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11 Memory characteristics in individuals with savant skills

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Introduction

In this chapter it is argued that memory performance provides a coherent picture of savant abilities, even though the talents displayed make different demands on memory and learning. The chapter opens with an introduction to savant talent, to issues in relation to domain-specificity and modularity, as well as the role of practice and implicit memory. These topics have been picked out because of their relevance to memory and also because of associations with autism. Three sections then follow which focus on savant memory performance amongst numerical and calendar calculators, musicians and artists, where the evidence from empirical studies is placed in the context of the issues raised in the Introduction. Finally, a theoretical interpretation is presented which, it is argued, provides a convincing account of the development of savant abilities.

Savant talent

Savants are often individuals of low general intelligence who nonetheless show outstanding capacity in a specific and often restricted domain, such as musical ability (e.g. Miller, 1989; Sloboda, Hermelin & O'Connor, 1985; Young & Nettlebeck, 1994), linguistic ability (Smith & Tsimpli, 1991; Dowker, Hermelin & Pring, 1996), calendar calculation (giving the correct day of the week that corresponds to a particular date), (Heavey, Pring & Hermelin, 1999), arithmetical calculation (Anderson, O'Connor & Hermelin, 1999), or drawing ability (e.g. Selfe, 1977; Pring & Hermelin, 1997). The majority of savants have a diagnosis of autism or Asperger syndrome, or show significant autistic-like features, together sometimes referred to as autistic spectrum disorders (ASDs). Approximately 9.8 per cent of individuals with autism exhibit special skills in comparison with individuals matched for mental age (Rimland, 1978), but it is rare for people with ASDs to display talent which is exceptional by the standard of cultural norms in the general population. The association between autism and talent has been related to obsessional preoccupations in the restricted area of interest (Hermelin & O'Connor, 1991), to visual impairment (Pring & Tadic, 2005; Treffert, 1989; Miller, 1989), to practice (Howe, Davidson & Sloboda, 1998) and, in particular, to the characteristic cognitive style of information processing found in autism (Pring, Hermelin & Heavey, 1995; Happé, 1999; Frith, 1989).

An uneven intelligence profile is typically found in autism, which is characterized by unexpectedly high scores in tests that require local rather than global, contextual or Gestalt information processing. Thus, although autism is a disorder characterized by impairment, certain cognitive–perceptual strengths are also present (Happé, 1999). According to Frith's weak central coherence theory (Frith, 1989), individuals with autism have difficulty drawing together information in order to construct higher-level meaning in context. Thus in their performance, especially perceptual performance, we see cognitive strategies characterized as weak coherence underlying exceptional skills. Indeed, this may play a significant role in predisposing certain individuals to develop their talents to savant level. Furthermore the adoption of these strategies, such as inhibiting the effects of context and focusing attention on details rather than on wholes, may extend beyond autism to help explain some of the psychological characteristics seen in high-achieving talented individuals drawn from the typical population, such as artists or mathematicians (Pring, Hermelin & Heavey, 1995; Hermelin, 2001).

Individuals displaying exceptional talent, including savants, may pose a challenge to many theories of intelligence, since their performance cannot be understood in terms of conventional intelligence tests and must be considered at least partially independent of general intellectual ability. Theoretical advances have instead turned to a consideration of domain-specific and domain-general processes as a way of understanding high-level expertise and the expression of talent.

Modularity and domain-specificity

From a psychological perspective, some would argue that there are more similarities between artists and scientists than differences between them (Root-Bernstein & Root-Bernstein, 2004). It can be argued that the skills needed to express talents are rather similar whatever the domain. The inventor, for example, may be someone who has 'intrinsic motivation towards work ... a problem-finding vision and a problem-solving focus' (Henderson, 2004, p. 120). On the other hand experimental studies of the component skills involved in talented performance have favoured the notion that talent and creativity is best considered from a 'domain-specific' viewpoint (e.g. Amabile, 1996; O'Connor & Hermelin, 1988). Winner (2000) argues that talents are unlearned, domain-specific traits that may be developed in favourable circumstances, but that cannot be manufactured. Others have defined talent as the *potential* for exceptional performance (Detterman, 1993; Feldman & Katzi, 1998) and as such it is more difficult to measure than ability and skill.

With regard to studies with savants, a number have shown that there is a difference between individuals with savant talents in drawing and painting when compared with individuals with a similar diagnosis of autism but no special drawing skills. For example the 'talented' group were significantly faster and more accurate at the Block Design test (Wechsler, 1992) and also at finding hidden or embedded figures from a display that contained either abstract visual patterns or representational pictures (Ryder, 2003; Pring, Hermelin & Heavey, 1995). Perhaps it is not so surprising that individuals with a talent for drawing, whether savant or not, might indeed have superior skills in domain-specific, i.e. visuo-perceptual, tasks (Getzels & Csikszentmihalyi, 1976; Ryder, Pring & Hermelin, 2002).

Such findings can fit well with Fodor's theory of modularity (Fodor, 1983), but can also be understood within a more interactive vision within the developmental neoconstructivist approach suggested by Karmiloff-Smith (2004) where certain brain-based subsystems, or modules, can be informationally encapsulated – in other words they are specific and independent, not only of each other but of general information processing capacity too. This could explain how individuals with low cognitive skills and poor performance on some intelligence tests might still display talent in a restricted domain (O'Connor & Hermelin, 1988). The definition of the term 'modules' has been loose and an appeal to more narrowly defined modules, referred to as 'micro-domains' (Karmiloff-Smith, 1992), such as poetry writing, numbers, music or painting, may be a more appropriate level of description in the context of savant talent.

Practice and implicit memory

The question of the development of talent in the context of autism remains uncertain. The influence of hormonal imbalance has been cited as a potential factor (Treffert, 2000), and genetic and other biological factors have also been considered, though sometimes rejected (Howe, Davidson & Sloboda, 1998). For example, reports of children with autism who display musical or number talents shared with other nonautistic members of their close family have led to the suggestion that talent is independently heritable. However, some have argued that the concept of talent itself is unhelpful in understanding exceptional performance and that the consequences of extensive practice have far greater explanatory power since, through practice alone, talents or skills may be developed and manifested (Howe, 1991; Howe, Davidson & Sloboda, 1998; Ericsson & Faivre, 1988). Certainly the development of talent has been associated with exceptional interest in, and preoccupation with, the subject domain (Ericcson 2003; Weissberg, 1999), such as is likely to sustain high practice levels. Moreover, in the present context it must be significant that individuals with autism typically display repetitive and obsessional interests. Hermelin and O'Connor (1991) referred to the high degree of obsessional traits in the personalities of the autistic savants they studied, even in relation to a comparison group of individuals with autism. Practice with the subject matter then may be something that comes easily both to individuals with high motivational levels and interest (Howe, Davidson & Sloboda, 1998) and to individuals with autism.

Certainly, long-term memory schemas built up on the back of practice can help to structure knowledge. This can have the consequence of freeing up limited resources as well as allowing individuals to capitalize on expectancies. There is, however, a problem in the use of the term 'practice', since it sidesteps issues concerning the nature of the mechanisms which might be used by savants to establish knowledge in long-term memory (LTM), the LTM knowledge structures that may underlie performance, and the retrieval structures which might be involved. Regarding the issue of retrieval from LTM, the model described by Ericsson & Kintsch (1995) referring to structures that are very complex and can activate both representational and action-based procedures, can be helpful in understanding expert performance. Regarding the mechanisms which might be active in savants' knowledge acquisition, however, there is a specific problem in that practice implies the use of explicitly determined cognitive strategies, whereas in the case of savants, reports seem to describe implicit processes based on simple exposure to the material as the basis for learning in LTM. Yet the explicit or implicit nature of the learning is often not given a great deal of emphasis (e.g. in Gobet's 1997 computational model). Moreover Trehub and Schellenberg (1998) refer to a three-factor model of high ability, arguing that none of the factors of explicit goal setting, evaluation or feedback are evident in savant activity.

Some researchers have appealed to 'rote' memory in connection with savant performance. Miller (1999) in the context of music, for example, identifies three core characteristics of rote memory: that it results in a high-fidelity representation of the original information, involves little reorganisation, and is primarily concerned with the physical aspects of the stimuli resulting in an inflexible and domain-specific output. Horowitz and his colleagues (e.g. Horowitz *et al.*, 1965) also seek to explain the performance of the outstanding calendar and numerical calculating abilities of the twins John and Michael in this way (see Sacks, 1985). However, recent evidence based on group studies, has shown that the information typically involved in the process of number or date calculation, graphic reproduction or musical performance is far from 'undigested' or 'inflexible', as the term rote memory implies, but is instead reliant on highly organized, flexible knowledge structures, capable of being used for generative and creative output (Heavey, Pring & Hermelin, 1999; Hermelin & O'Connor, 1986; Pring & Hermelin, 2002).

Especially important then, in the context of savant performance, is the likelihood that practice or exposure may afford the potential for implicit learning. In his model of learning (ACT*/ACT-R) Anderson (e.g. 1990) argues for a process of proceduralization that transforms declarative knowledge (explicitly represented) to an 'automated form' – an implicit knowledge system. Anderson's view of thinking and learning is complex, but essentially he argues that expertise is best understood as being based on a knowledge system which is developed piecemeal, dependent on the accrual and tuning of small units, which can be combined to produce complex cognition. Whereas explicit learning is subject to individual differences, implicit learning shows little variation as a function of age or intelligence. There is evidence to suggest that implicit learning is particularly suited to the acquisition of complex skills such as language (Reber, 1992). Reber (1989) for example, found that individuals were able to choose whether strings of words conformed to an artificial grammar, without being able to verbalize the rules for that decision process explicitly. Implicit learning of material can build up a complex but organized knowledge network, independent of cognitively mediated explicit processing of material. However, we still need to learn more about the mechanisms of this nondeclarative long-term memory (Squire & Zola, 1996; Bitan & Karni, 2004). Moreover it is a challenge to find a way of measuring the acquisition of, or indeed memory for, talent-related material in savant syndrome.

The following sections provide some descriptions and discussion of displays of savant skills and empirical studies of memory capacity and performance.

Savant abilities in different domains

Number and calendar calculators

Although very rare in occurrence, the outstanding performance of savant calculators, especially number calculators, has attracted much interest and been described in the literature (e.g. Smith, 1983; Heavey, 2003). Louis Fleury, for example, was described by Critchley (1979, p. 78) as a 'blind, intractable, destructive imbecile', whose calculation skills included multidigit multiplication and division, squaring, square and cubed roots, and algebra. In an average of four seconds, he could give the square root of any number running into four figures and in only six seconds the cube root of any number into six figures. Prime number calculation is also a skill that arithmetic calculators display. HP, a 31-year-old male with a diagnosis of autism (described by Heavey, 1997) could identify five-digit primes with ease; and Michael, also with a diagnosis of autism, with a nonverbal intelligence quotient (IQ) equivalent on the Raven's Progressive Matrices Test – Revised (Raven, 1998) to 128, but an unscorable test performance on the Peabody Picture Vocabulary Test (Dunn & Dunn, 1981), was able to generate prime numbers and recognize four- or five-digit primes taking about fifty seconds to generate them, and about eleven seconds to accurately identify them (Hermelin & O'Connor, 1990; Anderson, O'Connor & Hermelin, 1999). Often the speed of calculation has been emphasized but at other times it is the prodigious memory involved that has attracted attention. For example, when Jedediah Buxton (1702–72) was given a numerical problem to solve, after five hours of mental calculation (it seems without any written aide memoire), he asked in which direction the line of 28 numbers comprising the answer should be read!

In terms of LTM, a complex hierarchical associative network of number concepts and related numerical material may characterize the knowledge of these savants. How is this acquired? All ten savants described by Heavey (1997) show many autistic tendencies and are likely to fall within the spectrum of autistic disorders, with seven out of ten having a diagnosis of autism. The attention to detail observed in people with autism (see above) is likely to help focus on the basic information whether it is number factors (or for calendrical calculators, day, month or year attributes – see below). In addition, there is ready access to the material: a new date occurs every day and counting is a simple, cognitively undemanding numerical operation. The acquisition process builds in, through repeated association, the regularities apparent in the material. The network of complex associations and internal relationships among numbers can allow emergent properties to be accessed. Arithmetical solutions and shortcuts or rules may be integrated into the network. Such reasoning has been outlined by Heavey (2003) and explains both factorization and prime number recognition and generation.

Individuals with savant arithmetical ability are rare. However, such individuals often also have the ability to calendar calculate and there are many similarities in both the acquisition and operation involved in these skills, although the ability to calendar calculate may also occur in isolation. Calendar calculation refers to the ability to rapidly supply the day of the week of a given date, with some savants able to perform calculations spanning thousands of years (e.g. Horwitz *et al.*, 1965) or taking between 1.5 and 10 seconds to accurately identify the day of the week for dates such as 1 April 1850, 22 June 1979 or 15 December 1964 (Heavey, 1997).

The calendar conforms to certain regularities such as the 28-year rule, where in the Gregorian calendar the day–date configuration repeats itself every 28 years; or the corresponding month rule, where certain month pairs share the same day–date structure within a given year. A number of studies have reported evidence for calendar knowledge being represented within a structured knowledge network (Young & Nettlebeck, 1994; O'Connor & Hermelin, 1986; Ho, Tang & Ho, 1991). Thus speed of calculation is facilitated in certain predictable formulations such as in dates falling in years with identical structures.

To test these conjectures empirically, Heavey, Pring and Hermelin (1999) systematically investigated memory function in a group of savant calendar calculators and a group of age-, ability- and diagnosis-matched participants without savant ability. Their study showed that the savants did not have unusually increased memory capacity with respect to *general* short- and long-term memory as measured by digit span or recall of words from a list. They did, however, show clear recall superiority for calendrical material *in the absence of the calculation process*. This suggests that the calculators must encode date information unusually effectively, rather than having increased memory capacity. Furthermore in another study reported by Heavey *et al.* (1999), calculation facilitated memory retrieval suggesting that, as in language studies (e.g. Slamecka & Graf, 1978), active processing produces more accessible memories compared with passive learning conditions.

For the savants, with their characteristic poor verbal performance, it seems that the structure of their calendar information provides more cues for memory retrieval than perhaps even semantic knowledge. Tager-Flusberg (1991) tested the organization of semantic knowledge in a group of participants with autism. She found that their recall was not

Table 11.1. *Same-day and different-day examples presented to participants*

List 1: 1988 (Leap)	List 2: 1989
15 February 1988 (Monday)	11 July 1989 (Tuesday)
7 November 1988 (Monday)	4 March 1989 (Saturday)
24 October 1988 (Monday)	20 December 1989 (Wednesday)
18 July 1988 (Monday)	13 April 1989 (Thursday)
List 3: 1991	List 4: 1992 (Leap)
10 October 1991 (Thursday)	8 May 1992 (Friday)
27 June 1991 (Thursday)	19 October 1992 (Monday)
7 March 1991 (Thursday)	26 January 1992 (Sunday)
25 April 1991 (Thursday)	11 November 1992 (Wednesday)

enhanced by presenting a list of semantically related words (animal names) when compared with semantically unrelated words. Furthermore, the performance of the group with autism was not attributable to an encoding deficit; the participants were able to use semantic cues to facilitate word retrieval. This suggests that these word items are stored in a semantically related format in LTM, but these pre-existing links and associations are not activated in order to facilitate retrieval (see Toichi, this volume, Chapter 8, and Bowler & Gaigg, this volume, Chapter 17).

In a series of related investigations (Reidy & Pring, in preparation), we tested the knowledge organization of our group of savant calculators ($n = 8$)[1] by exploring their memory performance using the same paradigm as that of Tager-Flusberg (1991) but substituting semantically related and unrelated lists with specially constructed lists of dates. Examples are given in Table 11.1. Although the participants did not calculate the day of the week for the given dates (e.g. 10 October 1991), in the lists we showed them the dates presented either *shared* the day of the week (List 1 and List 3), or the dates referred to *different* days of the week (List 2 and List 4). In this way it was possible to discover whether sharing a day makes a list more memorable, presumably because it is coded in that way in LTM. Thus in the memory task the savants were presented (visually and auditorally) with blocks of individual dates taken from the lists, and asked to recall them later. They were advised not to try and calculate the day but only to try and remember the dates.

[1] The savant participants are described in Heavey, Pring and Hermelin (1999).

The results showed that our group of savant calculators recalled significantly more dates that shared the same day of the week (5.9 out of a maximum of 8) than dates from the list where the days came from different parts of the week (3.9), and furthermore a near significant advantage for leap years (5.1) when compared to nonleap years (4.5). This evidence shows that their memory performance is sensitive to the structure of the calendar material and reflects the organization of the material. Individuals with autism (and savant calculating skills) are not incapable of displaying complex structural knowledge regularities in memory performance; simply that this emerges in a domain of expertise (e.g. numerical or date material) rather than in the semantic/conceptual knowledge system.[2]

Musical savants

Music is typically highly regular and rigidly structured (Justus & Bharucha, 2001). By constructing, storing and recalling the use of the rules and patterns that govern music, musicians are able to build up cognitive representations of musical structure and thus process musical information more effectively than nonmusicians (Sloboda, 1985). These musical cognitive representations arise from probabilistic associations or rules learned implicitly whilst attending to music (Zatorre, 2003), and it follows that its structure conforms to the musical tradition or format to which the musician has most regularly been exposed (Peretz & Hyde, 2003; Justus & Bharucha, 2001; Sloboda, 1985).

In terms of musical ability, savant skills have at times been considered comparable to those of professional musicians, including the ability to transpose music across keys, render imitations of specific musical styles, distinguish constituent tones from chords, and to have an exceptional memory for music (Sloboda, Hermelin & O'Connor, 1985; Miller, 1989; Hermelin, O'Connor & Lee, 1987). Several studies of musical memory have suggested that the knowledge that musical savants have acquired is structurally based in that it embodies an associative network modelling musical grammar. In line with this, musical savants' errors in memory tasks tend to be structure-preserving. Precise intervallic relationships may not be remembered but overall pitch contours are (Sloboda, Hermelin & O'Connor, 1985). Furthermore, their structural knowledge influences memory performance so that they experience difficulty memorizing

[2] A complete description of this and related studies can be found in (Heavey, 1997; and in Reidy (nee Heavey) & Pring, in preparation).

music written in unfamiliar as opposed to familiar styles (Sloboda Hermelin & O'Connor, 1985: Young & Nettlebeck, 1995).

It is likely that such exceptional skills result from outstanding absolute pitch (AP) abilities (Miller, 1989; Treffert, 2000: Heaton, Hermelin & Pring, 1998). Absolute pitch is the ability to recognize, label and remember pitch information without reference to an external standard. It is extremely rare: only 1 in 10,000 in the normal Western population possesses AP (Takeushi & Hulse, 1993) and the acquisition of AP is automatic and unconscious and likened to the acquisition of language (Deutsch, Henthorn & Dolson, 2004). Early musical exposure or instruction can influence its development (Takeuchi & Hulse, 1993; Levitin, 1994) but it is not a necessary component of musical ability or talent, and many professional musicians do not possess it (though it was possessed by Bach, Beethoven and Mozart). By contrast, *all* cases of musical savants described in the literature do possess absolute pitch. Heaton, Hermelin and Pring, (1998) highlighted the incipient AP abilities in children with autism and the musical abilities of an autistic child with exceptional AP abilities (Heaton, Pring & Hermelin, 1999), arguing that these abilities are dependent on, or linked with, weak coherence. Children with profound visual impairments also appear to show a potential to develop absolute pitch ability (Ockelford, 1988) and certainly have excellent pitch memory (Pring & Painter, 2002). Hamilton, Pascual-Leone and Schlaug (2004) reported a very much higher than expected prevalence amongst blind musicians, and the relationship between autism and blindness has recently been discussed in relation to musical talent (see Pring, 2005). More research is needed to understand the relationship between AP, visual impairment and musical processing. The ability to hold in memory individual pitches independently, and the development of musical knowledge and the memory system supporting the performance of musical savants are clearly intimately related.

Although studies of musical savants make it clear that pitch memory and pitch reproduction are exceptional, the limits of such abilities have not often been the focus of experimental study. Recently, Ockelford and Pring (2005) measured the limits of the capacity of DP, a musical savant, from the viewpoint of both learning and memory. DP is a young man who suffered from retinopathy of prematurity and has been totally blind from birth, additionally he also has a diagnosis of autism and severe learning difficulties. In a longitudinal study (Ockelford & Pring, 2006) we asked DP to learn a specially composed piece of blues music over an eighteen-month period. His output, which was monitored in the learning phase bi-weekly and in the memory phase every three months, reflected fascinating additions and transpositions of the musical material, creative elements and the use of schematized representations.

To understand DP's basic capacities in terms of perception and learning however, we explored the limits of his perceptual/memory skills in relation to his ability to process pitch clusters and chords. One exacting measure of absolute pitch is based on the outstanding capacity of some possessors of AP to identify the pitches of individual notes in complex note clusters (chords). This is difficult to do not least because the material seems to be highly coalescent and presents a gestalt, which, by definition, is hard to break down into its constituent elements. Our investigation compared chord-disaggregation performance in DP and nonsavant musician SE, both with at least the basic attributes of absolute pitch. DP is an exceptional musician who knows from memory literally thousands of piano pieces ranging in style from classical, through jazz and the blues to contemporary popular music. He performs regularly in the UK and abroad. SE is comparable in age to DP and is also a jazz musician with absolute pitch. At the time at which the research was being carried out he was studying for a degree in music from Kings College, University of London. The task DP and SE were asked to perform involved the reproduction of chords[3] varying in size from four to nine notes, played on an electronic keyboard. The two participants heard (only once) twenty different examples of chords from each level of difficulty (i.e. 120 chords). A 'hear and play' paradigm was used, and the number of notes correctly reproduced was the measure of accuracy.

In the literature there are no accounts of chord disaggregation that go beyond the use of four notes, and deconstructing chords is an extremely rare skill (Huron, 2001). DP's performance was truly exceptional but unfortunately we had not realized that we would need two sets of hands if we were to find DP's limit in terms of accuracy! Figure 1 shows DP's results in comparison with those of SE, who himself performed extremely well, indicating very good absolute pitch abilities.

There are problems with what would constitute chance performance in such a study, since as chords have more and more notes in them, given the physical limits on what can be performed with eight fingers and two thumbs, guessing the notes that are present becomes an ever more profitable strategy. Nevertheless the results are striking. DP is nearly 97 per

[3] The pitch range was restricted from the C below middle C to the G two-and-a-half octaves higher. Chords were largely 'tonal' and 'tertian' in nature: that is, conforming to the pitch frameworks of the major and minor scales with the possibility of chromatic alterations, all of which are ultimately definable as concatenations of thirds. Some comprised clusters of notes (series of tones and semitones, e.g. E flat, F sharp, G, A flat, B flat) that lay beyond the confines of Western tonality.

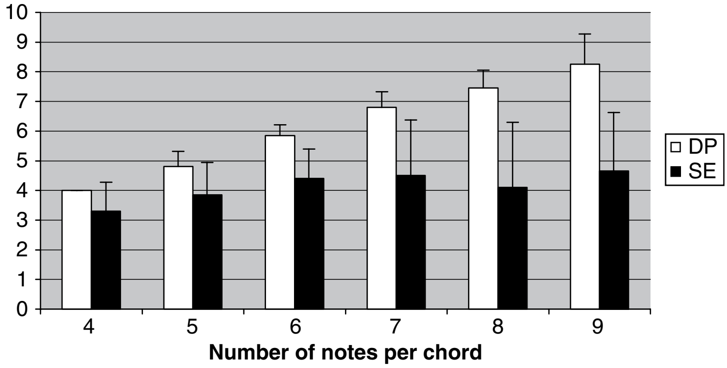

Figure 11.1 Figure displaying performance (DP: musical savant; SE: AP-matched control musician) on a disaggregation task

cent accurate overall. Moreover, his responses invariably followed the stimuli almost immediately (informally measured as between 400 and 1000 ms). It is not likely that such a rapid response is consciously mediated, and DP does not have the verbal skills to provide any potential insights into the process he uses to attain such high levels of performance. Nevertheless, DP shows evidence of an exceptionally detailed perceptual representation derived from the sensory stimulus and one that affords an immediate translation into fingering. It is hard to say if this should be considered a reflection of long-term memory knowledge representations or an episodically based short-term memory capacity for domain-specific material. DP's performance is so exceptional that it is effectively at ceiling, making it hard to say whether or not his performance would (at the limits) have similar characteristics to SE's performance. Analysis of SE's performance revealed that in playing a note cluster: (a) the top notes followed by the bottom notes were more accurate than the 'inner' notes; (b) notes corresponding to the black keys on a piano were correctly reproduced less often than white notes; and (c) intervallic size predicted accuracy (a cluster of notes a semitone apart was more difficult than for notes each a third apart). This suggests that the notes are retained in a sequence with flanker interference effects explaining the relatively accurate end-note accuracy. For DP it might be that there would be no note position effects indicating his 'direct' access to the individual notes, perceived and retained independently.

The importance of the motor aspect of DP's skills needs to be considered in more depth and it would be interesting to ask how far it is possible to measure DPs abilities without the 'playing' component. In studies of savant artists for example, exceptional performance often relies on measures based on drawing output, but not exclusively. There are examples where authors have tried to differentiate cognitive/perceptual mechanisms from the motor output components (Pring, Hermelin & Heavey, 1995; Hermelin & Pring, 1998; Mottron & Belleville, 1993). Informal descriptions of DP suggest that his musical processing is represented independently of his fingering, but it is hard to see how this could be tested empirically.

Savant artists

A number of explanations of savant artistic ability have focused on the outstanding memory often shown (Hill, 1975; Lafontaine, 1974). Selfe (1977) and Sacks (1985) have both highlighted the capacity of savant artists to produce visually correct, complex artistic outputs, in some cases several months after seeing the initial image. Selfe provided one of the best-known descriptions of this ability in her reports of child artist, Nadia (Selfe, 1977). Diagnosed with autism when she was 6 years old, Nadia possessed no expressive language skills and poor comprehension. However, at the age of 3 and a half years she developed an amazing capacity to draw. This drawing ability apparently arose spontaneously, omitting the scribbling stage of normal children's drawing development, and she went straight on to drawing very sophisticated images, mainly of animals but also including people, trains and other objects. She was also able to add and omit details and to draw images that were rotations from the original viewpoint. In addition, her drawings displayed linear perspective, foreshortening, occlusion and proportioning, all without any sort of training, although these features are not usually apparent in artistic output until much later in life.

The visual knowledge and understanding that must underlie the ability to portray linear perspective, to take into account size constancy, and to use perspective knowledge to achieve rotational transformations as Nadia did, are not well understood. Professional artists typically find these drawing techniques difficult or impossible to execute, even with training. Yet Nadia is not alone amongst artistic savants to display such exceptional drawing skill. It has been shown that adolescents with autism have a unique ability to draw accurate ellipses representing circle projections, demonstrating a facility with use of perspective (Ropar & Mitchell, 2002). EC, an exceptional draughtsman showing exactly the same abilities as Nadia, was described by Mottron and Belleville in a series of studies (e.g. 1993). Stephen Wiltshire (e.g. as described by Pring & Hermelin, 1997), who seems exceptional in his mastery of drawing spatial relationships, could also use linear perspective and take into account size constancy, albeit to a lesser extent. One may speculate that these individuals have implicitly learnt the geometry of spatial relationships and other computations necessary for such procedural memory and output to operate so effectively.

In the case of Nadia and EC, additional similarities associated with exceptional drawing style were also noted. Neither seems to have made mistakes or used an eraser even when producing highly complex drawings of unusual views. EC can draw perfect lines, circles and ellipses. Both draw without regard to the edge of the paper, 'the drawings stop at the end of the sheet, irrespective of the outline of the configuration in the real world. It is not rare to find a half-complete object or person missing an essential part' (Mottron & Belleville, 1993, p. 287), and this feature of drawing has been documented amongst other savant artists (Ryder, 2003). The sense that the image has been reproduced on a piecemeal basis, without regard to the holistic impression, is hard to miss in such drawing behaviour and seems to support the weak perceptual coherence theory described in connection with the cognitive style seen in autism.

Hermelin and Pring (1998) explored the use of two particular pictorial devices in a group of nine savant artists and nine gifted children of normal intellectual ability and advanced drawing skill. These devices were linear perspective, and size and shape constancy as dealt with in pictorial form. The pictorial rules of linear perspective were developed in fifteenth-century Italy and were derived from geometrical laws. They include the notion that lines that run parallel in the three-dimensional world must converge in a picture and must meet eventually in a vanishing point. According to Gombrich (1988) this feature has dominated Western art until the early twentieth century. Constancy refers to the way the brain creates a stable perceptual world by seeming to be immune to changes in the retinal image. A man walking towards the distance does not lose identity, and – however small the retinal image – is not viewed as 'a boy', though the computed size might suggest that. It is as well to remember that an artist can retain the absolute size of the image in a drawing, safe in the knowledge that the viewer will apply constancy as much for a painting or drawing as s/he does for the 3D world it depicts.

Young children do not spontaneously use linear perspective or draw far away objects smaller than those that are near (Freeman & Cox, 1985). They, along with many artistically naïve adults, fail to properly implement these pictorial drawing devices. This is true not only for drawing but also in dealing with model constructions. Hermelin and Pring (1998) tested gifted child artists and artistic savants on a pair of tasks, the first of which involved drawing cars or planes at various distances from the viewer along a road or a runway; and in the second part of which the participants had to select models of cars or planes of varying proportions and place them within a road or runway represented by bricks. Both groups of children could implement size and shape constancy in their drawings, unlike normally developing children. Significantly, though, while the gifted children could transfer their understanding to a model construction task, the artistic savants failed to do so, their performance seeming to be restricted specifically to drawing.

Similarly, O'Connor and Hermelin (1987) reported a study with a group of savant artists and an IQ-matched nongifted comparison group. They presented participants with a variety of simple memory tasks, involving both recognition and reproduction of concrete and abstract drawn shapes. The performance of the savants was comparable to that of the IQ- matched comparison group on a short-term memory-matching task, but superior when the task involved a drawn response, such as reproduction of a complex figure from memory. The results, therefore, show that while superior visual memory can be indexed with a drawn response, visual recognition memory in savant artists is no better than that of nongifted, IQ-matched participants. Indeed, Mottron and Belleville (1993) report the same pattern in relation to EC. This again then implicates some implicit mechanisms involving procedural or LTM components in savant performance, rather than basic short-term memory capacity.

A theoretical model of savant abilities

The recent model of '*Enhanced Perceptual Function*' in autism (Mottron *et al.*, 2006) advances the ideas encapsulated in weak perceptual coherence and provides a convincing account of the development of savant abilities. Recent evidence from neuroimaging studies in autism provides support for this model by suggesting ways for neural circuitry to differ both in top-down processing and in the progression of sensory analysis. Thus, Frith (2003) observes that over a wide variety of tasks early sensory processing areas of the brain are activated normally or even *over*-activated in individuals with autism, whilst later processing areas are under-activated. The greater volume in brain size seen in autism may occur because of a lack of neuronal pruning. Frith speculates that sensory processing may be exceptional and higher-level processing under-represented (e.g. in the failure to show activation of the fusiform gyrus in face processing).

Thus, perceptual enhancement leading to unique and potentially more detailed percepts might result. Such differential circuitry would impact not only on behaviour at the perceptual level, but also on the resultant memory representations. This would be in line with the autism advantage seen in perspective drawing (Ropar & Mitchell, 2002) where higher-order knowledge can have an interfering rather than an advantageous effect. It is also consistent with musical perception in individuals with autistic spectrum disorder in whom pitch memory is characterized as retaining uniquely specified individual percepts/representations (see above, in relation to musical savants). If the unusual binding processes and neuronal circuitry indicated in autistic spectrum disorders (with the associated limitations to higher-order specialization and increased sensory processing) are confirmed, clearly it could explain why savants build up *differently structured* memory stores that are accurate in perceptual terms and may mediate different styles of learning and behaviour.

Summary

Talent is an elusive concept. However, there appears to be sound evidence that both savants and experts share important qualities. Implicit (unconscious) learning and the organization of proceduralized knowledge play an important part in the manifestation and development of savant talent. However, it would be inappropriate to consider the knowledge and memory systems underlying such expertise as rigid. There is evidence that savant performance includes a level of flexibility and creativity in art (Hermelin *et al.* 1999), music (Hermelin, O'Connor & Lee, 1987) and number (Pring & Hermelin, 2002), suggesting that the description of savant memory as 'rote' would be inappropriate. The particularly detailed way of thinking and processing of perceptual material in individuals with autism, plus their restricted and specific interests, may predispose them to build up complex knowledge structures in LTM. This may help to explain the existence of superior mnemonic abilities in many of the musical savants, calendrical or arithmetical calculators, and savant linguists described in the literature. It is harder to understand the basis of savant artistic talent. However, it may be related to the unique perceptual skills and consequent LTM organization of visuo-spatial knowledge. It is suggested that Mottron *et al.*'s theoretical model of 'Enhanced Perceptual Processing' provides a convincing account of the acquisition of savant abilities, and that recent evidence from neuroimaging studies of individuals with autism is consistent with this model.

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References

Amabile, T. M. (1996). *Creativity in context*. Boulder, CO: Westview.

Anderson, J. R. (1990). *The adaptive character of thought*. Hillsdale, NJ: Erlbaum.

Anderson, M., O'Connor, N. & Hermelin, B. (1999). A specific calculating ability. *Intelligence*, *26*(4), 383–403.

Bitan, T. & Karni, A. (2004). Procedural and declarative knowledge of word recognition and letter decoding in reading and spelling. *Cognitive Brain Research*, *19*(3), 229–243.

Critchley, M. (1979). *The divine banquet of the brain*. New York: Raven Press.

Detterman, D. K. (1993). Discussion. In G. R. Bock & K. Ackrille (eds.), *Ciba Foundation Symposium 178: the origins and development of high ability*, pp. 22–43. New York: Wiley.

Deutsch, D., Henthorn, T. & Dolson, M. (2004). Absolute pitch, speech and tone language: some experiments and a proposed framework. *Music Perception*, *21*(3), 339–356.

Dowker, A., Hermelin, B. & Pring, L. (1996). A savant poet. *Psychological Medicine*, *26*, 913–934.

Dunn, L. M. & Dunn, L. (1981). *Peabody Picture Vocabulary Test – revised*. Circle Pines, MN: American Guidance Service.

Ericsson, K. A. (2003). Exceptional memorizers: made, not born. *Trends in Cognitive Sciences*, *7*, 233–235.

Ericsson, K. A. & Faivre, I. A. (1988). What's exceptional about exceptional abilities? In I. K. Obler & D. Fein (eds), *The exceptional brain: neuropsychology of talent and special abilities*, pp. 436–473. New York: Guilford Press.

Ericsson, K. A., Krampe, R. & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, *100*, 363–406.

Ericsson, K. A. & Kintsch, W. (1995). Long-term working memory. *Psychological Review*, *102*, 211–245.

Feldman, D. H. & Katzir, T. (1998). Natural talents: an argument for extremes. *Behavioral and Brain Sciences*, *21*, 414–415.

Fodor, J. A. (1983). *Modularity of mind.* Cambridge, MA: MIT Press.

Freeman, N. H. & Cox, M. V. (1985). *Visual order: the nature of development of pictorial representation*. Cambridge: Cambridge University Press.

Frith, C. (2003). What do imaging studies tell us about the neural basis of autism? *Autism: neural basis and treatment possibilities; Novartis Foundations Symposium*, *251*, 149–176.

Frith, U. (1989). *Autism: explaining the enigma*. Oxford: Blackwell.

Getzels, J. W. & Csikszentmihalyi, M. (1976). *The creative vision: a longitudinal study of problem finding in art*. New York: Wiley.

Gobet, F. (1993). A computer model of chess expertise. *Proceedings of the 15th Annual Meeting of the Cognitive Science Society*, 463–468.

Gombrich, E. H. (1988). *Art and illusion: a study in the psychology of pictorial representation*. London: Phaidon Press.

Hamilton, R. H., Pascual-Leone, A. & Schlaug, G. (2004). Absolute pitch in blind musicians. *Neuroreport*, *15*(5), 803–806.

Happé, F. G. E. (1999). Autism: cognitive deficit or cognitive style? *Trends in Cognitive Science*, *3*, 216–222.

Heaton, P., Hermelin, B. & Pring, L. (1998). Autism and pitch processing: a precursor for savant ability? *Music Perception*, *15*, 291–305.

Heaton, P., Pring, L. & Hermelin, B. (1999). A pseudo-savant: a case of exceptional musical splinter skills. *Neurocase*, *5*, 503–509.

Heavey, L. (1997). Memory in the calendar calculating savant. Unpublished PhD thesis, University of London.

(2003). Arithmetical savants. In A. Dowker and A. J. Baroody, A. J. (eds.), *The development of arithmetic concepts and skills: constructing adaptive expertise*, pp. 409–433. Mahwah, NJ: Erlbaum.

Heavey, L., Pring, L. & Hermelin (1999). A date to remember: the nature memory in savant calendrical calculators. *Psychological Medicine*, *29*, 145–160.

Henderson, S. J. (2004). Inventors: the ordinary genius next door. In R. J. Sternberg, E. L. Grigorenko & J. L.Singer (eds.), *Creativity*, p. 120. Washington, DC: American Psychological Association.

Hermelin, B. (2001). *Bright splinters of the mind*. London: Jessica Kingsley.

Hermelin, B. & O'Connor, N. (1986). Idiot savant calendrical calculators: rules and regularities. *Psychological Medicine*, *16*, 885–893.

(1990). Factors and primes: a specific numerical ability. *Psychological Medicine*, *20*, 163–169.

(1991). Talents and preoccupations in idiots– savants. *Psychological Medicine*, *21*, 959–964.

Hermelin, B., O'Connor, N. & Lee, S. (1987). Musical inventiveness of five idiots–savants. *Psychological Medicine*, *17*, 685–694.

Hermelin, B. & Pring, L. (1998). The pictorial context dependency of savant artists: a research note. *Perceptual and Motor Skills*, *87*, 995–1001.

Hermelin, B. & Pring, L., with Buhler, M., Wolff, S. & Heaton, P. (1999). A visually impaired savant artist: interacting perceptual and memory representations. *Journal of Child Psychiatry and Psychology*, *7*, 1129–1139.

Hill, A. L. (1975). An investigation of calendar calculating by an idiot savant. *American Journal of Psychiatry*, *132*, 557–560.

Ho, E. D. F., Tsang, A. K. T. & Ho, D. Y. F. (1991). An investigation of the calendar calculation ability of a Chinese calendar savant. *Journal of Autism and Developmental Disorders*, *21*, 315–327.

Horwitz, W. A., Kestenbaum, C., Person, E. & Jarvik, L. (1965). Identical twin – 'idiot savants' – calendar calculators. *American Journal of Psychiatry*, *121*, 1075–1079.

Howe, M. J. A. (1989). *Fragments of genius: the strange feats of idiots savants*. London: Routledge.

Howe, M. J. A. (1991). *The origins of exceptional ability*. London: Routledge.

Howe, M. J. A., Davidson, J. W. & Sloboda, J. A. (1998). Innate talents: reality or myth? *Behavioral and Brain Sciences*, *21*, 399–342.

Huron, D. (2001). Absolute pitch. *Music Perception*, *19*, 45–54.

Justus, T. & Bharucha, J. (2001). Modularity in musical processing: the automacity of harmonic priming. *Journal of Experimental Psychology: Human Perception and Performance*, *27*, 1000–1011.

Karmiloff-Smith, A. (1992). *Beyond modularity: a developmental perspective on cognitive science*. Cambridge, MA: MIT Press.

(2004). Cognitive modularity. In R. Gregory (ed.), *Encyclopedia of cognitive sciences*, pp. 184–186.

LanFontaine, L. (1974). Divergent abilities in the idiot savant. PhD thesis, Boston University.

Lehmann, A. C. (1997). Acquisition of expertise in music: efficiency of deliberate practise as a moderating variable in accounting for sub-expert performance. In J. A. Sloboda & I. Deliege (eds.), *Perception and cognition of music*, pp. Mahwah, NJ: Erlbaum.

Levitin, D. J. (1994). Absolute memory for musical pitch: evidence from the production of learned memories. *Perception & Psychophysics*, *56*, 414–423.

Miller, L. K. (1989). *Musical savants: exceptional skill in the mentally retarded*. Hillsdale, NJ: Erlbaum.

Miller, L. (1999). The savant syndrome: intellectual impairment and exceptional skill. *Psychological Bulletin*, *125*, 31–46.

Mottron, L. & Belleville, S. (1993). A study of perceptual analysis in a high-level autistic subject with exceptional graphic abilities. *Brain and Cognition*, *23*, 279–309.

Mottron, L. & Belleville, S. (1995). Perspective production in a savant autistic draughtsman. *Psychological Medicine*, *25*, 639–648.

Mottron, L., Dawson. M, Soulières, I., Hubert. B. & Burack. J. A. (2006). Enhanced perceptual functioning in autism: an update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders*, *36*, 27–34.

Norris, D. (1990). How to build a connectionist idiot (savant). *Cognition 35*, 277–291.

O'Connor, N. & Hermelin, B. (1987). Visual memory and motor programmes: their use by idiot–savant artists and controls. *British Journal of Psychology*, *78*, 307–323.

(1988). Low intelligence and special abilities. *Journal of Child Psychology and Psychiatry*, *29*, 391–396.

(1989). The memory structure of autistic idiot–savant mnemonists. *British Journal of Psychology*, *80*, 97–111.

Ockelford, A. (1988). Some observations concerning the musical education of blind children and those with additional handicaps. Paper presented at the 32nd Conference of the Society for Research in Psychology of Music and Music Education (now SEMPRE) at the University of Reading.

Ockelford, A. & Pring, L. (2005). Learning and creativity in a prodigious musical savant. Edited summaries selected from the Proceedings of the International

Conference of the Royal National Institute for the Blind held in London April 2005, *International Congress Series*, *1282*, 903–907.

Ockelford, A. & Pring, L. (2006). Learning and creativity in a musical savant. Paper presented at the 4th Mary Kitzinger International Conference on Visual Impairment, Kingston University, July 2006.

Peretz, I. & Hyde, K. L. (2003). What is specific to music processing? Insights from congenital amusia. *Trends in Cognitive Science*, *7*, 362–367.

Pring, L. (2005). Savant syndrome. *Developmental Medicine and Child Neurology*, *47*(7), 500–503.

Pring, L. & Hermelin, B. (1997). Native savant talent and acquired skill. *Autism*, *1*, 199–214.

(2002). Numbers and letters: exploring an autistic savant's unpractised ability. *Neurocase*, *8*, 330–337.

Pring, L., Hermelin, B. & Heavey, L. (1995). Savants, segments, art and autism. *Journal of Child Psychology and Psychiatry*, *36*, 1065–1076.

Pring, L. & Painter, J. (2002). Recollective experience in the visually impaired: the role of sensory and conceptual processing. *British Journal of Visual Impairment and Blindness*, *20*, 24–32.

Pring, L. & Tadic, V. (2005). More than meets the eye: blindness, autism and talent. In L. Pring (ed.), *Autism and blindness: research and reflections*, p. 66. London and Philadelphia: Whurr.

Raven, J. C. (1998). *Raven's standard progressive matrices test*. San Antonio, TX: Harcourt.

Reber, A. S. (1989). Implicit learning and tacit knowledge. *Journal of Experimental Psychology: General*, *118*, 219–235.

(1992). The cognitive unconscious: an evolutionary perspective. *Consciousness & Cognition*, *1*, 93–113.

Rimland, B. (1978). Inside the mind of the antistic savant. *Psychology Today*, *12*(3), 69–80.

Root-Bernstein, R. & Root-Bernstein, M. (2004). Artistic scientists and scientific artists: the link between polymathy and creativity. In R. J. Sternberg, E. L. Grigorenko & J. L. Singer (eds.), *Creativity*, pp. 127–151. Washington, DC: American Psychological Association.

Ropar, D. & Mitchell, P. (2002). Shape constancy in autism: the role of prior knowledge and perspective cues. *Journal of Child Psychology and Psychiatry*, *43*(5), pp. 647–654.

Ryder, N. (2003). The creative and generative capacity of savant artists with autism. Unpublished PhD thesis, University of London.

Ryder, N., Pring, L. & Hermelin, B. (2002). Lack of coherence and divergent thinking: two sides of the same coin in artistic talent? *Current Psychology*, *21*, 168–175.

Sacks, O. (1985). *The man who mistook his wife for a hat*. London: Duckworth.

Selfe, L. (1977). *Nadia: a case of extraordinary drawing ability in an autistic child*. London: Academic Press.

Shah, A. & Frith, U. (1993). Why do autistic individuals show superior performance on the Block Design task? *Journal of Child Psychology and Psychiatry*, *34*, 1351–1364.

Slamecka, N. J. & Graf, P. (1978). The generation effect: delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning and Memory*, *4*, 592–604.

Sloboda, J. A. (1985). *The musical mind: the cognitive psychology of music*. Oxford: Oxford University Press.

Sloboda, J. A., Hermelin, B. & O'Connor, N. (1985). An exceptional musical memory. *Music Perception*, *3*, 155–170.

Smith, S. B. (1983). *The great mental calculators*. New York: Columbia University Press.

Smith, N. & Tsimpli, I. (1991). Linguistic modularity? A case study of a 'savant' linguist. *Lingua*, *84*, 315–351.

Snyder, A., Mitchell & Bossomaier, J. (2004). Concept formation: 'Object' attributes dynamically inhibited from conscious awareness. *Journal of Integrative Neuroscience*, *3*(1), 31–46.

Squire, L. R. & Zola, S. M. (1996). The structure and function of declarative and nondeclaritive memory systems. *Proceedings of the National Academy of Sciences, USA*, *93*, 13515–13522.

Tager-Flusberg, H. (1991). Semantic processing in the free recall of autistic children: further evidence for a cognitive deficit. *British Journal of Developmental Psychology*, *9*, 417–30.

Takeuchi, A. H. & Hulse, S. H. (1993). Absolute pitch. *Psychological Bulletin*, *113*, 345–361.

Treffert, D. A. (1989). *Extraordinary people: understanding 'idiot-savants'*. New York: Bantam.

(2000). Savant syndrome. In A. E. Kazdin (ed.), *Encyclopedia of psychology*, vol. 7, pp. 144–148. London: Cambridge University Press.

Trehub, S. E. & Schellenberg, E. G. (1998). Cultural determinism is no better than biological determinism. *Brain and Behavioural Sciences*, *21*, 427–428.

Wechsler, D. (1992). *Wechsler Intelligence Scale for Children*, 3rd UK edn. London: Psychological Corporation.

Weisberg, R. W. (1999). Creativity and knowledge: a challenge to theories. In R. J. Sternberg (ed.), *Handbook of creativity*, pp. 226–250. New York: Cambridge University Press.

Winner, E. (2000). Giftedness: current theory and research. *Current Directions in Psychological Science*, *9*, 153–156.

Young, R. L. & Nettelbeck, T. (1994). The 'intelligence' of calendrical calculators. *American Journal on Mental Retardation*, *99*, 186–200.

Young, R. L. & T. Nettelbeck, T. (1995). The abilities of a musical savant and his family. *Journal of Autism and Developmental Disorders*, *25*, 231–248.

Zatorre, R. J. (2003). Absolute pitch: a model for understanding the influence of genes and development n neural and cognitive function. *Nature Neuroscience*, *6*, 692–695.