THE STRUCTURED REPRESENTATION OF INFORMATION IN LONG-TERM MEMORY: A POSSIBLE EXPLANATION FOR THE ACCOMPLISHMENTS OF "IDIOTS SAVANTS"

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Abstract — Traditional accounts of the "idiot savant" — the development of a superior skill in otherwise subnormal individuals — are challenged through the examination of two cases, a pair of twins with extraordinary numerical ability but otherwise moronic, and Nadia, an autistic girl with extraordinary drawing ability. It is suggested that these phenomenal but particular skills are due to the functional reallocation of representational space in long-term memory. The hierarchical schematic organisation of the mnemonic space, normally used for a range of conventional skills such as language, is employed instead for the hypertrophy of one particular skill. What may appear to be feats of rapid calculation or artistic creativity actually represent automatic routings through long-term memory and translation into motor activity, possibly attributable to an unorthodox context of socialisation and social interaction. Evidence from such cases therefore proves to be inconclusive with regard to determining the nature of intelligence.

Cases are occasionally reported of individuals with specific skills developed to such an extent that they appear to be outside the usual continua of human accomplishment. Sometimes the skills are developed by people of normal or superior intelligence (Hunter, 1962: Smith, 1983), sometimes in people who otherwise appear markedly subnormal. Most often the skill involves memorising information or apparently rapid calculation; the classical example is the individual who can rapidly calculate what day of the week a certain date years away will fall on. Rarer are exceptional musical talents and rarer still (Selfe, 1977) are drawing or painting talents. Since generalisations about the abilities of "idiots savants" are all but worthless, I shall briefly describe two of the most exceptional cases, to serve as a challenge for theoretical explanation and a focus for the arguments to follow.

The first case is of a pair of twins. These twins possess extensive recall ability for the events of their lives, and numerical skills including calendar calculation (Horowitz, Kestenbaum, Person & Jarvik, 1965; Sacks, 1985; Smith, 1989). One of the twins was an accurate calendar calculator with a range of 45,000 years, mostly into the future (apparently acquired with the aid of extensive study of a perpetual calendar from the age of six). They can repeat a series of 300 or more digits (Sacks, 1985). They also possess what seems to be an intuitive appreciation not only of numbers but also of mathematical properties such as primeness. According to Sacks, on one occasion when a box of matches fell to the floor both twins immediately cried out "111," which Sacks later verified as the number of matches spilled. Then, one after the other, they called out "37," "37," "37,"
which happens to be not only one-third of 111 but also a prime number. Sacks also found them engaged in a “conversation” which consisted entirely of the exchange of six-digit numbers, which Sacks later discovered were all primed. With a little prompting they were able to work their way up to 20 digit numbers, though Sacks does not report how many of these were primes. Sacks comments that this exchange seemed to be a source of pleasure. In other respects the twins functioned at moronic level, and indeed were scarcely able to add or subtract.

A rather different case is that of Nadia (Selfe, 1977), a girl diagnosed as autistic who had an extraordinary drawing ability. In drawing, but not in other activities, she had highly developed motor control even at the age of four. In her drawings she paid attention to those features, such as faces, that receive attention from intelligent children; she had as early as four a sophisticated command of pictorial perspective and foreshortening, which normally appear in adolescence. Both Newson (1977) and Selfe (1977, especially chapters 4 & 5 make it clear that Nadia’s skills lie entirely beyond what is possible for a normal child. Newson describes Nadia as “a child who turns upside down all our notions of graphic representation.” (p. 1)

It is hard to give an impression of the quality, vigour and assuredness of Nadia’s drawing without reproducing an example. It is worth noting, however, that her method of drawing was quite unlike that of a normal child. In a videotape, she draws a horse by starting with a line for the neck and mane, then proceeds to the front of the neck and chest. The head, connecting these two areas, is drawn later, rather than first as would be usual.

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Theories have been proposed to explain such talents. In the case of calendar calculators, it has been suggested that they possess some algorithm known or unknown to mathematicians. Some theories of calculation, and the methods of mathematicians such as Aitken (see also Hunter, 1962) have been described by Smith (1983). Sacks (1985) quotes Rosenfeld describing a method the twins could use. For calendar calculation, one starts by working out the number of days and the given date (which is the number of whole years times 365 plus the remaining number of days, including leap years), and divides the result by seven. If there is no remainder, it is today’s day; if there is one remaining, it is yesterday’s day, and so on. Whether the twins could use this method, in view of the fact that they seem to have no concept of division, is doubtful. Also it would explain only one aspect of their abilities: it does not explain how they count matchsticks in a flash, or compute primes.

One possible source of a calculating skill could be an “atypical focalised habit system” (Jones, 1926). Essentially, a person even of poor intelligence could develop a skill by obsessive concentration on what is involved in it, to the exclusion of other activities. The twins, and some other calendar calculators, do show obsessive tendencies, and appear to live in a world composed of little other than numbers. Nadia, however, showed little persistence and drew relatively infrequently; also her skill was supposed to have emerged almost fully fledged at the first attempt, or at least developed very rapidly. Obsessive tendencies may be
part of the explanation, but are not sufficient to explain how the feats described are performed, or what is acquired as a result of the obsession.

It has also been suggested that idiots savants may be aided by eidetic memories — complete and literal visual memory for a percept which can be retrieved and scanned at will. Some calendar calculators do seem to rely on memory, eidetic or not, but eidetic memory cannot explain all facets of either the twins or Nadia. Again, it does not explain instant counting of matches; nor does it explain the skilled re-interpretation and creation in Nadia's drawings. Moreover, if an idiot savant has an eidetic memory, why does it not help them with tasks and skills other than the one thing they are good at?

While all of these ideas may help to explain some cases, none of them is a complete explanation, and none even provides a necessary condition for idiot savants skills. All involve memory in some form, however, and it is the concept of memory that will form the theme of the remainder of this discussion.

**REPRESENTATIONAL SPACE AND SCHEMAS**

Let us begin with some general observations. What makes the twins and Nadia seem remarkable is the particular skill they have — specifically the fact that it is one that is not part and parcel of "normal" development. Yet it can be argued that we all do have the same general skill, but that it operates upon different particulars. One set of skills that normal people develop is that to do with language, both comprehension and production. Because this set of skills is both universal and mainly automatic we tend to have little appreciation of what is remarkable about it. Some simple examples will show, however, that we can do things with language that are broadly similar to what the twins do with numbers, and Nadia with drawings.

Miller (1962) gives an example originally designed to show that what we are aware of tends to be the product of a mental process, rather than the process itself. He asks: "What is your mother's name?" When the answer is given, he asks "How did you think of that?" Usually people are unable to answer the latter question and say that it just came to them. Both Smith (1983) and Sacks (1985) observe that the twins give similar reports about their performances; for example that they just "see" the answer. Miller chose a very elementary task, but a great deal is involved in it, nonetheless. There are countless entries in long-term memory, among them at least several thousand words; yet the correct word is reliably retrieved within a fraction of a second, much less time than it would take to look up a word in a dictionary. Somehow, Miller's first question triggers the activation or retrieval of a specific entry in long-term memory with great rapidity. Events in the world have the same power. When we see a train we can immediately cry out "train!" and then, if we wish, "engine," "carriage," "carriage". Small children often do this, and it is a skill that requires both the selection and analysis of information in input, and the use of that information in the same rapid, accurate retrieval process.

We have at least two other skills with words that are of a similar nature. One is the retrieval of a word that has some kind of similarity with a given word, which we can accomplish at will or on command. Associations can be by acoustic
similarity ("butterfly" — "flutter-by"), semantic similarity ("butterfly" — "moth"), category membership ("butterfly" — "red-admiral"), functional relatedness ("butterfly" — "caterpillar"), and so on. The other skill is the construction, by means of a set of rules, of strings of words in well-formed sentences and longer utterances. Both of these skills are also rapid, fluent and at least partly automatic; we are unable to provide informative reports on how they are accomplished.

A common view among psychologists working in the area of memory is that these skills are partly enabled by the presence of stable "knowledge" structures, often referred to as "schemas" or "schemata" (Bartlett, 1932; Rumelhart, 1984). A knowledge structure is an abstract frame for the representation of information; units of information are related to each other in ways defined by their location in the structure. Thus, rather than a mere collection of entries, long-term memory is a hierarchically and heterarchically organised store, in which relations between items are functionally relevant to retrieval and retrieval-related processes. For example one might have a schema for "living things" organised in a hierarchy of category membership relations. Under "animals" might come a set of entries for different classes of the animal kingdom; under one of these ("insects") might come "butterfly", among others; and under "butterfly" a set of types of butterfly. Orthogonal to but interpenetrating that might be a knowledge structure representing information about life cycles or stages of growth; this structure could also include an entry for "butterfly," but in relation to such entries as "caterpillar," "pupa," "metamorphosis," "mating on the wing," etc. Such structures are not merely collections of labels, of course: the labels are markers for concepts. But part of the meaning of a concept is derived from its location in a structure and relation to other items in the same structure. The properties of knowledge structures are still under investigation: fuller accounts of theoretical possibilities can be found in Minsky (1975), Rumelhart (1984) and others.

Essentially, then, a retrieval operation involves guidance to the correct entry by means of the structural nature of stored information. Likewise, existing knowledge structures can play a role in the analysis of information from perceptual input, so that some people can correctly identify a piece of music from the first chord alone, others can recognise a face and retrieve information about the personality of its owner, and others can interpret the positions and movements of players on a football field so as to select almost instantaneously an advantageous pass. Exactly what kind and degree of skill one has at these activities depends upon not only what items of information are in long-term memory but more importantly on how they are organised. For example, it is type of organisation of stored information, more than anything else, that distinguishes a great chess player from an ordinary one (De Groot, 1965).

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The only necessary characteristics of the representational space in long-term memory are that it be very large and that it be capable of representing a variety
of specific types of relation between entries in an organised manner. Thus, a region that might be used for verbal language skills, or perhaps musical skills, in most people, would also be capable of being used for number skills or drawing skills. It is the main proposal of this paper that in idiot savants the representational spaces that are normally used for language or possibly music skills are used instead partly or wholly for the skill the idiot savant develops.

In support of this contention, Selfe notes that Nadia had virtually no language. She spoke a handful of words, and could comprehend a small number of simple instructions. Typically for an autistic child, she avoided social interaction and had little in the way of social skills. In a postscript to Selfe's account, Newson describes Nadia's progress in a special school between the ages of seven and nine. Her verbal and social skills improved and more spontaneous and complex speech began to occur, as well as simple sentences. At the same time, her drawing skill began to regress: although still superior to that of most normal children it was, as Newson puts it, "no longer . . . unbelievable." One possible explanation for this is that portions of the representational space were being functionally re-allocated to verbal language from drawing. This hypothesis would explain why these extraordinary skills occur most often in individuals of otherwise limited or subnormal cognitive development: it is only in someone with few other skills that there is "room" for the development of one skill to such pitch, or, conversely, development of that one skill leaves little room for others that we regard as "normal." By "room" one means not so much a limitation on space per se as, probably, a limitation on the speed with which things can be put into that space in an organised fashion. The twins have more language than Nadia, but function in general at an I.Q. level of around 60, and have poorly developed social skills.

This is incidental evidence. The important question is that of how the devotion of a large section of long-term memory to one skill could explain the observed performances of these individuals. Let us begin with the twins. Numbers have the advantage of being simple and distinct entities with easily relatable properties — for example all numbers ending in zero can be related by that common feature with no ambiguity or uncertainty. This may help to explain why number skills are more common among idiots savants than drawing skills.

With numbers, as with words, complex organised representations can be built up on a few simple relational properties. The most basic must be the learning of the digit sequence 0, 1, 2, 3 . . . and the fact that these represent an ordered series. A number of features can be erected on this basis. Probably the most important is what may be called the addition series. The most elementary addition series is expressed by the rule "add 1." This rule defines a route through the digit sequence which can be traced by serial applications of the rule. The effective realisation that the difference between 2 and 3 is the same as that between 3 and 4, etc., is an important first step in the mastery of number concepts because it is a simple and basic relational principle. Once an addition series is established as a route, it can be traced in either direction: tracing backwards can of course be expressed by the rule "subtract 1."

Out of this can develop less basic addition functions such as "add 7." This, in
conjunction with a starting-point (most usually zero), also defines an addition series and a potential route which can be traced through the digit sequence. It can become, in effect, an organisational principle. The operation of addition is then nothing more than the tracing of the route through the representational space. No calculation need be involved. Moreover, each number in the store can be tagged with its addition series membership: in retrieving "49," for example, one can also retrieve the fact that it is a member of the "add 7" sequence without having to trace the entire route from 0 to 49. Addition series will be used in an attempt to explain some of the twins' abilities.

One feature of schemas noted by Rumelhart (1984) is that they may be, in his terms, either conceptually-driven or data-driven. That is, one may proceed from the activation of a higher-order element to activation of elements subsumed under it (e.g., from category to instances), or from a lower-order element to one under which it is subsumed (e.g., from instance to category). This has a parallel with number concepts. One can proceed from the input to a number (e.g., "111") to the activation of an addition series of which it is a member (e.g., "add 37"); or from the addition rule ("add 37") to any number that is a member of the addition series expressed by that rule (e.g., 111). Therefore the twins do not need to calculate that 111 can be divided by 37 into whole numbers (or by 3 into 37s), nor even to have a concept of division; the fact is given in their structural representation and the ways in which it can be used.

A second feature of schemas noted by Rumelhart is that they influence not only retrieval operations but also perception. Indeed schemas are thought by some to be essential to the problem of making sense of perceptual input. Now if a significant proportion of one's schemas are number-related then the processing of perceptual input will tend to be dominated by number interpretations. A collection of matches strewn on the floor can be perceived as "111" if one uses number schemas preferentially in the interpretation of input. The things on the floor fit only the "111" schema out of all numerical possibilities just as, for normal people, they fit only "dropped matches" out of all entity category label possibilities. Discriminating "111" from "110" for the twins is rather like discriminating matches from toothpicks is for us.

More complex functions can emerge from simple ones. Multiplication and division are fundamentally addition and subtraction respectively. Thus if one sets up an addition series expressed by the rule "add 7," one automatically has a multiplication (or division) table. To repeat, one can retrieve a number together with the fact that it is a member of an addition series, so that it is not necessary to trace the entire route. Any given number can of course be a member of more than one addition series, so that the different series form independent but interpenetrating classifications. Eight, for example, may be in the series "add 1," "add 2," and "add 4." Now with this scheme there will sometimes be a number, \( n \), such that \( n \) fits into no series other than "add 1" and "add \( n \)." The numbers that have that property happen to be all and only prime numbers. To recognise a prime, therefore, it is not necessary to have a concept of primeness as such; it is simply necessary to recognise that the given number belongs on no addition series other than "add 1" and "add (itself)." Speaking a number aloud does not
Idiots savants constitute recognising that it is a prime; possibly the twins derive interest from identifying numbers that do not fit their classification devices. The twins could therefore tell whether “247” is a member of any addition series simply by retrieving it, just as we can tell whether or not “butterfly” is a member of the class “insects” by retrieving it.

The only problem for the twins is that of identifying new entries as primes or not primes. This can be accomplished by the following method. Let us suppose that 29640371 is a new entry and that every number lower than that is established in the representational space. To find out whether or not 29640371 is a prime, subtract n from it, and if the result is tagged as a member of the “add n” series then 29640371 is not a prime. The best procedure would be to begin with “add 2” and work upwards. The reason for this is that if 29640371 minus 2 is not on the “add 2” series, then 29640371 is not a member of any series “add t” where “t” is a number on the “add 2” series. Thus ruling out “add 2” automatically rules out “add 4,” “add 6,” and indeed half of the numbers between 29640371 and zero. The only addition series that need to be checked, therefore, are series of the type “add p,” where “p” is a prime number. Moreover, only one number — 29640371 minus “p” — needs to be checked for any given “add p” series, because in each case that number is tagged with its addition series membership. Furthermore, since the checking sequence is invariable it can become highly skilled — automatised — and it would therefore take a fraction of a second to check each series.

In each case, if the result of the operation 29640371 minus “p” is a number on the “add p” series then 29640371 is not a prime (and 29640372 can be tested). If the result is not a number on the “add p” series, then the next “add p” series can be tested, and so on until “add 2964037 divided by 2” is reached.

Although it seems laborious at first glance, the twins had years in which to practise and automatise the method, and perhaps even improve on it. The method is not entirely unrelated to checking procedures that normal people use with different concepts. For example, suppose one encounters a strange small animal and wonders what sort of beast it is. One could attempt to retrieve all known names of beasts, but this would be very laborious. Instead one can use short-cuts similar in effect to the elimination of sets of addition rules: “Is it an insect? Well, insects have six legs. Does this animal have six legs? No. Then it’s not an insect.” This result means that we automatically exclude all members of the category “insects” from our deliberations, and save a great deal of time.

Prime numbers may function for the twins like category labels: a prime number “p” subsumes under itself all rules of the form “add pn” where n is a positive whole number. Rejecting “add p” implies rejection of all rules “add pn,” just as rejecting “insect” implies rejection of all species of insect.

To give some idea of how simple this can be when well practised, suppose you are handed a booklet listing 2,000 English women’s first names in random order. Assuming your mother has an English first name, how long would it take you to verify that your mother’s name is not on the list? For the twins to check “add p” rules may be no more difficult or time-consuming than that.

There is an alternative possibility which involves projection rather than testing
a given number. Assume all addition series memberships are known for every number up to 296403. Now use the "add 1" rule to generate and store numbers from there on — let us say 2,000 further on. Then establish the addition series membership of each of those 2,000 new numbers. This is done by taking the highest known member of the series "add \(n\)" and re-iterating the operation "add \(n\)" until the new highest number is reached. Again, this need be done only for prime numbers, so one would start with "add 2" and work up through the prime number addition series from there. When all addition series rules up to the new highest number divided by two have been projected in this way, it is simply necessary to scan through the 2,000 new numbers and see whether any of them have not been tagged with any addition series membership (other than "add 1," of course). Those, if there are any, are prime numbers. This procedure again is extremely rapid if well practised, and it extends the organisation of known numbers in a systematic manner, based on the operation "add 1." It may therefore be simpler and easier than the first method. It is not certain that the twins use either of these methods, of course, but either would account for the skill and rapidity of their performance.

This does not exhaust the range of things the twins can do with numbers in the context of the relational devices described. They can, for instance, retrieve a single number together with its identifying tags — addition series of which it is a member — and, presumably, they can do the same for two numbers at once, much like a musical chord or a face. Perhaps a pair sharing the same series membership have something equivalent to consonant harmony, and pairs having partially or completely different series membership have the numerical equivalent of dissonance. Two notes in a musical scale derive their relatedness to each other in part from their respective locations in a common frame of reference; perhaps the same is true for two numbers in an addition series. The closest analogy in memory to the "add 1" rule may be a musical scale.

One further note: Sacks claims that, with prodding, the twins worked their way up to 20-digit numbers. To achieve this with the methods described would require them to store \(10^{20}\) numbers each tagged with its addition series membership. There might be room for this but it would be a prodigious memorising feat. Moreover, before Sacks interfered the twins were exchanging six-figure primes, which suggests that that is as far as they had got. Since Sacks does not report how many of these 20-digit numbers were primes, there is no way of telling what the twins were trying to do. They may, for example, just have been stringing together shorter primes into a sequence, like notes into a melody.

Explaining Nadia's drawing skills in this way is more difficult because the relational principles and the elements upon which they operate are less unambiguous. Moreover there is a motor component in the skill that is not required by the twins. Whether the motor component is any more precise and coordinated than the motor control of speech output is hard to say. But one can only attempt to infer the structural organisation of information in Nadia's long-term memory from clues in the content of the drawings, which is regrettably indirect.

Nadia's drawings all involve lines, and she drew only with a ball-point pen;
coarser implements are not used, and colour and shading are absent. A line is an abstraction. To use it as a representational device requires relational principles; it can only make representational sense in the context of a group of other lines which together with it constitute a drawing. Yet Nadia had learned to represent the visual world, expressively at least, in terms of lines. The world is not composed solely of lines, nor are pictures. Most pictures, however, exhibit a greater reliance upon lines as representational devices than the world might appear to justify — this is certainly the case for the pictures on which Nadia based many of her drawings (e.g., Figure 4 from Selle, 1977). If we suppose that Nadia’s schemas for expressive representation of information about the world are based on line relations, then pictures of that sort will be of greater help to the development of such schemas than will the world itself. This may help to explain why her drawings are greatly influenced by pictures. Pictures have other advantages: they are informationally simpler, can be studied at leisure, and are two-dimensional representations of three-dimensional space. Anyone who draws must struggle with the problem of representing three dimensions in two, and Nadia would obviously be helped by a source which solved the problem for her.

But pictures (e.g., Figure 4 from Selle) also have areas of shading and some have colour. These features Nadia did not attempt to reproduce, which supports the claim that her representational schemas involve line relations. It is hard to imagine that Nadia drew without understanding of the symbolic function of line groupings, but her grasp of such things need not have been great. Just as the twins could identify prime numbers without a concept of primeness, so Nadia could draw representations of objects without a profound conceptual grasp of the objects being drawn. Line schemas could do the work for her, much as addition series would for the twins. Selle notes that the drawings are more literal than conceptually sophisticated. Drawings of horses, for example, contain minute details of buckles, bridles etc., even though it is most unlikely that Nadia knew either what they were or what they were for. Also, she tended to draw what one would see if one looked at an object rather than, as most children of a similar age would, what one knows is there. Nadia may also have had no grasp of perspective as such — it could have been a by-product of her line schemas.

More evidence for well developed line schemas comes from the fact that throughout the execution of a given drawing Nadia had a consistent conception of what she was doing. The most striking example is in the videotape record reproduced on p. 30 of Selle’s book, in which it is not possible to guess what is being drawn or what the lines represent until about halfway through, when they suddenly become recognisable to the onlooker as the neck and chest of a horse.

Line schemas are both more complex and more nearly concrete than number series schemas; there is therefore less opportunity for systematic manipulation of them. Nadia’s drawings, however, do show evidence of at least two kinds of manipulation.

One is orientational variation. Nadia’s earliest drawings tend to be in a constant orientation — most are in flat profile, full frontal or both. In addition there is relatively little sense of depth or perspective. Later, presumably with increasing visual experience, Nadia becomes better able to alter the orientation
of the figures, tackling three-quarter views. One possible means of accomplishing this is by rotational principles, that is, rotational functions which operate upon part or whole of a given line schema so as to reorganise the lines to produce something equivalent to a change in orientation. This is a difficult process involving new functional lines or the adaptation of existing ones, and the rejection of redundant old ones. Nadia eventually became quite skilled at orientational variation. For example, one drawing that influenced her (Figure 4 in Selfe, 1977) is a view of a cockerel with the head in profile. In Drawing 38 (age 6.4 years) Nadia produces a three-quarter view of the cockerel’s head. A striking feature is the second eye, which is not visible at all in the original, but which in Nadia’s drawing is appropriately placed vis-à-vis the nearside eye (the eyes as a pair are more frontal than that of the cockerel in the original). On the other hand, Nadia’s range of subjects was small and the drawings are repetitive. Perhaps the skill was too difficult to be generally applicable.

The limited range of subjects and the inappropriate eyes on the cockerel suggest one way in which the rotational schema could be developed, and this is the second type of manipulation mentioned above. Sub-schemas of lines can fit into more than one full schema. Lines that represent eyes on a horse can represent eyes on a cockerel as well. If, therefore, Nadia sees a picture of a horse in three-quarter orientation and one of a cockerel in profile, she can produce a three-quarter view of a cockerel’s head by replacing parts of the horse schema into the cockerel schema. Nadia does tend to use the same sort of eye in cockerels, horses, humans and squirrels (Drawing 24).

There is more evidence for the re-location of sub-schemas. For instance, Self comments on Drawing 33:

Nadia has begun a second rooster at the bottom of the drawing, and upside down. Occasionally, a line in one drawing would suggest another subject to her, and two drawings would appear — one on top of the other.

In Drawing 34, the cockerel’s orientation has been altered to resemble that of many of the horse drawings, and the lines representing the cockerel’s neck and breast look somewhat like those representing the neck and chest of the horse. Even more striking is the leg of the cockerel in 33, which is virtually indistinguishable from many of the horses’ legs (e.g., Drawing 30), and does not resemble the leg of the cockerel in Figure 4. This use of existing sub-schemas is part of what Rumelhart (1984) terms “restructuring.”

One can only guess at the comprehension processes Nadia used. The apparently sudden emergence of skilled drawings suggests the development of line schemas at an early stage. Nadia may have perceived the world in terms of lines much as the twins perceive it in terms of numbers. This is not to say that they see nothing other than lines or numbers, but that line or number processing devices are predominant and well developed, just as speech and object concept processing devices are for most of us.
CONCLUSION

The skills developed by Nadia and the twins do not resemble the skills developed by most normal people with drawings and numbers, respectively. They do, however, resemble other sorts of skills that normal people do develop, particularly skills with words and perhaps music. The basic ingredients of these skills are the use of a large representational space in long-term memory and the development of hierarchies of schemas representing relations between the items stored in long-term memory — lines, numbers, or words and word meanings. The performances of Nadia and the twins reflect not so much sophisticated feats of artistic creation or rapid calculation as the predominantly automatic tracing of routes through the long-term memory representation, and the translation of the products of that activity into motor output. This is analogous to the retrieval of words and their use in speech.

Since verbal language is a virtually universal human accomplishment, it is perhaps natural to suppose that that specifically is what the language centres of the brain are specialised for. Chomsky, for example, seems to regard the development of generative rules for constructing well-formed utterances from deep structures as based on genetically endowed competence. The arguments presented in this paper suggest a more abstract kind of endowed competence: the competence concerns more the capacity for organised representation of large amounts of items relating to a common domain. It is a propensity to develop relational schemas, and different types of relation at different hierarchical levels, and the potential for the active participation of such structures in perception and behaviour generation, that is endowed. What particular sort of informational domain becomes the subject of schema development is of rather less importance. It may be influenced by the nature of the world in which we find ourselves and by the intrinsic ease of relating items in a given domain — it is the latter, perhaps, that makes Nadia's achievement especially unlikely. Perhaps idiots savants occur because they do not, for one reason or another, participate in those aspects of socialisation and social interaction that favour the devotion of large areas of representational space to verbal language, and as a result devote it to some other domain.

Some authors (e.g., Gardner 1983) argue that idiots savants tend to support a modular concept of intelligence, where level of intelligence in one domain or module is essentially independent of that in another, within the same individual. The present argument suggests at least partial modification to that view: some different types of intelligence may be related or complementary to the extent that they depend upon the same underlying type of structure. Idiots savants are worse at one thing because they are better at another, or vice versa. In other respects, however, idiots savants are far from ideal arenas in which to test theories of the nature of intelligence. Also, the complementarity envisaged is probably a function of the relative amounts of time spent on different activities. It is unlikely that there is a serious space limitation in long-term memory, but the Evidence from idiots savants is therefore inconclusive with respect to the nature of intelligence.
REFERENCES


