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Annotation: The savant syndrome

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Background: Whilst interest has focused on the origin and nature of the savant syndrome for over a century, it is only within the past two decades that empirical group studies have been carried out. **Methods:** The following annotation briefly reviews relevant research and also attempts to address outstanding issues in this research area. Traditionally, savants have been defined as intellectually impaired individuals who nevertheless display exceptional skills within specific domains. However, within the extant literature, cases of savants with developmental and other clinical disorders, but with average intellectual functioning, are increasingly reported. **Results:** We thus propose that focus should diverge away from IQ scores to encompass discrepancies between functional impairments and unexpected skills. It has long been observed that savant skills are more prevalent in individuals with autism than in those with other disorders. Therefore, in this annotation we seek to explore the parameters of the savant syndrome by considering these skills within the context of neuropsychological accounts of autism. A striking finding amongst those with savant skills, but without the diagnosis of autism, is the presence of cognitive features and behavioural traits associated with the disorder. **Conclusions:** We thus conclude that autism (or autistic traits) and savant skills are inextricably linked and we should therefore look to autism in our quest to solve the puzzle of the savant syndrome. **Keywords:** Savant, autism, talent, intelligence.

History

Fifteen years have passed since Neil O'Connor and Beate Hermelin published their annotation 'low intelligence and special abilities' in the *Journal of Child Psychology and Psychiatry*. This paper described research findings by the authors as well as other researchers in the savant field and raised important questions about the co-occurrence of low levels of intelligence and high-level skills in savants. These studies marked a sea change in approach to the study of the savant, bringing a scientific rigour to an area of psychology that had historically been dominated by anecdotal reports. Since the publication of this article (O'Connor & Hermelin, 1988), interest in this phenomenon has continued unabated and has culminated in the publication of well over 100 journal articles and book chapters as well as six books (Hermelin, 2001; Howe, 1989; Obler & Fein, 1988; Sacks, 1995; Smith & Tsimpli, 1995; Treffert, 1989) in the English language alone. A comprehensive review of this literature is beyond the scope of our annotation so readers are referred to Miller's (1999) recent paper on this topic. Instead, we will here focus primarily upon research and theoretical issues arising since the publication of the seminal paper of O'Connor and Hermelin (1988).

Defining the savant

The term 'idiot-savant' was first used by Down (1887) to describe intellectually impaired individuals with contrasting outstanding abilities. More recently, there has been a terminological shift and the terms 'monosavant' (Charness, Clifton, & MacDonald, 1988) and 'savant syndrome' (Treffert, 1989) have come into general usage. Whilst the pejorative connotations of the 'idiot-savant' label necessitated such a change, these more current terms inevitably fail to adequately reflect the paradoxical nature of this intriguing syndrome.

Although rarely mentioned in the extant literature, one topic worthy of discussion is the examination of how the savant syndrome has traditionally been defined. This conceptual controversy was recently reviewed by Miller (1998), who proposed that defining savant status in an individual should be similar to the approach taken for defining learning disability in the United States. More specifically, Miller endorses a 'discrepancy-based model' wherein one compares intra-individual performance across functional domains. One example would be the comparison of academic achievement (e.g., reading) and intellectual functioning (measured by standardised IQ tests). Unfortunately, a reliance on standardised tests that do not allow for difficulties in reading comprehension and semantic processing (e.g., Minshew & Goldstein, 2001) has often limited our understanding of intra-individual performance across domains. For example, George, one of the calendar-calculating twins initially described by Horwitz, Kesterbaum, Person, and Jarvik (1965) and later by Sacks (1985), was unable to multiply 7×4, although he could calculate the total number of days in 4 weeks. The calendar-calculating savant described by Ho, Tsang, and Ho (1991) showed poor performance on the Arithmetic subtest of the WAIS

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(Wechsler Adult Intelligence Scales) but quite good performance on the Stanford Diagnostic Mathematical Test. In the Wechsler Arithmetic subtest, items are presented as story problems, whereas the Stanford Diagnostic Mathematical Test relies on the manipulation of numbers.

Related to Miller's discrepancy-based model is Treffert's (1989) splinter skill category, which would seem to be a natural consequence of the uneven cognitive profile seen in developmental disorders like autism (Happé & Frith, 1996; Rumsey, 1992) and Williams syndrome (Bellugi, Lichtenberger, Mills, Galaburda, & Korenberg, 1999). Here, specific skills might be developmentally on-line, thus fulfilling norms for chronological age, but providing a contrast with overall mental age of subjects. Treffert's formulation also extends to include talented and prodigious levels of skill, which reflect comparisons both within and across groups, in the former case to other cognitively impaired individuals and in the latter case to cognitively unimpaired talented people. Young (1995) used Treffert's criteria in her comprehensive study of 51 savants and determined that savant status should be reserved for those individuals falling in the talented and prodigious categories as outlined by Treffert. Thus, Young validates the use of across-group comparisons as appropriate measures of savant talent.

Like Miller (1998), we propose that intra-individual comparisons could be of great utility in defining the savant syndrome. However, we also propose the utilisation of other measures (instead of general intellectual functioning), such as adaptive functioning, to contrast with unexpected skills. Support for de-emphasising IQ derives from the finding that approximately 20% of individuals with autism (in whom savant skills are over-represented) score in the average range on measures of nonverbal intelligence (Volkmar & Lord, 1999), and from the fact that the majority of savants in Young's sample showed intellectual impairment at only mild to borderline levels. Although Young's study was not population-based and therefore may not extrapolate to the whole savant population, it is nevertheless the largest savant group study carried out to date. Also of relevance are reports of individuals with autism who are considered savants despite average, or above average, intellectual functioning (Heavey, Pring, & Hermelin, 1999; Young & Nettlebeck, 1995). Deficits in adaptive behaviour, which may be viewed as difficulties in 'everyday' intelligence, are commonly reported in high-functioning individuals with autistic spectrum disorders (e.g., Klin, 2000), thus validating the inclusion of such subjects within the savant category.

Crucial to defining the savant are questions regarding the extent and nature of demonstrated skills. As previously mentioned, Treffert (1989) has delineated a three-tier classification system for the differing skill levels observed. Typically, savants develop calendar calculation, memory, music, art or arithmetic skills (Hill, 1974). However, there are also reports of savants with prime number identification skills (Anderson, O'Connor, & Hermelin, 1999; Hermelin & O'Connor, 1990; Kelly, Macaruso, & Sokol, 1997), mechanical (Brink, 1980; Hoffman & Reeves, 1979; Tredgold, 1952), and linguistic skills (Dowker, Hermelin, & Pring, 1996; Smith & Tsimpli, 1995). Also of relevance in situating the savant syndrome are decisions about what constitutes a savant skill. For example, hyperlexia (for review, see Nation, 1999) generally involves a significant discrepancy between reading decoding and reading comprehension, with the former being superior (Snowling & Frith, 1986). However, hyperlexia is rarely designated as a savant skill in the extant literature, partly due to developmental factors. More specifically, this decoding skill eventually ceases to be outstanding because there is a ceiling on ability. But, in fact, at earlier points in development, hyperlexia meets criteria for a skill that is exceptional relative to overall ability (Welsh, Pennington, & Rogers, 1987), and exceptional relative to that of normally developing peers, thus satisfying requirements of the traditional savant definition. Importantly, hyperlexia is most commonly noted in autism, although it has also been observed in other developmental disorders such as speech–language impairment (Cohen, Hall, & Riccio, 1997), Williams syndrome (Bellugi, Birhle, Neville, Jernigan, & Doherty, 1992), Turner's syndrome (Temple & Carney, 1996) and idiopathic MLD (Snowling & Frith, 1986). These findings highlight the importance of utilising a uniform approach to defining savant status across domains and disorders in order to assist researchers in delineating their relevance to neurocognitive models of various developmental disorders.

Rates of occurrence

Owing to a lack of rigorous epidemiological investigations, the true prevalence of savant skills in autistic spectrum disorders and more broadly in developmental disorders is unknown. However, surveys carried out by Hill in 1977 and Rimland in 1978 provided important data regarding putative numbers of savants in intellectually impaired and autistic populations. In Hill's study, 107 institutions (out of 300 approached) for individuals with cognitive disabilities identified 54 savants, a prevalence rate of approximately .06% or 1 in every 2000 cognitively impaired residents. However, Rimland (1978) targeted parents of 5,400 children with autism, and here 531 individuals, constituting 9.8% of the autistic population, were identified as savants. This then suggests that there is a significantly greater prevalence of savants in populations of autistic as opposed to intellectually impaired individuals. However, it should be noted that the respondents in Hill's study were careworkers, whereas Rimland's respondents were parents, who might have shown a positive bias in reporting their children's skills. It is also of relevance that in the Hill (1977) study, criteria for savant status were not clearly defined and the superintendents of the various institutions screened relied on their own operational definitions and interpretations.

Another difficulty in accurately determining the co-occurrence of the savant syndrome and autism concerns changes in diagnostic criteria and practice in the past 25 years that have led to a sharp rise in numbers of individuals diagnosed with autistic spectrum disorders (Charman, 2002; Fombonne, 2002; Wing & Potter, 2002). This raises the possibility that many of the intellectually impaired savants described in the past research literature might meet current criteria for an autistic spectrum disorder. Moreover, Young (1995) observed that all of the 51 savants in her sample showed some characteristic autistic behaviours, although some had never received a formal diagnosis. Case study descriptions of savants with complex patterns of disability (e.g., congenital blindness, intellectual impairment and language disability) also frequently make reference to behavioural features commonly associated with autism (e.g., musical savants; Miller, 1989). Taken together, this evidence strongly suggests that savant talent is most closely associated with autistic spectrum disorders. However, savant talent is occasionally seen in individuals with other psychological disorders and these will be further discussed.

Savant skills and intelligence

The earliest documented cases of savants provide largely descriptive accounts of individuals then described as 'idiot-savants'. For example, Jebediah Buxton (b. 1702, reported by Smith, 1983) showed slow but impressive mental calculation abilities (see Heavey, 2003), Thomas Wiggins (b. 1849, described by Southall, 1979, 1983) was an accomplished concert pianist (see Miller, 1989) and Gottfried Mind (b. 1768) drew such realistic and detailed pictures of cats that he became known as 'The Cat's Raphael' (Hindermann, 1982). Because severe intellectual disabilities were often documented in these individuals, the unexpected presence of outstanding skills aroused significant interest. This juxtaposition of skill and disability remained a question of key theoretical interest for many years as it was believed that the idiot-savant might help elucidate the nature of intelligence. More specifically, it was thought that they might provide insights into whether a general intelligence factor (Spearman, 1927) should be discarded in favour of a model positing independent intelligences (Gardner, 1983). However, whilst researchers have attempted both to explain the savant within the context of current models of intelligence (for review, see Nettelbeck & Young, 1996) and to develop new models within which the savant can be situated (Anderson, 1998), there has been something of a change in direction and the belief that the savant can inform our understanding of the nature of intelligence has in itself become a matter of speculation. Indeed, it has been suggested that savants do not pose a challenge to current theorising about the nature of intelligence (Nettelbeck & Young, 1996) as their behaviours are not essentially intelligent (Spitz, 1995), but reflect purely localised knowledge. However, data from empirical studies (e.g., Anderson et al., 1999; Cowan, O'Connor, & Samella, 2001; Heavey et al., 1999; Hermelin & O'Connor, 1986; Miller, 1989; Mottron & Belleville, 1993, 1995; Pring & Hermelin, 1993; Pring, Hermelin, & Heavey, 1995; Young & Nettelbeck, 1994, 1995) clearly show that these skills are supported by memory and information processing mechanisms that contribute to, or underpin, general intelligence (Nettelbeck & Young, 1999). Nevertheless, it remains unclear as to whether savant skills have relevance to notions and theories of intelligence, and from the evidence so far accumulated, we are inclined to believe that savant skills are domain specific and therefore somewhat independent from general intellectual functioning. One method for examining the theoretical significance of savant skills is to utilise a neuropsychological framework in which a variety of basic cognitive processes are examined. Two of these cognitive functions are highlighted here (i.e., memory and learning), as well as prominent neuropsychological theories that seek to explain the savant syndrome.

Memory and cognitive strategies

One suggestion that has frequently been made is that savants show exceptional rote memory (Hill, 1978). However, if rote memory is defined as the veridical encoding of information, this clearly does not explain savant talents within the classical domains of music, art and calendar calculation, where greater flexibility in the manipulation of domain-specific information is essential and indeed evident in savants. For example, investigations into the musical memory of savants (Sloboda, Hermelin, & O'Connor, 1985; Young & Nettelbeck, 1995) show that whilst long-term memory is good, or indeed exceptional, reproduction of heard materials is not verbatim, and reproduction errors preserve the important structural characteristics of the compositions. Moreover, studies with calendar calculators have shown how the regularities inherent within calendars are extracted and utilised in on-line computation (Cowan et al., 2001; Heavey et al., 1999; Nettelbeck & Young, 1996; O'Connor & Hermelin, 1984, 1987a, b, 1990). Findings from investigations comparing savants and normal individuals with talents in the same domain sometimes suggest that similar mechanisms underpin skill in both groups. For example, in one study of an autistic prime number calculator, Anderson et al. (1999) found that both the savant and a trained mathematician used an algorithm described by Erastosthenes in the 3rd century. Similarly, Kelly et al. (1997) found that a calculating savant used similar computational strategies to those of normal expert calculators. In studies of art savants, participants have often been shown to apply similar graphic representational rules to those of unimpaired talented artists (O'Connor & Hermelin, 1987a, b, 1990; Pring & Hermelin, 1993; Pring et al., 1995; Selfe, 1983). However, the savant draughtsman described by Mottron and Belleville (1995) clearly used different strategies to controls in graphic reproduction. This savant began his reconstruction of the presented models by drawing details and then progressing to global outlines. This strategy has also been noted in a high-functioning child with Asperger syndrome and exceptional graphic talent (Wallace, personal communication). Given the evidence outlined above, it is clear that a categorical answer to the question of whether savants use similar or different cognitive strategies cannot be given. However, our position is that many of the information processing mechanisms crucial to performance within savant domains are spared in autism. For example, intact recognition of patterns or artificial grammars has been noted in autism (Klinger, Lee, Bush, Klinger, & Crump, 2001). Such abilities might well be crucial and provide building blocks for knowledge acquisition within the domains of music and number. We also believe that a detail-focused information processing style, characteristic of autism (Happé, 1999), but acquired by typically developing people during specialist training, advantages those with autism. Indeed, we propose that this cognitive style best explains the overrepresentation of individuals with this disorder in savant populations. Taking the example of the most prevalent neurodevelopmental disorder, Down syndrome, where savant skills are not widely reported, we see an exaggeration of the normal tendency to process stimuli globally. In a study by Bellugi and colleagues (Bellugi, Birhle, Jerningham, Trauner, & Doherty, 1990), participants with Down syndrome produced drawings that were globally coherent but were weak on internal detail. In contrast, a group of subjects with Williams syndrome reproduced details but neglected global outlines. Individuals with Williams syndrome typically show the lowest sub-test performance on the Block Design task from the Weschler Intelligence scales (Udwin & Yule, 1991; Bellugi, Wang, & Jernigan, 1994). This task requires subjects to perceptually segment visually presented designs in a way that corresponds to a set of patterned blocks, which are then used to replicate the design. Thus good performance on the task requires both the disembedding and coherent reformulation of visual segments. Repeatedly, studies examining performance on the Weschler Intelligence Scales by subjects with autism (Happé, 1994; Rumsey, 1992) have found that the most frequent peak sub-test score occurred on the Block Design task. This suggests that in autism, unlike Down and Williams syndromes, both disembedding and reformulation abilities are intact. The savant artists previously described apply a local processing strategy in picture production but are nevertheless able to produce output that is globally intact. Thus, whilst processing strategies are strongly featurally biased, this does not appear to convey a disadvantage within savant talent domains.

Whilst the question of similarities and dissimilarities in cognitive strategies between savants and other gifted individuals may be controversial, it is nevertheless clear that savant skills do not solely rely on rote memory but instead reflect an enhanced or spared ability to represent and manipulate highly organised domain-specific information.

On standardised tests of memory savants do not tend to show generally good levels of performance (Howe, 1989). However, as previously suggested, tests relying on intact comprehension and semantic encoding skills may not be appropriate tools for probing savant memory, especially where there is a diagnosis of autism (Nettelbeck & Young, 1999). Digit span is sometimes seen as a measure of short-term memory (Jackson & Warrington, 1986), and some investigators (Duckett, 1976; Spitz & LaFontaine, 1973) have found that calendar calculators display better sub-test performance for digit span than would be predicted from full-scale IQ. However, this finding was not replicated in the sample of calendar-calculating savants described by Heavey (1997). Similarly, memory performance on tests where stimuli reflect the savant domain has been found to be good in some studies (Valentine & Wilding, 1994; Heavey, 1997) but not in others (Young, 1995). However, despite this lack of consensus, it remains the case that anecdotal reports of savants invariably describe outstanding memory abilities and it may be that methodological limitations rather than truly unexceptional memory accounts for this lack of experimental validation. For example, in Young's (1995) sample of individuals with savant and splinter skills, 37 of 39 parents reported precocious levels of memory. On a standardised measure, the Wechsler Memory Scales-Revised, Young found elevated performance on the Delayed Memory Quotient, indicating good recall for well-encoded information. Based on these findings, Nettelbeck and Young (1996) suggest that declarative (rote) memory, facilitated by an ability to make associations, is essential for savant skills. Converging evidence therefore suggests that memory is an important cognitive component of savant skill.

Indeed, exceptional memory may in itself constitute a savant talent (e.g., Mottron, Belleville, Stip, & Morasse, 1998).

Explicit and implicit learning

In savants with the diagnosis of autism, language and communication impairments severely curtail their ability to profit from explicit instruction. In addition to these difficulties, intellectual impairment is found in the majority of individuals with autism spectrum disorders (Volkmar & Lord, 1999). Indeed, studies of individuals without autism but with intellectual impairment and/or Down syndrome have shown deficits in explicit learning in comparison to controls (Carlesimo, Marotta, & Vicari, 1997), so this difficulty appears to be a general outcome of intellectual impairment. However, performance on tasks of implicit learning reveals quite a different pattern. Generally, individual differences within normal populations on tasks of implicit learning are smaller than those seen on explicit learning tasks (Reber, Walkenfeld, & Hernstadt, 1991) and performance on some implicit learning tasks appears to be relatively unaffected by intellectual impairment (Ellis, Palmer, & Reeves, 1988). For example, in a study testing implicit memory for spatial location (Ellis, Woodley-Zanthos, & Dulaney, 1989) in college students and cognitively impaired individuals, group differences emerged only when IQ fell below 47. The 51 savants included in Young's (1995) sample had IQ scores ranging from 50 to 114. If, as this evidence suggests, the majority of savants for whom IQ data is available show impairment in the mild to borderline categories, it may be that implicit learning mechanisms are unimpaired in savants. Of relevance to this question are findings showing intact implicit memory in subjects with autism and Asperger syndrome (Bowler, Matthews, & Gardiner, 1997; Kamio & Toichi, 2000; Renner, Klinger, & Klinger, 2000; Toichi & Kamio, 2001). Given these findings, the development or adaptation of current implicit learning paradigms in order to investigate domain-general and domain-specific implicit learning in savants could provide a fruitful focus for future research.

An important commonality amongst the various savant skill areas is high internal structure (Miller, 1989) and we believe that this is potentially relevant to our understanding of the savant syndrome. Each of these domains has rules that govern the application of skills, and previous work (Heavey et al., 1999; Miller, 1989; Nettelbeck & Young, 1996; O'Connor & Hermelin, 1984, 1987a, b, 1990; Sloboda et al., 1985) has alluded to the importance of organised, rule-based knowledge in savants. If we take the example of harmonic structure in music, we know that the rules governing key relations are predictable and invariant and can be acquired by very young children without explicit musical instruction (Sloboda, 1985). If, in intellectual impairment and in autism, implicit learning is largely spared, and the highly structured nature of savant domains makes them optimally amenable to implicit learning, it may be that mechanisms involved in knowledge acquisition in these domains do not distinguish intellectually impaired from normally developing groups and no special explanation for these skills needs to be invoked. However, it also seems unlikely that differences between savants and similarly talented normally developing individuals, at both cognitive and behavioural levels, will not exert some qualitative influence on manifested talent. An important research question concerns the high preponderance of autistic individuals in savant samples. Therefore, in the following sections, theoretical models of the savant syndrome will be outlined and evaluated within the context of our current understanding of cognitive characteristics well documented in autistic spectrum disorders.

Autism and savants: cognitive neuropsychological accounts

Psychological accounts of autism, such as the executive function (Russell, 1997) and theory of mind (Baron-Cohen, Tager-Flusberg, & Cohen, 2000) hypotheses, have historically focused upon and addressed deficits observed in these individuals. However, one notable exception to this trend, Weak Central Coherence theory (WCC) (Frith, 1989; Happé, 1999), directly addresses the question of why splinter and savant skills should preferentially emerge in autism. WCC proposes that autism is characterised by a cognitive style that biases processing in favour of local features over global, context-dependent meaning or Gestalt (Happé, 1999) and predicts that enhanced performance will be found on tasks where good featural processing conveys an advantage. In line with these predictions, Heaton, Hermelin, and Pring (1998), Heavey et al. (1999) and Hermelin (2001) have argued that a tendency towards featural processing can be advantageous to savants at the early stages of knowledge acquisition as it facilitates accurate memory for the individual elements upon which increasingly highly structured information is based.

Studies into visual perception have shown that people with autism have increased sensitivity to unique features in visual stimuli, but difficulties in recognising shared features between stimuli (Plaisted, O'Riordan, & Baron-Cohen, 1998). Therefore, Plaisted (2001) has hypothesised that difficulties in perceiving shared features between stimuli result in deficient categorisation and generalisation, both commonly observed phenomena in autism. However, the extent to which such problems are evident within savant domains has yet to be demonstrated.

Experimental evidence has shown that non-savant children with autism are as able as normally developing children to categorise music into major and minor modes (Heaton, Hermelin, & Pring, 1999) and musical savants demonstrate an ability to generalise melodies when they transpose them from one key to another (Miller, 1989). Similarly, calendar-calculating savants are able to generalise knowledge about corresponding months and years when generating dates in the future (Heavey, 1997). However, given the difficulty of knowing how such terms can be operationalised within savant domains, the existence of such deficits remains unproved.

Another promising and early perceptual-level account for special skills was put forward by Waterhouse (1988). Her ideas arose in response to the failure of theoretical models of intelligence to account for these special skills. Importantly, Waterhouse proposed that special cognitive talents and abilities in savants are qualitatively different from those of typical individuals. She believed that they were separate in source from human intelligence and therefore did not represent end points of the normal distribution of various skill areas. Specifically, she proposed that special skills derive from a preconscious and specific set of memory and processing mechanisms that facilitate 'acutely accurate and extremely extensive representation of visual images and sounds' and allow 'the rapid recognition and facile manipulation of patterns involving those visual and auditory representations' (Waterhouse, 1988). According to the model, the savant may both generate and elaborate upon these complex mental representations, but also see or hear complex patterns embedded within relevant visual or auditory stimuli. Similar to our argument, Waterhouse highlights the importance of the induction of regularities or of structural elements within various perceptual systems by savants. According to Waterhouse, special skill development is genetically driven and brain-based, via cortical rededication. Presumably, for special skills in the context of autism, areas of cortex (or significant portions of these areas) usually devoted to social functioning would be reallocated to perceptual pattern recognition. Consequently, this functional rededication would result in superior performance on perceptual pattern recognition tasks and correspondingly poor performance on tasks of social cognition.

During the same time frame, Treffert (1989) also proposed a neurologically mediated multi-factor model of savant skills. Brain-based factors include compensatory right-hemisphere functioning after left-hemisphere damage and reliance upon lower-level procedural memory due to damage to higher-level (e.g., semantic) memory circuitry. The effortless, automatic nature of savant skills and the intact aspects of memory functioning are noted and proposed to be necessary but not sufficient for savant skill development. Treffert also notes the restricted range of savant talent domains and utilises the results of various neuropsychological studies to demonstrate that these skills are mediated (at least to a significant degree) by the right hemisphere. Thus the importance of the nature of, and commonality between, these domains is highlighted. An additional element to this model is the focus upon the single-mindedness of savants for the skill area in question. Thus concentration, repetition, and practice are considered to be important and reinforcing for the maintenance and elaboration of skills. In an attempt to explain the preponderance of savant skills in autism, Treffert drew on research suggesting that right-hemisphere functioning, at least as relevant to savant domains, and procedural memory are generally intact in autism. However, importantly, Treffert makes a clear demarcation in his model by requiring that the action of genetic factors are reserved for only the most exceptional, i.e., prodigious, savants. Therefore, whilst there are multiple paths to the end points of splinter skill or talented-level savant skill expression, one does not reach prodigious levels of performance without a significant genetic predisposition.

In the most recent theoretical account of savant skill development, Mottron and Burack (2001) have outlined a model proposing enhanced perceptual functioning in autism. According to this model, lower- and higher-level processing mechanisms are dichotomously grouped, with low-level mechanisms being domain specific and neurally specified and higher-level mechanisms being domain general and distributed across several brain regions. These authors suggest that people with autism show over-development of low-level perceptual abilities at the cost of high-level processing mechanisms. Thus, it is postulated that autistic splinter and savant skills will involve operations that are largely perceptual, with the proviso that they can include different modalities or the simple operations of associating, combining and matching on tracks of visual or auditory stimuli. A major strength of this model is that it takes a developmental approach, whereby an early, unspecified cognitive deficit results in an enhanced cognitive operation via compensatory action. This subsequently improved aspect of cognitive functioning becomes increasingly over-trained and heavily researched, leading to the development of a restricted interest. Moreover, citing the example of excellent spatial orientation in autism, these authors conclude that their model has distinct advantages over WCC theory since this domain of functioning does not on the surface require featural processing.

In summary, the savant theories proposed by Waterhouse, Treffert and Mottron and Burack all highlight highly efficient computational abilities operating on domain-specific material. However, Birbaumer (1999) and his colleagues (Pauli, Lutzenberger, Birbaumer, Rickard, & Bourne, 1996) have shown that arithmetic calculation becomes automatically and rapidly processed in typical individuals as a result of extensive practice. Thus, according to some accounts, savant skill is simply one outcome of over-training or practice (Ericsson & Faivre, 1988). However, a major limitation of measuring outcome is that it fails to provide insights into the question of whether an innate facility (talent) for working with specific types of domain-relevant information contributes to savant skill development.

Furthermore, despite its obvious strengths, Mottron and Burack's proposal that savant abilities never include aspects of relative weakness among persons with autism fails to account for several individuals described in the savant literature. For example, Smith and Tsimpli (1995) have described one savant who shows outstanding foreign language acquisition abilities, and Dowker et al. (1996) have described a savant poet. There are also examples of autistic savants who are very sensitive to the affective dimensions within their talent domain. For example, Richard Wawro, the savant artist described by Hermelin, Pring, Buhler, Wolff, and Heaton (1999), is very sensitive to colour, and in his compositions he changes and intensifies colours in order to manipulate overall mood. It may then be the case that language and affect processing deficits, characteristic of autism, exert less influence within savant domains. The question of domain-specific sparing of affect perception will be further discussed.

A striking weakness in many theoretical accounts of savants is that they fail to allow for the wide variation in manifested ability in savants. Although Treffert highlighted variations in talent in his model, the evaluation of output (music/art) by individuals with sufficient expertise within the relevant savant domains is rarely carried out, and reliable qualitative data on manifested talent is not available. In line with Treffert, we propose that splinter skills, talented and prodigious levels of talent can be identified, and further suggest that the genesis of such abilities can also be distinguished. As previously suggested, we believe that splinter skills arise as a function of the cognitive style characteristic of autism (Happé, 1999). Thus skills dependent on good visual and auditory discrimination will be fairly common in autism. As this information processing style will also characterise cognition in talented and prodigious savants, they may develop splinter skills in areas outside of their talent domains. For example, the savant artists Stephen and Claudia both possess outstanding pitch discrimination and memory abilities. However, we propose that within their talent domains savants will differ from individuals with splinter skills in several important ways. First, they will show a highly focused interest in a specific area, for example, music, art or number. Second, they will demonstrate an ability to manipulate domain-specific information in order to generate their own output. Thus, whilst a good memory for dates, commonly seen in autism, would constitute a splinter skill, a talented savant will have acquired calendar knowledge which can be extrapolated to the past and the future. Taking the example of music, Heaton et al. (1999) reported the case of an adolescent with Asperger syndrome and exceptional musical splinter skills. On tasks of pitch, interval and contour discrimination the subject's performance scores were frequently at ceiling. However, he had not developed skills for musical performance, and though his abilities were outstanding, they were perceptual and analytic in nature.

We propose that differences between talented and prodigious savants are reflected in qualitative differences in output, the identification of which necessitates cross-disciplinary collaboration. When specialist evaluations of savant output are carried out, for example when Sir Hugh Casson examined the work of the savant artist Stephen Wiltshire, prodigious talent is sometimes identified. We therefore suggest that the superiority of prodigious savants is a result of inherent talent, dependent upon genetic factors.

The notion of talent as a psychological and scientific construct has been the subject of considerable debate (Howe, Davidson, & Sloboda, 1998). However, Simonton (2001) has recently proposed an emergenic-epigenetic model of talent development that we believe provides a useful framework for theorising about the savant syndrome. According to this model, talent is not contingent upon a single trait but depends on cognitive, dispositional, physical and physiological components which operate in a multiplicative way to facilitate the manifestation of superior expertise within domains. Talent domains can make simple or complex demands, thereby varying in the number of essential components needed for talent realisation. Thus, whilst physical and physiological components will be far less important for the development of calendar or numerical skill than for piano playing, cognitive and dispositional components may make similar demands across music and number domains. A major strength of this model, when applied to savants, is that it is able to account for the observed variations in levels of talent manifestation. Specifically, these relate to levels of development, under genetic control, of specific talent components and the interactions between them. Furthermore, the model also allows for heterogeneity among skill profiles that result in similar levels of overall talent manifestation. So whilst the savant artist Stephen (Hermelin, 2001) demonstrates a good sense of form and detail, Richard (Hermelin et al., 1999; Hermelin, 2001) shows strengths in the creative use of colour. We therefore subscribe to Simonton's talent model and propose that whilst preserved or enhanced perceptual/cognitive mechanisms are necessary conditions for certain types of savant talent realisation, they are not in themselves sufficient for it.

Deficits in executive functions have been documented in autistic savants (Steel, Gorman, & Flexman, 1984; Rumsey, Mannheim, Aquino, Gordon, & Hibbs, 1992; Mottron, Peretz, Belleville, & Rouleau, 1999); however, there is an obvious confound as to the specificity of the executive dysfunction. Unfortunately, from the limited evidence, it is unclear as to whether the executive dysfunction is the result of the presence of an autistic spectrum disorder, in which executive functioning is a robustly documented deficit (e.g., Ozonoff, 1995; Rumsey & Hamburger, 1988), or whether it is integral to the cognitive landscape of the savant syndrome. Generativity or fluency is one subdomain of executive functioning, which has been demonstrated as deficient in autistic spectrum disorders (Dunn, Gomes, & Sebastian, 1996; Turner, 1999). However, consistent with the ideas of limitations for measuring cognitive mechanisms, valid assessment of executive functioning, particularly generativity, requires both domain-specific and domain-general assessment. Of relevance here are studies by Ryder, Pring, and Hermelin (1999) comparing autistic savant artists to control groups of normal art students, individuals with autism and those with moderate learning difficulties. Findings from these studies demonstrate that on tasks of design fluency and visual synthesis, autistic savants showed as severe a fluency deficit as non-savant autistic controls. However, on the Torrence Test of Creative Thinking the output of the autistic savants was more elaborate than that of the two IQ-matched control groups (individuals with autism and those with moderate learning difficulties), and on the visual synthesis task originality scores equalled those of gifted art students. Thus, whilst these autistic savants showed a pervasive fluency deficit characteristic of autism, they were nevertheless able to produce highly elaborated and original responses within their talent domain.

Affect perception, savants and autism

Whilst a lack of expressiveness in music and art productions has sometimes been reported in savants (O'Connell, 1974), this is certainly not always the case (Selfe, 1977; Miller, 1989; Hermelin et al., 1999). Both early and recent accounts of autism (Kanner, 1943; Hobson, 1989) have proposed core affective and interpersonal deficits in autism. Children with autism often show difficulties in understanding social emotions (e.g., pride and embarrassment), although they report personal experiences of emotions as frequently as normally developing children and are also able to understand the primary emotions of happiness and sadness (see chapter by Kasari, Chamberlain, & Bauminger, 2001). The savant domains of music and art are rich in affective content and questions regarding the extent to which affect processing difficulties characteristic of autism generalise into these domains is important in the current context. A recent study (Heaton, Happé, Williams, & Cummins, 2003) attempted to cast some light on this question. In this study, non-savant children with autism were required to match excerpts of orchestral pieces to visual images depicting the affective categories of love, triumph, fear and anger. The results showed that low-functioning children with autism performed as well as normally developing children matched for verbal mental age and high-functioning children with autism performed at levels that were consistent with chronological age. Correlations between scores for music/emotion identification and a task of social emotion identification (Baron-Cohen, Wheelwright, Scahill, Lawson, & Spong, 2001) were non-significant. Given that the limited research to date provides more evidence for domain-specific sparing than for a domain-general deficit, it cannot be assumed that affect processing difficulties in interpersonal and social domains necessarily generalise into the savant talent domains of music and art.

Obsessions and restricted interests

By definition, individuals with autism show obsessive and restricted interests (APA, 1994). Whilst this tendency to engage in repetitive activity in narrowly focused areas is generally disadvantageous for people with autism, in that it gives rise to a restricted repertoire of behaviour and experience, this may not always be the case. For example, if this tendency co-occurs with other cognitive, emotional and/or physical talent components, it may serve to function as a motivational trait (Simonton, 2001), thereby enhancing the probability of talent emergence. Asperger (1991), who along with Kanner (1943) first described the autistic disorder, proposed that the personality characteristics exhibited by his patients could facilitate high-level skill development. Indeed, one of Asperger's patients was a successful composer. Several lines of evidence support the view that obsessions and restricted interests might play a role in the development of savant talent. First, although individuals with autism represent a relatively small proportion of the cognitively impaired population, the majority of talented, but cognitively impaired individuals have been diagnosed with autism. Second, in cases where savant talents are reported in individuals without autism, they frequently have developmental or acquired disorders that include obsessive behaviours and/or restricted interests as clinical features (e.g., Tourette's syndrome and frontotemporal dementia). Finally, mild autistic features have been noted in some professional groups, for example musicians with absolute pitch (Brown et al., 2003), who are noted for high achievement. Therefore, converging evidence highlights the significance of obsessive and restrictive interests in the development of savant talent, both in and out of the context of autistic spectrum disorders.

The presence of savant skills in other groups

Traditionally, specific disorders/conditions associated with savant skills have been limited to autistic spectrum disorders and visual impairment. However, other disorders have been noted to co-occur with unexpected skills and they too may inform our understanding of the savant syndrome. For example, DeLong and Aldershof (1988) described a group of clinically referred children with manic-depressive illness and special skills. Although the group included children with average to above-average intelligence, they all exhibited autistic-like symptoms, with repetitive and obsessive-compulsive behaviours being most common. This behavioural expression stands in stark contrast to the nonsavant manic-depressive children in their sample who did not demonstrate such tendencies. Although savant skills in individuals with this disorder have not been widely reported in the extant literature, support for this co-occurrence derives from the long and continuing history documenting manic-depressive disorder in adults with exceptional creative talents (e.g., Andreasen, 1987).

Another disorder occasionally mentioned in the savant literature is Gilles de la Tourette's Syndrome (GTS), a neurodevelopmental disorder resulting in a variety of tics and/or echolalia and coprolalia. Significantly, autism is more prevalent in GTS than would be expected from population base rates alone (Baron-Cohen, Mortimore, Moriarty, Izaguirre, & Robertson, 1999). Thus, it is not surprising that a number of savant case studies document the presence of GTS (e.g., Nelson & Pribor, 1993), sometimes without a diagnosis of autism, but with the shared traits that may be important for the development of savant skills (e.g., obsessive-compulsive behaviours/tendencies). There is at least one recorded case of a calendar-calculating savant with GTS (Moriarty, Ring, & Robertson, 1993) who does not appear to show behaviours associated with autism. However, given that this case was described before the widespread recognition of Asperger syndrome, and that detailed clinical data are not provided, it is difficult to rule out any autistic-like tendencies.

A striking development, which may have pertinence to understanding savant skills, is the documentation of multiple cases of emerging and/or preserved artistic and other skills in the context of dementia (Miller, Ponton, Benson, Cummings, & Mena, 1996; Miller et al., 1998). Unlike the previously provided examples of developmental disorders, these unexpected skills occur in the presence of an adult-onset disorder, frontotemporal dementia (FTD). This particular type of dementia is a progressively degenerative disorder isolated to the anterior temporal and prefrontal neuroanatomical regions, resulting in dramatic behavioural changes, the most characteristic of which are social in nature. Expression of these social deficits can be quite variable, from frank antisocial behaviour to a lack of social awareness and empathy. Other symptoms may include hyperorality, stereotypies, extreme distractibility, or obsessive-compulsive behaviours.

As the dementia progresses, these individuals' interest in their skill area becomes increasingly restricted. Social, cognitive, and adaptive skills deteriorate simultaneously, resulting in negligence of occupational and personal responsibilities in favour of focus on the skill area (Miller, Boone, Cummings, Read, & Mishkin, 2000). Moreover, the cognitive style of these individuals reflects an increasing interest in the details of various auditory and visual stimuli. Importantly, the above-mentioned attributes bring to mind characteristics of autistic spectrum disorders, particularly their preponderance for restricted interests (APA, 1994) and for a featurally biased information processing style (Happé, 1999).

Individuals with savant skills who have been diagnosed with the diverse set of disorders described above clearly show cognitive features and behavioural traits characteristic of autism. We thus conclude that these traits are crucially important and facilitating for savant skill development, both within and outside of the context of autism.

Summary

In this annotation we have attempted to draw together a variety of experimental findings and theoretical accounts of the savant syndrome. We have outlined evidence suggesting that the savant syndrome is most closely associated with autism, although we have also considered savant talents in individuals with other clinical disorders. In order to accommodate findings of outstanding talents in autistic individuals without cognitive impairment, we have proposed that functional impairments may be contrasted with skills in these cases. In evaluating issues relating to intelligence in savants we have concluded that global measures of intelligence, derived from standardised IQ tests, fail to provide insight into the savant syndrome. However, specific cognitive mechanisms, underpinning intelligence and spared in autism (Anderson, 1998), are proposed to be necessary for skill development in savants. We have briefly reviewed neuropsychological accounts of autism that provide potentially important insights into information processing in savants, although we also present evidence suggesting that deficits in creativity and affect processing characteristic of autism may be less applicable to savants, particularly within their talent domains. In line with Treffert (1989), we propose that innate talent is a necessary condition for the development of prodigious savant skill. Utilising a model of talent development delineated by Simonton (2001), we propose that traits predisposing individuals towards highly focused attention within specific domains facilitate high-level achievement in those with both developmental and late-onset disorders.

Interest in savants has a long history, stretching back to the early 18th century; nevertheless, the savant syndrome remains as much a mystery now as it did when it was first described. Given that many questions about the existence and nature of savant talent remain unanswered, it seems likely that research efforts will continue unabated.

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