1960). The reason why this is so unexpected is that our brains obviously possess all of the necessary visual information required to draw, but we are apparently unable to access it for the purpose of drawing. For example, our brain performs the calculations necessary to label three-dimensional objects. Yet the difficulties of drawing even a simple sphere are legion. We are not consciously aware of how our brains derive shape from shading, perspective from gradients of texture, size invariance with distance and so on.

Fig 1 Autistic child's drawing at about three and a half years (Selfe 1977).

Clearly, it is the object label or symbolic identification that is of ultimate importance and not the actual attributes processed by the brain to formulate the label (Snyder and Barlow 1988). Indeed, normal preschool children draw, not so much what they see, but rather from what can be called their mental schema. And, these schema, like those of Fig. 2, tend to be invariant across cultures. The horse is conventionally drawn side-on, head to the left, and in bold outline form as is typical of late preschool art. Somehow, the autistic savant Nadia can directly tap the way in which our brain derives perspective, whereas normal individuals can not. Yet these autistic savant artists often struggle to recognise familiar faces (Selfe 1977).

So we believe that artistic savants have direct access to 'lower' levels of neural information prior to it being integrated into the holistic picture - the ultimate label. All of us possess this same 'lower' level information, but we can not normally access it. Ramachandran (1998 p. 287) in his remarkable new book enriches this possibility by suggesting neurobiological mechanisms.

In our opinion, all savant skills can be explained as analogous to those of drawing (Snyder, 1998). Put simply, savants have privileged access to lower levels of 'raw' information. Take the ability of perfect pitch as an example. Our mechanism for hearing consists of discrete frequency analysers which allow for the possibility of perfect pitch. But, surprisingly only one in 10,000 persons possess absolute pitch (Profita and Bidder 1988) and it is debatable whether or not absolute pitch can be taught (Takeuchi and Hulse 1993). So, in analogy to our discussion above on vision, it is the holistic information content that is important for hearing and not the component attributes from which this is derived (Miller 1989;

Heaton, Hermelin and Pring 1998). Yet, all musical savants possess absolute pitch (Miller 1989). They apparently have access to lower levels of auditory information while we do not.

These and other savant skills (Treffert 1989; Rimland and Fein 1988), including the extraordinary ability to recall seemingly meaningless detail as opposed to recall of concepts, unusual sensory discrimination of smell and touch, and even time keeping abilities, reinforce our view that savants are able to tap something that is in us all, but which is not normally accessible. And this is consistent with numerous observations as captured by O'Connor's (1989, page 4) statements that their "gift springs so to speak from the ground, unbidden, apparently untrained and at the age of somewhere between 5 and 8 years of age. There is often no family history of the talent" and it "is apparently not improved by practice." Also, the talents are "chiefly in the direction of imitation and there is little capacity for originality or for creativity" (Treffert 1989, page 9).

Fig 2 Representative drawings of normal children, each at age four years and two months. (Emma and Teneal, Parents on Campus Preschool, Australian National University).

To our knowledge no *young* savant (when the skill first emerges) has ever given any insight into the methods used, nor can they learn or be taught. With maturity the occasionally offered insights are suspect, possibly being contaminated by expectations or the acquisition of concepts concerning the particular skill. Furthermore, savant skills often recede or are lost altogether with the onset of maturity (Selfe, 1977; Treffert 1989; Barnes and Earnshaw 1995).

All of this suggests that the unusual skills of savants can be used as a diagnostic tool to probe information from lower level mechanisms which are not available to introspection of the normal mind. But, the savant has not revealed unknown or unexpected mechanisms in the case of drawing or perfect pitch. The physics of natural scenes already tells us how perspective must be computed by the brain and discrete frequency analysers are already known to be the primary auditory receptors. Nor, in this vein, should the savants' astonishing feats of recall for detail reveal anything new about mental processing, since much evidence supports the view that we all store an enormous amount of information, with only a minute subset available for recall (Treffert 1989, Penfield and Roberts 1966). Indeed, our recall like our drawing skills appear to be concept oriented (Bartlet 1932).

So the extraordinary drawing skills of savants, their astonishing recall of detail and their ability of perfect pitch do not reveal unexpected mental processing. We all have the same raw information but just can not directly access it, at least on call. But what does the existence of savant lightning calculators tell us about mental processing in the normal mind?

3. Savant lightning calculators

Because normal children struggle to learn multiplication and division, it is surprising that some savants perform integer arithmetic calculations mentally at ‘lightning’ speeds (Treffert 1989, Myers 1903, Hill 1978, Smith 1983, Sacks 1985, Hermelin and O'Connor 1990, Welling 1994, Sullivan 1992). They do so unconsciously, without any apparent training, typically without being able to report on their methods, and often at an age when the normal child is struggling with elementary arithmetic concepts (O'Connor 1989). Examples include multiplying, factoring, dividing and identifying primes of six (and more) digits in a matter of seconds as well as specifying the number of objects (more than one hundred) at a glance. For example, one savant (Hill 1978) could give the cube root of a six figure number in 5 seconds and he could double 8,388,628 twenty four times to obtain 140,737,488,355,328 in several seconds. Joseph (Sullivan 1992), the inspiration for the film *Rain Man* about an autistic savant, could spontaneously answer "what number times what number gives 1234567890" by stating "9 times 137,174,210". Sacks (1985) observed autistic twins who could exchange prime numbers in excess of eight figures, possibly even 20 figures, and who could ‘see’ the number of many objects at a glance. When a box of 111 matches fell to the floor the twins cried out 111 and 37, 37, 37. Similar skills were reported as early as 1801 about a child named Dase, who was also "singularly devoid of mathematical insight" and of low general intelligence (Treffert 1989, Myers 1903).

4. Is integer arithmetic fundamental to mental processing?

If, as we believe, all savant skills have a common origin, then the skill for integer arithmetic, (like that for drawing, perfect

pitch, and recall for meaningless detail), arises from an ability to access some mental process which is common to us all, but which is not readily accessible by normal individuals.

From this reasoning, we believe that everyone has the underlying facility for performing lightning fast integer arithmetic. This facility can not normally be tapped for the purpose of arithmetic nor do we have any idea of its primary function. Rather, we must learn arithmetic the way we learn to draw naturalistic scenes, by implementing tricks and algorithms (Gombrich 1960; Snyder and Barlow 1988; Snyder and Thomas 1997). Learning arithmetic is hard work for normal individuals (Dehaene 1997), whereas it seems effortless for mathematical savants. Why this should be is deeply mysterious.

As with drawing, tricks and algorithms can be learned for doing rapid arithmetic, but some savant lightning calculators vastly out-perform those who adopt these methods, both in speed (Hermelin and O'Connor 1990) and complexity (Sacks 1985; Waterhouse 1988). For example, in a pioneering empirical study, a mathematics graduate trained in the appropriate algorithms took 11.46 seconds to generate all the primes between integers 301 and 393 whereas a non-verbal autistic young man who had not previously confronted such a task took only 1.16 seconds (Hermelin and O'Connor 1990). Not only was the savant ten times faster, but he also made far fewer errors. Importantly, no practically realisable algorithm has yet been invented for rapidly identifying primes in excess of 8 figures as apparently performed by the autistic savant twins (Sacks 1985).

It would be interesting to compare the active (functional) brain images of autistic savant calculators with those of individuals who calculate via learned algorithms. We might anticipate significant differences between the two, possibly analogous to those between native and second language performance as recently observed by Hirsch's groups (Kim, Relkin, Lee and Hirsch 1997). Our native language is acquired unconsciously, whereas second language acquisition is hard work. Accordingly, the arithmetic ability of autistic savants could be functionally like that of a native language whereas it is expected to be more like a second language in most of us.

5. What is required for arithmetic calculations?

Apart from learning the nomenclature or the symbolic representation of numbers, integer arithmetic is simply the ability to separate groups into an equal number of elements - that is to equipartition. For example, 12 elements can be represented as two equal groups of 6 elements or 4 equal groups of 3 elements. Equipartitioning may also be pertinent to another common skill of autistic savants - calendar calculating - where the day of the week is given upon being presented with any date, say 1000 years in the past or future (Sacks 1985; Hermelin and O'Connor 1986; Treffert 1989; Young, R.L. and Nettlebeck, T. 1994). **We surmise from this that equipartitioning is fundamental to some yet unknown aspect of mental processing.** It is intriguing to contemplate which aspect, analytical or perceptual.

The actual method of calculation, while intriguing, is not central to our thesis. Rather, our hypothesis rests on the very existence of an ability to do lightning calculations without training. Perhaps mathematical savants tap a mental process which spatially represents groups and patterns (Welling 1994)

and equipartitions them analogous to the mathematical procedure of factorising. This could also explain why primes to mathematical savants are the odd man out in groups of numbers and are reacted to as if they are very peculiar indeed (Hermelin and O'Connor 1990). Others have suggested the possibility of savants using modular arithmetic (Sacks 1985; Steward 1975).

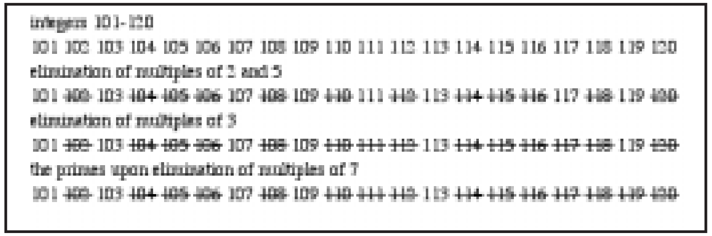


Fig 3 Generating primes: to determine whether it is has any factors other than 1 or itself. We need only consider prime factors less than the square root of the number. There are well known tricks for rapidly determining whether a number is divisible by 2, 3, 5 or 11, but in general it is necessary to divide by each prime. However if we are testing a sequence of consecutive numbers it is not necessary to test every number separately by dividing by each prime. Once you have determined that a number is divisible by 7 then you know every 7'th number thereafter is divisible by 7 . This gives us an alternative way to find primes, one known in antiquity, that does not explicitly involve division. Above we have adapted this ancient method to find the primes in the range 101-120 (row 1). First we eliminate the even numbers and numbers ending in 5 (row 2). Dividing 101 by 3 leaves a remainder of 2, revealing 102 as the first multiple of 3. We then eliminate every third number starting with 102 (row 3). Finally, dividing 101 by 7 leaves a remainder of 3, revealing 105 as the first multiple of 7. We then eliminate every seventh number starting with 105 (row 4). Since we need only consider prime factors less than the square root of 121 equals 11, the remaining numbers are all prime.

Memory and algorithms (learned or induced) are known to play a crucial role in the techniques employed by lightning calculators from the normal population (Smith 1983; Dehaene 1997). But the beautiful work of Anderson, O'Connor and Hermelin (in press) has ruled out the role of memory for savant calculators. They also found that the performance profile of the savant calculator closely matched that of the control who was using the Eratosthenes algorithm for identifying primes as suggested earlier by Hermelin and O'Connor (1990). But it remains possible that other strategies for finding primes (see Fig. 3), not all of which need be arithmetic, could also have similar performance profiles. Whatever the case, this suggests that savant calculators have privileged access to some form of algorithmic mental processing.

6. Music and number

Some autistic savants have the ability to keep time for extended periods with accuracy to the second (Treffert 1989). Apparently, our internal clocks are more precise than might have been imagined. For example, when one autistic child was awakened he said, "It's 2.14 AM", then he went back to sleep (Rimland and Fein 1988, p 485). This ability to equipartition time could also contribute to the impressive musical skills of many autistic savants (Treffert 1989, Hill 1978; Miller 1989) and, when coupled with equipartitioning of space, could suggest a mechanism which interrelates music and mathematics.

There no doubt are other surprises that can be revealed by those ‘abnormal’ minds which are somehow aware of interim mental processes and information not normally available through introspection. For example, is it possible that the

senses of normal individuals are mixed and accessible for comparison in a way that individuals with synaesthesia (Luria 1987; Cytovic and Wood 1982) might suggest?

7. Discussion

As Howe (1989, p. 83) so aptly puts it, “We experience only ‘the whole’: it takes the evidence provided by unusual people in whom mental integration is incomplete owing to retardation, brain damage, or some other kind of mental ‘disturbance’ to make us appreciate how smooth functioning of a person’s total mental system depends on the parts, or subsystems, that underlie it.” This philosophy underpins our present investigation. In particular, we believe that savants offer a window into ‘lower’ level information used to construct our percepts and our judgements. From this we have argued that some mental processing exists in us all, for purposes yet unknown, which is recruited by autistic lightning calculators to perform precise integer arithmetic calculations, such as multiplication, division, factoring and identifying primes.

This highly quantitative numerical ability of autistic lightning calculators is in sharp contrast with the well known qualitative sense of numerosity displayed by human babies and even animals (Gallistel and Gelman 1992; Gallistel 1990; Wynn 1992; Wynn 1995; Dehaene 1997). For example, babies and animals can estimate the number of objects in a collection with an error that is proportional to the number itself. This turns out to be accurate for perceiving and estimating 1, 2 or 3 objects but is grossly inaccurate for judging large numbers. As Dehaene 1997 (p 119) concludes in his authoritative overview, "An innate sense of approximate numerical quan tities may well be imbedded in our genes; but when faced with exact symbolic calculation we lack the resources".

Our paper is concerned with mathematical savants. Now, savants are far more prevalent in the autistic population than in any other group and also it is among this group where multiple savant skills most frequently occur (Rimland and Fein 1988; Triffert 1989). But, only a small fraction of the total autistic population are savants. And, this fraction tends to be predominately composed of those with early infantile autism (Treffert 1989), a condition first described by Kanner (1943). Our theoretical perspective is derived from savants in this category, although it could apply to savants in general. We believe that savants with early infantile autism have privileged access to lower levels of information and that they are impoverished in concept formation, compared with the general autistic population (Charman and Baron-Cohen 1993). With maturity certain concepts can be acquired, but often at the loss or reduction of their savant skills (Selfe 1977; Smith 1983).

It is worth mentioning, as have mathematicians of acclaim (Hadamard 1949), that savant lightning calculations are idiosyncratic and not representative of what would normally be considered a mathematical talent. Mathematicians are primarily concerned with the conceptual, whereas autistic savants have extreme difficulty with learning even the simplest mathematical concepts. In this regard it is interesting that Baron-Cohen and his colleagues (1997) have recently found that fathers and grandfathers of children with autism were more than twice as often in the field of engineering than were fathers and grandfathers of normal children. Similarly, they found that autism occurred significantly more often in

families of students in the field of physics, engineering and mathematics (Baron-Cohen et al. 1998). Although these studies address the general autistic population and are not restricted to savants, they are nonetheless fascinating and deserve further investigation.

Prevalent explanations for savant skills: Mathematical savants have fascinated their investigators through the centuries (Smith 1985, Treffert 1989) so it should be of no surprise that various theories have been advanced to explain the phenomenon. These are discussed in depth elsewhere (Treffert 1989; Nettelbeck and Young in press). We critique the conceptual thrust of the most prominent views so that they can be contrasted with the perspective leading to our claim that integer arithmetic is fundamental to mental processing. Essentially there are two popular explanations for savant skills: one holds that obsessive focussed learning promotes savant skills just as it does for any expertise: the other postulates that genius and savants alike have highly developed domain specific neural structures (innate talent). In contrast, our view is that the mechanism for savant skills resides equally in us all but that (without some abnormality like autism) it can not normally be accessed for the skill in question.

Mathematical savants arise from obsessive learning: Many authors believe that the extraordinary feats of lightning calculators are a consequence of their passion and preoccupation for learning mathematics in much the same way it is for truly innovative mathematicians, see for example, e.g. Smith (1983) and Rimland and Fein (1988). Dehaene (1997, p. 164) especially presents a compelling discussion, concluding that, “A talent for calculation thus seems to arise more from precocious training, often accompanied by an exceptional or even pathological capacity to concentrate on the narrow domain of numbers, than from an innate gift". Howe (1989 p. 150) agrees, "The circumstances that give rise to a retarded savant's achievements are not entirely different from those in which a person of normal or above average intelligence chooses to specialize in a particular area of interest".

Savants have better brains for arithmetic: Another view holds that both genius and savant alike are endowed with exceptional domain specific neural structures (innate talent) which promote their specialized skills. This view also has a number of distinguished advocates. For example, O'Connor (1989, p. 19) says "But just as there are specialized centres mediating speech, so there may be centres for calculation, graphic skills or music. One can suffer deficits in these abilities so why not also have specific gifts!" Ramachandran (1998, p. 197) enriches the story further, speculating about savants, "that some specialized brain regions may have become enlarged at the expense of others", e.g. the angular gyrus for mathematical talent. Howe (1989, p. 153), also suggests that the savant artist Nadia and the man with the seemingly perfect memory, Shereskeskii, might fall into this category.

While the obsessive learning and the better brains theory for savant arithmetic may not be mutually exclusive (Hermelin and O'Connor 1990) and while they have their compelling aspects, we find them improbable for the following reasons: those who have protracted experience with savants frequently report that the core ability behind the skill emerges '**spontaneously**' and does not improve qualitatively with time even though it might become better articulated (O'Connor 1989; Selfe 1977; Treffert 1989). This argues against obsessive learning. Furthermore, from the perspective of either theory,

it would appear highly coincidental that such a peculiar subset of mathematics should be so compelling to a significant fraction of autistic savants across all cultures, and also that many of these same savants simultaneously have several savant skills (Rimland and Fein 1988) each of which are similarly peculiar and restricted. And why is there little or no invention or creative component in the skill? All of this mitigates against either obsessive learning or better brains being a plausible explanation for mathematical savants, as does the fact that savant skills can even arise after an accident or illness in otherwise normal individuals (Treffert 1989).

The mechanisms for savant mathematics reside equally in us all but can not normally be accessed: Now in contrast to the popular views discussed above, the unique aspect of our perspective is that the mechanism and information drawn on for savant mathematics **resides equally in us all** but it can not be recruited by us for mathematics. In other words, we believe that mathematical savants, like all autistic savants, arise from their privileged access to lower levels of raw information. Their skills are essentially a form of mimicry, and thus naturally lead to drawing, perfect pitch, time telling, astonishing recall, hyperlexia, echolalia, etc. Hence, the very same peculiar savant skills appear across different cultures. However, unlike drawing and perfect pitch, we do not know what lower levels are recruited for savant mathematical skills. But, we hypothesize that savant mathematics is propelled by some fundamental mechanism which equipartitions - possibly in both space and time. Why is it that savants have privileged access to lower levels of information? Perhaps it is promoted by a loss of those centres that control executive or integrative mechanisms as elaborated on by Treffert (1989) and also by Baron-Cohen (1995) in relation to the fact that individuals with autism lack a theory of mind. This in turn could leave savants less concept driven (Snyder and Thomas, 1997; Snyder 1998), or as Frith (1989) argues, lacking central coherence (Pring, Hermelin and Heavey 1995; Heaton, Hermelin and Pring 1998).

An intriguing question remains. Although we do not normally have access to the lower levels of information as do savants, is there nonetheless some artificial means to promote this access, say via induced altered states of consciousness? Possibly pertinent to this suggestion is the fact mentioned above that savant skills have been known to follow a severe physical illness, an operation, or a near drowning (Treffert 1989). This reinforces our belief that savant skills are innate in us all but are normally suppressed.

So in conclusion, we believe that the mental apparatus to perform 'lightning fast' integer arithmetic calculations such as multiplication and division resides in us all, even though it is not normally accessible. The brain appears to perform something tantamount to arithmetic calculations (or analogously equipartitioning) for some unknown aspect of mental processing. The challenge now is to unravel which aspect.

We appreciate the critical insights of Mike Anderson, Kirsty Galloway McLean, Ted Nettlebeck, Mandy Thomas and Robyn Young.

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The following text is drawn from the cover story of the popular *New Scientist* magazine (*www.newscientist.com*) on research from the Centre for the Mind. 'I'm a Genius' suggests that just switching off part of the brain may reveal superhuman skills. The article declares this research "startling".

Tune in, turn off

New Scientist, 9 October 1999

You too could have seemingly superhuman mental skills. All you have to do is switch off part of your brain. Sounds bizarre? Rita Carter investigates.

James can tell you the precise time – to the second – without looking at a clock. Jennifer can measure anything to within a fraction of an inch just by glancing at it. And Christopher can speak 24 languages – including a couple of his own devising. Amazing? Definitely. But unusual? Not necessarily. According to a controversial new theory you too can do these things. Or at least you could – if only you could just stop being so clever for a moment.

Christopher, James and Jennifer are autistic savants – people who score low on IQ tests and have severe difficulties in communicating and interacting with others but who nevertheless have seemingly superhuman competence in a specific area like music, art or maths. About one in ten autistic people have notable talents, but truly prodigious savants like Stephen Wiltshire, who can draw spectacularly detailed and accurate representations of buildings, or the lightning card-counting calculator played by Dustin Hoffman in the film *Rain Man* are very rare. There have probably only been about 100 people described as savants since the phenomenon was first identified a century ago and only about 25 are alive at the moment.

Such is our fascination with these people that nearly all of them are publicly known and celebrated, and many of their skills have been studied exhaustively. Yet there is still no

generally accepted understanding of how savants do whatever it is that they do. Theories range from enlargements of certain specialised brain regions to the simple ‘practice makes perfect’ – but none of them alone satisfactorily explains all the weird anomalies.

The latest contribution to the puzzle is startling because it proposes that savant skills – far from being unique – are possessed by everyone, and might even be unleashed with quite simple, existing technology.

The idea comes from psychologists Allan Snyder and D. John Mitchell from the Centre for the Mind at The Australian National University in Canberra. Essentially they think that savant skills are the manifestation of brain processes that happen within us all, all the time, but are usually speedily swamped by more sophisticated conceptual cognition. While this high-level stuff fills our consciousness, the savant-style information-crunching that the researchers suggest precedes it is relegated to the unconscious back rooms of the brain.

“It's not that savants are cleverer than the rest of us,” says Snyder, “it’s just that most of us go one step further in our brain processing – from detailed facts to meaningful concepts – and once we've done that we can’t go back.”

Snyder and Mitchell formulated their theory from analysis of many existing studies of savants – mainly mathematically gifted ones. Among the findings they rely on are brain-imaging experiments, which reveal the extent of unconscious processing that goes on before we ever become aware of perceptions, thoughts and feelings.

A visual image falling on the retina, for example, takes about a quarter of a second to pop up in a person's mind as a conscious perception. Before that moment, each element of the image – including its colour, shape, movement and location – is identified separately by various specialised regions in the brain. These components are then assembled into a pattern which is shunted onwards to regions that attach meaning to it. Normally we have no idea that all this is happening – we only become conscious of it after the detailed processing is complete and we have a fully constructed perception.

"What matters for survival is that we have a concept we can work on – it's a face and it's friendly, say – not a mass of detail about how we arrived at that conclusion," says Snyder. "So in normal people the brain takes in every tiny detail, processes it, then edits out most of the information leaving a single useful idea which becomes conscious." Taking these ideas a step further, he asserts: "In savants the suppression doesn't happen so they see the picture in fantastically detailed components, like individual pixels in a photograph."

Using the same reasoning, Snyder believes that if, for example, you were asked to calculate the day of the week on which any particular date falls (an obsession peculiar to savants) or to discern the precise pitch, length and sequence of notes in a musical score, you would do it, more or less instantly, in your unconscious mind. But because knowing what day of the week 1 September 2056 would be is of no practical use, he thinks the information would be edited out before it passed into consciousness. Equally, because notes in isolation usually carry little meaning you would tend to hear the music as a melody rather than as separate sounds.

If Snyder and Mitchell are correct in supposing that savant cognition is happening in us all, is it possible that we could learn to shift our consciousness back a gear and become aware of it? Niels Birbaumer of the Institute of Behavioural Neurobiology at the University of Tübingen, in Germany, an enthusiastic supporter of Snyder and Mitchell's theory, believes we could. Birbaumer recently led a team that fitted paralysed patients with scalp electrodes that picked up signals from the brain and translated them into movement of a computer cursor. The patients first had to learn to control brain activity that was normally unconscious (*New Scientist*, 16 January, p 4). Birbaumer thinks it would be possible to access pre-conscious savant cognitive processes in much the same way – and that some people have already learnt to do so, without even realising what they were doing.

Accessing the subconscious

He cites, for example, a non-autistic student whose calculating skills rival those of the best mathematical savants. Electrical monitoring of the student's brain waves while he was doing a calculation showed that his brain was more active than usual at the start but less active just before he answered (*Psychophysiology*, vol 33, p 522). "Later cognition involves more cortical activity and is associated with conceptual thinking," says Birbaumer. "This student seems to be able to prevent this activity from occurring when he is calculating – leaving him free to access the earlier low-level processes."

Other researchers in the field – though expressing polite interest in Snyder and Mitchell's theory – remain sceptical that we all have latent savant skills. The most commonly favoured explanation for savant talents is that they are 'islands' of highly developed ability, probably linked to physically enlarged specialist brain regions. In most people the development of such skills is held back because the brain's resources are focused from an early age on conceptual thinking and what is known as 'global processing' – pulling together various thoughts and perceptions and extracting meaning from the overall picture rather than concentrating on the concrete details of each perception.

Autistic people seem to be unable to process things in this way. The result is a detailed but incoherent cognitive style described by autism experts Uta Frith from the Institute of Cognitive Neuroscience at University College London, and Francesca Happé, senior scientist at the Institute of Psychiatry, also in London, as "weak central coherence". Their idea is different from Snyder and Mitchell's because they assume that savant processing never happens in non-autistic people – consciously or unconsciously. They believe the drive towards central coherence is so strong that it sweeps perceptions and thoughts into meaningful concepts before every tiny detail of them is registered, so we wouldn't be able to access this information.

Happé explains: "If you were able to look inside the brain of an autistic savant I think you would find that their talent arises from very specific and circumscribed brain areas which are neurologically isolated from the areas which bind things together to make concepts. This allows the areas dedicated to savant abilities to develop without interference from parts of the brain which deal with concepts. As a result they may turn into large specialised brain areas like those that normal people have for speech."

The idea that unusually enlarged brain regions may create exceptional artistic, mathematical or musical skills in the people who possess them took an interesting turn recently. An anatomical study of Einstein's carefully preserved brain showed the area associated with maths was bigger than normal and not dissected by the usual groove. Grooves often mark the boundaries of functional brain areas, so it's fascinating to toy with the notion that the mathematical 'module' in his brain had annexed neurons from an area next door that would normally do something else.

The trouble with the big brain hypothesis is that anyone's brain will enlarge or get denser in an area that is constantly active, so it is hard to know if an enlarged module is the cause or result of a particular skill.

Vilayanur Ramachandran, Director of the Center for Brain and Cognition at the University of California, San Diego, has charted neuronal hijacking in cases of 'phantom limbs' – when amputees continue to feel their lost body parts because the brain regions that once gathered sensory signals from the limb are drawn into the regions monitoring neighbouring body parts. He thinks something similar might explain the astounding quality of savant cognition. "Maybe when the brain, or a bit of it, reaches a critical mass new and unforeseen properties emerge," he speculates. "So a doubling of neurons wouldn't produce a doubling of talent but a hundred-fold increase."

A simpler explanation comes from Michael Howe, a psychologist at Exeter University who has studied both autistic and non-autistic people with exceptional skills and believes that constant practice is generally enough to account for both types of talent. “Savants seem to just ‘see’ things effortlessly,” he says, “but I think if a non-autistic chess player who has been immersed in the game for thirty or forty years looks at a game in progress they just ‘see’ the position and the best moves in a similar way.” He adds: “The main difference between experts and savants is that savants do things which most of us couldn’t be bothered to get good at.”

Not just practice

Howe admits, though, that mere practice cannot account for the abilities shown by very young savants, simply because they have not had time to hone their skills. One celebrated artistic savant, named Nadia, drew stunningly animated pictures of prancing horses in perfect proportion and perspective from the age of three. She did not seem to learn the skill. Unlike normal children, who go through very specific stages as they develop drawing ability, such as putting huge heads on people and showing limbs as sticks, Nadia was drawing brilliantly from the moment she could grasp a pencil. And there are children who can do the amazing day of the week calculations, who have not yet learnt to divide and have developed the skill without adult help.

It may be that all very young children perceive the world in a savant-like way. One incredible skill shown by children is language acquisition. Eight-month-old babies seem to carry out fantastic calculations in order to work out where word boundaries fall in a stream of speech (*New Scientist*, 21 August, p 36). They do not consciously work it out. They simply learn to ‘know’ when a word begins and ends, just as a mathematical savant may say they just ‘know’ the square root

of a six-figure number. Adults, by contrast, have to labour over learning these patterns in a new language; simply immersing themselves in it is usually not enough.

Similarly some researchers believe that perfect pitch – a skill common in musical savants – is easily acquired by children but rarely develops in adulthood. And eidetic memory – the automatic perception, storage and retrieval of visual images in photographic detail – is far more common in children than in adults.

Savant-like skills may be lost – or hidden, according to Snyder and Mitchell's theory – in non-autistic people as they grow up because of a shift in the way we process information. Imaging studies show that brain activity in newborn babies is limited to regions we are unconscious of in adults but which register incoming sensory information and respond to it by generating urges, emotions and automatic behaviour. The cerebral cortex – the area associated with conscious thought and perception – becomes active within a few months, however, and as the child grows up an increasing proportion of information processing is done cortically. This shift accelerates in non-autistic children around the age of eighteen months, when they start to babble, and language acquisition may help to ‘kick-start’ activity in the frontal cortex where conceptual processing is mainly carried out.

In autistic children this shift appears to be slowed or incomplete and so their savant-like processing style may be preserved. Autistic savants who do seem to make the change, albeit belatedly, may thus lose their abilities. Nadia, for example, lost much of her prodigious talent when she finally mastered language around the age of 12.

Language development also seems to bring about the dominance of one hemisphere of the brain. In right-handers this is nearly always the left hemisphere, where the main language regions develop, but in left-handers language may occupy the right brain. Many researchers argue that savant skills tend to be those which are associated more with the right hemisphere: music, identifying mathematical patterns and art, for example, rather than skills that are predominantly associated with the left-hemisphere. Even the rare savants who have amazing word power, like Christopher, tend to be less interested in reading or the meaning of words, and more interested in skills like translation. Because of this, many have suggested that savant skills are produced by a dominant right hemisphere which has flourished in the absence of effective communication with or inhibition by the left.

Held back

"Autistic people often show both structural and functional dysfunction in the left hemisphere," says Wisconsin psychiatrist Darold Treffert, author of a book called *Extraordinary People: Understanding Savant Syndrome*, back in 1989. "Most cases are probably due to some prenatal interference with brain development which prevents normal development of the cortex and left hemisphere," he says. "Testosterone, for example, is known to inhibit left-hemisphere development and in male fetuses temporary slowing of the left hemisphere may be a normal developmental stage. In autism that slowing may be protracted beyond normal, resulting in an overdeveloped right hemisphere and stunted growth on the left. This could explain why autism, and savant skills, are

about six times more common in males that in females."

His theory seems to be supported by a number of extraordinary cases in which normal people have suddenly developed savant-like abilities after left-sided brain injuries. One 9-year-old boy, for example, was transformed from an ordinary school-kid to a genius mechanic after part of his left hemisphere was destroyed by a bullet.

And Bruce Miller and co-workers at the University of California Los Angeles School of Medicine recently reported five patients who developed amazing drawing skills after dementia destroyed part of the left side of their brains (*Neurology*, vol 51, p 978). "One of our patients had spent his life changing car stereos and had never shown any interest at all in art," says Miller. "Then he developed dementia which destroyed neurons in the left frontotemporal cortex – an area which gives meaning to things – and suddenly he started to produce sensational images recalled from early childhood. It was as though the destruction of those brain cells took the brakes off some innate ability that had been suppressed all his life, and opened access to an amazing personal memory store he never knew he had."

As yet it isn't clear whose interpretation of these cases is correct, if indeed anyone's is, but Snyder thinks there might be a way to test it. He is planning an experiment in which, he hopes, the unconscious savant will be unleashed at the flick of a switch. Magnetic pulses can interfere with normal brain activity. If you time and position the surge just right, it can temporarily turn off activity in a particular region. Snyder's plan is to 'switch off' the conceptualising area. If his theory is correct, and if he can find the area, this should cause the normally pre-conscious savant skills to burst into consciousness.

"I'm thinking of trying it on myself first," says Snyder. "If I start to get crystal clear pictures of my childhood or a sudden knowledge of prime numbers I'll really know I'm onto something."

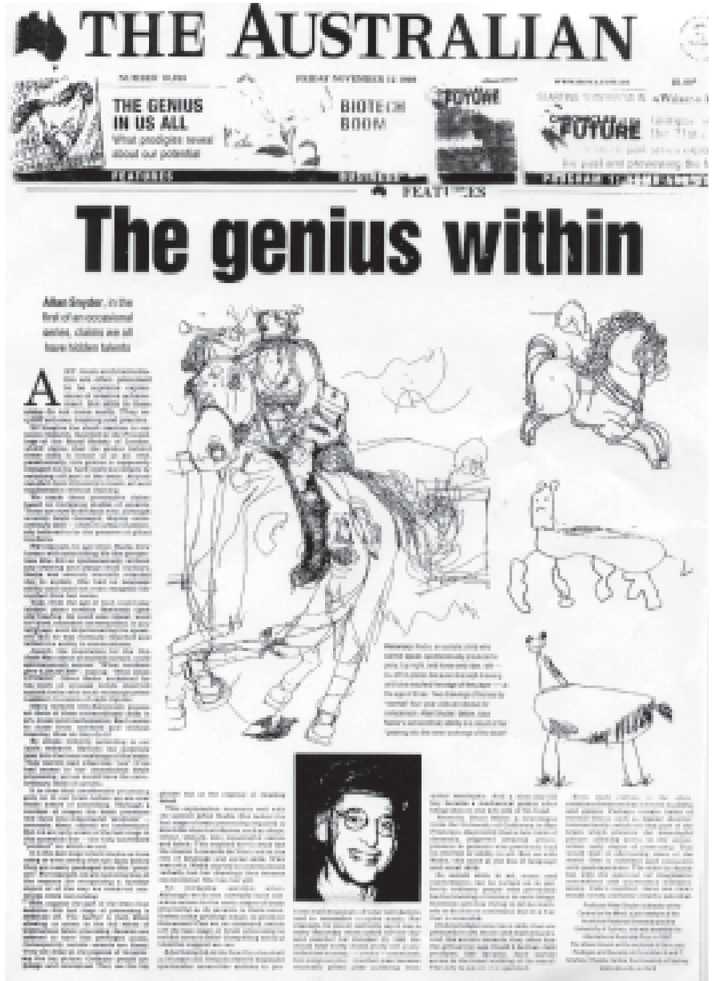
Rita Carter is author of *Mapping the Mind*, published in paperback by Seven Dials, price £14·99.

James and Jennifer are not the real names of the people described.

Further reading:

Extraordinary Minds by Howard Gardner, (Phoenix, 1998).

'Is integer arithmetic fundamental to mental processing? The mind's secret arithmetic' by Allan W. Snyder & D. John Mitchell, *Proceedings of the Royal Society* B, vol 266, p 587 (1999).


THE AUSTRALIAN

THE GENIUS IN US ALL

What prodigies reveal about our potential

BIOTECH BOOM

FUTURE

The genius within

Allan Snyder, in the first of an occasional series, claims we all have hidden talents

The following text is a popularised version of the article, published in the *Proceedings of the Royal Society*, London. 'The Genius Within' explores the secret powers of the mind. The article, by Professor Allan Snyder, appeared in *The Australian*, November 12, 1999, as part of his occasional 'Mindspace' column.

The Genius Within

Professor Allan Snyder

Art, music and mathematics are often presumed to be the supreme expressions of creative achievement. But, skills in these areas do not come easily. They require arduous training and practice.

So, imagine the shock reaction to our latest research, reported in the *Proceedings of the Royal Society* of London, which claims that the genius behind these skills is innate to us all! And, paradoxically, this genius is supposedly released, not by hard work, but simply by switching off part of the brain. Anyone can then have virtuosity in music, art and mathematics without training.

We made these provocative claims based on intriguing studies of savants. These are rare individuals who, although severely brain damaged, display extraordinary skill – often in areas traditionally believed to be the preserve of gifted intellects.

For example, by age three, Nadia drew horses with astonishing life-like perspective. She did so spontaneously, without any training and always from memory. Nadia was severely mentally retarded due to autism. She had no language ability and could not even recognise her mother from her nurse.

Tom, from the age of four, could play Mozart piano sonatas flawlessly upon one hearing. He could also repeat, word for word, extended conversations, in any language, even impersonating the speakers. But, he was mentally retarded and lacked the ability to communicate.

Joseph, the inspiration for the film *Rain Man* about an autistic savant, could spontaneously answer "What numbers give 1234567890?", stating "nine times 137174210". Oliver Sacks, acclaimed for his work on unusual minds, observed autistic twins who could exchange prime numbers in excess of eight figures.

Many savants simultaneously possess all three of these extraordinary skills in art, music and mathematics. Each seems to come from nowhere and without training. How do they do it?

By simple mimicry, according to our latest research. Savants can somehow peer into the inner workings of the brain. They merely copy what they 'see'. If we had access to our unconscious brain processing, we too would have the extraordinary skills of savants.

It is clear that considerable processing goes on in our brain before we are ever made aware of something. Through a number of stages, the brain processes raw facts into meaningful 'products' – concepts, ideas, objects we understand. But, we are only aware of the last stage in this assembly line – the fully assembled 'product' on which we act.

It is this last stage which blocks us from using or even seeing the raw facts before they are neatly packaged into this 'product'. For example, we are not conscious of the reasons for recognising a familiar object or of the way we construct sentences while conversing.

Now, suppose the part of the brain that executes this last stage of processing is switched off. The barrier is then lifted, allowing us access to the full riches of unconscious brain processing. Savants are believed to have this privileged access. Consequently, autistic savants are literal. They see detail at the expense of recognising the big picture. Ordinary people are holistic and conceptual. They see the big picture but at the expense of recalling detail.

This explanation resonates well with the autistic artist Nadia. She lacked the last stage of brain processing required to assemble object attributes, such as shape, colour, texture, into meaningful names and labels. This enabled her to draw like the master Leonardo da Vinci, but at the cost of language and social skills. With maturity, Nadia started to communicate verbally, but her drawings then became conventional. She lost her gift.

An intriguing question arises. Although we do not normally have conscious access to the early stages of brain processing as do savants, is there nonetheless some artificial means to promote this access? Can we, on command, switch off the last stage of brain processing to exhibit savant skills? Compelling medical histories suggest we can.

After being hit in the head by a baseball at ten years old, Orlando Serrell displayed spectacular savant-like abilities to perform mathematical calendar calculations and to remember complex music. For example, he would correctly say it was a rainy Saturday when asked for the day and weather for 23

October, 1982. He would hear every chord, every riff, every inflection in a rapper's voice – sometimes two songs at once. Another man became musically gifted after suffering from spinal meningitis. And, a nine-year-old boy became a mechanical genius after being shot on the left side of his head.

Recently Dr Bruce Miller, a neurologist from the University of California in San Francisco, discovered that a rare form of dementia triggered amazing artistic prowess in patients who previously had no interest or ability in art. But, as with Nadia, this came at the loss of language and social skills.

So, savant skills in art, music and mathematics can be turned on in perfectly ordinary people who previously had no training or interest in such things. Scientists are now trying to devise methods to do this on command, but in a way that is reversible.

Child prodigies also have skills that are primarily in art, music and mathematics. And, like autistic savants, they often lose this gift as they age. Could it be that child prodigies, like savants, have partial access to the inner working of the mind? The jury is out on this question.

Even more curious is the often mentioned relationship between madness and genius. Perhaps certain forms of mental illness, like bipolar disorder, intermittently switch off that part of the brain which presents the meaningful picture, allowing access to the unconscious early stages of processing. This would lead to alternating views of the world. One is coherent and consistent with past experience. The other is chaotic but with the potential for imaginative connections and unorthodox interpretations. Taken together, these two views would convey awesome creative potential.

Professor Allan Snyder is Director of the Centre for the Mind, a joint venture of the Australian National University and the University of Sydney, and was awarded the International Australia Prize in 1997.


THE WEEKEND AUSTRALIAN

FOCUS

Game, mindset and match

In the second of an occasional series, Allan Snyder says we are all innately prejudiced

The following text is from Professor Allan Snyder's occasional 'Mindspace' column in *The Australian*. 'Game, mindset and match' was published in the 4-5 December, 1999, *Weekend Australian*. The article explores the theme that we can only look at this world through our prior experiences.

Game, Mindset and Match

Professor Allan Snyder

Allan Snyder, in the second of an occasional series, says we are all innately prejudiced.

I want to confront a disturbing reality. One that no-one ever wishes to admit. We are all by nature prejudiced. We can only see this world through our mindsets – our preconceptions derived from past experiences and our prior knowledge. Put simply, it is extremely difficult to experience the world anew.

And, in my opinion, there is no escaping this condition. Our brains have craftily evolved this particular strategy for good reason. Mindsets are a biological necessity if we are to manoeuvre rapidly in important and familiar situations.

How can we ever become more receptive to novelty when our minds are subject to these powerful constraints? I say ride with the tide. Take on all the more mindsets. Because the more mindsets we imbue, the more different snapshots we have of this world. The lesson is clear. After mastering one situation, move on to master another.

Have you ever wondered why you can see meaningful pictures in what are obviously randomly formed cloud formations? And, why two people who look at the very same cloud often see completely different objects? The portrait painter sees a face of dignity while the ultrasound sonographer sees a diseased gall bladder. Clearly, our interpretation of the world depends on our frame of reference.

This somewhat apocryphal observation about cloud gazing lays bare a master plan of the mind. There is no definitive interpretation of the raw sensory information that bombards our senses. It would take an eternity for our brains to work through all the possibilities. But, we have no interest in all possibilities, only the most likely ones. So, we have evolved a rather cunning strategy for rapid decision making. We make assumptions about what is most likely. Our brains do this by constructing mindsets or mental images about what is familiar and important. These mindsets then act as templates through which we view this world.

Mindsets facilitate rapid decision-making. They are the building blocks for acquiring expertise. Skilled medical diagnosis is a classic case. A doctor automatically matches a constellation of symptoms to the most likely disease out of a finite number of known diseases.

The act of recognition is another example where mindsets facilitate expertise. We often have difficulty recalling faces. But it is effortless to recognise them, even when they are radically altered. When someone familiar to you shaves his heavy beard, you are often uncertain of what is different about him even though he has dramatically changed his appearance. In other words we are conscious of names and labels of things and not all the detailed reasons assembled for the label in the first instance. Mindsets allow for these short cuts in decision making.

But as a consequence of mindsets, we are vulnerable to prejudice in the form of illusions and assumptions. Put simply, there is a cost for adopting any strategy that accelerates our decision making process. Nothing can be seen within a neutral frame of reference.

Anyone who doubts this fact is reminded of the myriad of illusions, jokes and puzzles which capitalise on our prejudice from prior knowledge. For example, consider these two sentences:

The president is waiting for the boy's father before awarding the boy with a gold medal. Coincidentally, the boy is the president's son.

Now, this can only appear puzzling if we have a mindset that all presidents must be male. Few people are confused if the president is replaced by a nurse. Yet, everyone knows that there are female presidents and male nurses. But even so, our minds still jump to the most familiar possibility, instead of logically sifting through alternatives.

Many visual illusions operate in precisely the same way. Take the illustration on this page as an example. You see a square, but in reality no square exists. Why? Our mind has assumed that the most likely interpretation of this image is a square in front of four circular objects. So, we mentally extrapolate a fictitious square boundary to match our expectation.

This is but one of many assumptions we unconsciously use when interpreting our visual world. For example, all of us unconsciously assume that light comes from above. Bizarre illusions occur when objects are illuminated from below such

as concave surfaces appearing convex.

Powerful images distort our view about what is most likely. For example, airline crashes feature prominently in the news. They are great stuff for crystallising our mindsets about the horrors of flying. So, fear of flying prevails despite solid statistics that airlines are far safer than cars. Statistics are even ridiculed, as an old joke reveals:

If you are afraid of being on an aeroplane with a bomb, then you should always carry a bomb on the plane with you. After all, what is the probability of there being two bombs on the same aeroplane?

These examples should convince everyone that we experience this world through our mindsets, assumptions which are derived from our past experiences. This is the state of ordinary minds. Only a pathological mind sees the world unfiltered through prior knowledge. But this comes at the enormous price of being unable to cope with decision making. I have discussed such individuals in this column previously (12 November, 1999, page 15). For example, people with infantile autism observe the world without interpretation or expectation. Everything for them must be evaluated anew. Basically, they lack mindsets. So they compensate for this by repetitive and stereotyped behaviour.

Clearly, mindsets are a masterful strategy which allows us to operate automatically in familiar situations. But, they come at the unavoidable cost of prejudice. We only see a filtered version of the world. What then is my suggestion for seeing more and thus becoming more open-minded and creative?

Obviously, it is to take on more mindsets. Because the more mindsets we imbue, the more different views we have of the world. So, after mastering one situation, it is best to go on and master another. The rabbit-duck drawing on this page serves as an illustrative example.

If we only know about ducks, then we only see a duck when looking at this drawing. And, if we only know about rabbits, then we only see a rabbit. But, familiarity with both rabbits and ducks gives us the luxury of having two interpretations. My suggestion that creativity is facilitated by having an enormous repertoire of mindsets complements the opinion of the brilliant historian of ideas, Jacob Bronowski. "We become creative by finding a likeness between things which were not alike before. The creative mind is a mind that looks for unexpected likenesses." In other words, creativity flourishes by juggling our mindsets. The more we can juggle, the better. So our mindsets make us prejudiced, but in return they bestow immense creative potential.