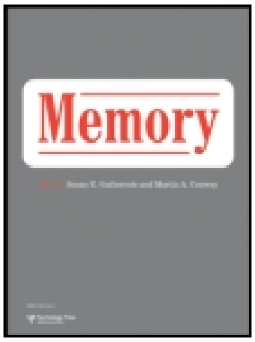

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Atypical Memory Performance in an Autistic Savant

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This study explored the mechanisms underlying the hypermnesia of an autistic savant (NM) through three experiments. The first two served to assess whether absence of interference was responsible for NM's exceptional list memory. The third investigated the type of cues used in recall. Results indicated absence of retroactive interference but presence of slight proactive interference in list recall of proper names. Normal interference effects were found, however, in list recall of common nouns. Exceptional performance was also demonstrated in a missing-name task involving spatial and verbal recall cues. The findings suggest that the outstanding episodic memory presented by some savant persons with autism might be related to an abnormally high resistance to interference.

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INTRODUCTION

Persons with autism present with a characteristic cognitive profile marked by strengths in certain areas and gross weaknesses in others (Rumsey & Hamburger, 1988). This phenomenon is robust and stable across IQ and developmental levels (Tymchuck, Simmons, & Neafsey, 1977) and, consequently, may eventually be recognised as a pathognomonic symptom of this disorder (Frith & Happé, 1994). Besides their particular cognitive profile, another fascinating aspect of the cognitive atypicalities observed among persons with autism involves the special abilities displayed by certain autistic individuals. These are defined as abilities in which performance levels far exceed expectations based on the person's IQ. Although the relationships between the cognitive profile typical of persons with autism and their special abilities are unknown, both represent better performance than their average, and neither involve social competences (Frith, 1997). Epidemiological studies have revealed that a substantial portion of the autistic population has special abilities (Hill, 1978). The figure of 10% was proposed by Rimland and Fein (1988), but this is probably an underestimation, given that previously isolated syndromes such as hyperlexia are now recognised as autistic special abilities (Aram & Healy, 1988; O'Connor & Hermelin, 1994; Patti & Lupinetti, 1993). The inclusion of Asperger's syndrome among the Pervasive Developmental Disorders in the DSM-IV (American Psychiatric Association, 1994) has also raised the profile of special abilities. These are common in persons affected with this syndrome (Szatmari, 1991; Tantam, 1991). The growing use of previously unrecognised high-functioning autistic persons in experimental and epidemiological studies (Wing, 1993) has had a similar effect. The specificity of special abilities to autism has become more obvious in the last few years. Whereas special abilities were once thought to be found equally in autism and mental deficiency (Hermelin & O'Connor, 1991), they are now considered, together with Wing's triad (Wing & Gould, 1979), to be one of the major symptoms of autism (Frith & Happé, 1994).

These special abilities have been the subject of curiosity as far back as two centuries before the seminal description of autism (Foerstl, 1989). Although accounts of these abilities remained entirely anecdotal for the longest time, they helped to determine that the areas in which autistic persons demonstrate exceptional skills are actually few in number and generally restricted to music, the memorisation of lists, three-dimensional drawing, and mental calculation. These early descriptions, however, shed no light on the cognitive basis for the phenomenon. Yet, certain recent findings and theoretical developments have made it clear that the heterogeneity of performance found in autism, both in terms of cognitive profile and special abilities, is not anecdotal and has to be accounted for by cognitive as well as by neurological models of autism (Frith & Happé, 1994; Joliffe & Baron-Cohen, 1997; Mottron & Belleville, 1993, 1994;

Mottron, Belleville, & Stip, 1996; Mottron et al., 1997; Shah & Frith, 1993). The emergence of cognitive models of autism (Morton & Frith, 1994) has indeed spurred greater interest in these phenomena as a means of understanding the cognitive deficits typical of persons with autism. These models postulate that various neurobiological factors are responsible for the impairment of a restricted number of basic cognitive functions in autistic persons. As these functions are required for numerous and heterogeneous operations, their impairment causes an apparently unrelated set of symptoms. Hence, heterogeneity in intellectual capacities may stem from a dissociation between normal and abnormal cognitive functions. In this connection, recent cognitive models of autism have proposed anomalies in the structuring of visual and verbal information (Frith, 1989; Frith & Happé, 1994; Mottron & Belleville, 1993), and deficits in executive functions (Pennington & Ozonoff, 1996).

While several studies have investigated special abilities in groups of autistic persons (Hermelin, O'Connor, & Lee, 1987; O'Connor & Hermelin 1984), others have opted instead for the model-based single-case methodology favoured by cognitive neuropsychology (Mottron & Belleville, 1994). The use of this approach with autistic savants has made it possible, among other things, to detect perceptual abnormalities in the processing of the whole–part relationship in visual stimuli (Mottron & Belleville, 1993, 1995). The goal of the present study was to use this approach to investigate how an autistic person with hypermnesia achieves outstanding levels of performance. The participant, NM, shows an exceptional ability for memorising proper names. We have shown in a previous study that his special ability was limited to proper names because they are devoid of semantic content (Mottron, Belleville, & Stip, 1996). However, this first study did not address directly how NM manages such a high level of memory proficiency. The matter, in our opinion, warranted further investigation.

The purpose of the present study was to examine particularities of NM's memorisation that might explain his hypermnesia. The strategy adopted was to assess two aspects underlying memory successes and failures in normal subjects. The first, interference, has long been an important concept in memory research (for review see Baddeley, 1990; Dempster & Brainerd, 1995) and is generally considered a major determinant in forgetting. We hypothesised that NM's hypermnesia related to an absence of interference. This was assessed through Experiments 1 and 2. A second mechanism involved in retention is encoding specificity (Tulving & Thomson, 1973). When material is encoded in relation to a particular context, presentation of the context at recall enhances performance. NM's remarkable memory might result from the use of cues irrelevant to normal subjects. We examined this aspect in Experiment 3 by manipulating verbal and spatial cues present at the recall stage.

CLINICAL HISTORY OF THE PATIENT

NM was 36 years old at the time of testing. He is a right-handed, unilingual French-speaking Canadian. Apart from an abdominal trauma suffered by the mother during pregnancy, his prenatal history and delivery were normal. Signs of autism, including language deficits, social withdrawal, echolalia, and the serial disposition of objects, surfaced during development. This autistic syndrome was later accompanied by several special abilities in musical memory, jigsaw puzzles, calendar calculation, mental computation, and proper-name recall. NM memorises telephone directories and obituaries in the newspapers he collects. He also regularly visits the local cemetery, where he has memorised the names and date of death of most of the persons buried there, and copies lists of apparently unrelated names. NM manifests his special ability in normal life by being able to give the name and date of birth of every person he has met. This is done in a ritualised format starting with the last name, as is the case in directories. At the time of testing, NM led a relatively autonomous existence in a small house near his parents. Nonetheless, his symptomatology was severe and dominated by stereotyped hand gestures, echolalia, echopraxia, tiptoe walking, ritualistic behaviour, head banging, ‘‘sameness’’ reactions when interrupted, and a special interest in proper names. NM met 13 of the 16 criteria for autism under the DSM-III-R (American Psychiatric Association, 1987), which is well above the minimum required for a positive diagnosis. A standard neurobiological examination, including CT-scan, proved unremarkable. At age 35, NM’s verbal IQ was estimated at about 65 on the basis of the information (scaled score = 5) and digit span (scaled score = 6) subtests of the WAIS-R; his memory quotient was found to be 72 on the Wechsler Memory Scale. His memory was more formally assessed in a previous study (Mottron et al., 1996) and proved much better than that of IQ-matched controls, but only when using proper names. Recall was better for proper names than for common names even when the latter were presented as names of people. Low recall in face–name learning procedures suggests that NM’s exceptional recall ability is restricted to list-learning tasks. A more detailed clinical account of NM, including neuropsychological assessment, history of special abilities, and biological and psychiatric explorations, can be found elsewhere (Mottron et al., 1996).

CONTROL SUBJECTS

The performance of NM in the three experiments was compared to that of a group of eight non-autistic men matched for IQ (mean IQ: 72; range = 63–83). Their mean age was 29 years (range = 16–43) and their average level of education was 9.25 years (range = 8–11). In addition, a group of eight participants with average IQ were tested for purposes of comparison with the literature on typical participants. Their mean age was 26.8 years (range = 22–40) and their average level of education was 15.6 years (range = 12–19).

EXPERIMENT 1 EFFECT OF INTERFERENCE ON PROPER-NAME LEARNING

Experiment 1 explored the effects of interference on memorising proper names. Interference tasks typically involve subjects learning and recalling a List A, then learning and recalling a List B, and then recalling List A again. Proactive interference refers to the detrimental effect of A on the recall of B. Retroactive interference revers to the detrimental effect of B on the recall of A (McGeoch & McDonald, 1931; Slamecka, 1960).

Method

Materials. Two different sets of lists were constructed to measure interference. Each set comprised two lists of 15 proper names. One served as List A and the other as List B (i.e. interfering material). For the first set (A1, B1), items were taken randomly from lists of proper names copied by NM and found in his house. This ensured that the items were familiar to the subject and thus would optimise recall performance. For the second set (A2, B2), family names were selected according to frequency of usage—average number of occurrences in the Montréal telephone directory = 701 and 666, $t(14) = 0.469$, n.s.—in order to allow a more direct comparison with the performance of control subjects. This is an important factor as we have already demonstrated that, like normal subjects, NM is sensitive to frequency in proper-name recall (Mottron et al., 1996; Segui, Mehler, Frauenfelder, & Morton, 1982). Names that are extremely frequent in the French-Canadian population were excluded to avoid success by guessing. In both sets (1 and 2), the items in the two lists (A vs B) were matched for frequency, length, frequency of letter in the initial position, ambiguity (items that could also be a common name, e.g. Baker), and ethnic origin (French vs. English).

Procedure. Items were printed on paper in uppercase letters. Participants were asked to read them aloud and memorise them. List A was learned first. After a 30-second verbal interference activity, participants were asked to recall items from the list aloud. Immediately after, List B was learned in the same way. After completing their recall of List B, participants were required to recall as many items as possible from the first list (A′). After a minimum one-week interval, the procedure was repeated with the other set of lists.

Results

Given that the two sets of lists differed according to item characteristics, preliminary analyses were performed to determine whether sets had an effect on outcome. Results of an analysis of variance (ANOVA) revealed neither a set nor a set-by-list effect in any of the control groups. Furthermore, no difference was observed between the two sets in NM's results when using separate chi-square analyses. Consequently, the data from the two sets were pooled for subsequent analyses.

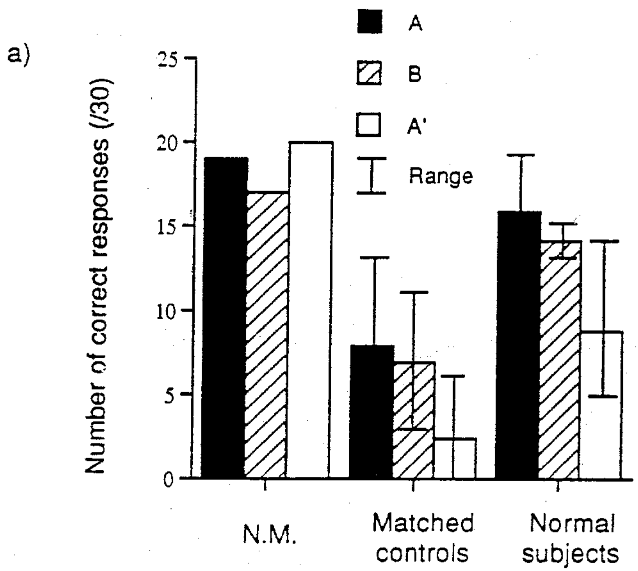
Figure 1a shows the number of words correctly recalled by NM and by the two control groups. Normal subjects were clearly affected by proactive interference as evidenced by their diminished recall performance with B compared with A. They also suffered the effects of retroactive interference, given the reduced recall of A′ compared with A. This was substantiated by a one-way ANOVA which showed a significant list effect [$F(2,14) = 48.127$, $P < .0001$]. Recall of A was significantly higher than recall of both B [*t*-test, 2-tailed; $P < .05$] and A′ ($P < .01$). A similar pattern of performance was observed in matched controls, whose recall performance with A′ and B was lower compared with A. The ANOVA revealed a significant list effect [$F(2,14) = 15.021$, $P < .001$] attributable to the fact that recall of A was significantly higher than that of A′ (*t*-test, 2-tailed; $P < .01$). The effect did not reach significance, however, when A and B were compared.

Analysis of NM's data underscores, first and foremost, a remarkable hypermnesia. NM's scores for correct recall are unquestionably higher than those of matched controls, and his performance level generally surpasses that of normal subjects. Figure 1a suggests that NM was subject to proactive interference, as recall performance with B was lower than with A. There was no retroactive interference, however, as the second recall of A (i.e. A′) was even better then the first (A).

Individual interference scores were computed in order to compare the effect of interference on NM and the two control groups (see Fig.1b). The proactive score represented the difference in recall between A and B (A minus B). The retroactive score was the difference in recall between A and A′ (A minus A′). It indicated that retroactive interference was more detrimental to recall than was proactive interference in the two control groups [$t(7) = -4.277$, $P < .01$ in matched controls and $T(7) = -5.381$, $P = .001$ in normal subjects]. The opposite was true for NM, with proactive interference bearing more heavily than retroactive interference. Furthermore, while proactive interference fell within the normal range, retroactive interference was markedly lower in NM than in any of the controls.

EXPERIMENT 2 EFFECT OF INTERFERENCE ON COMMON-NAME LEARNING

The purpose of this experiment was to determine whether NM's hypermnesia was specific to proper names. We thus examined the effects of proactive and retroactive interference on the memorisation of common nouns.



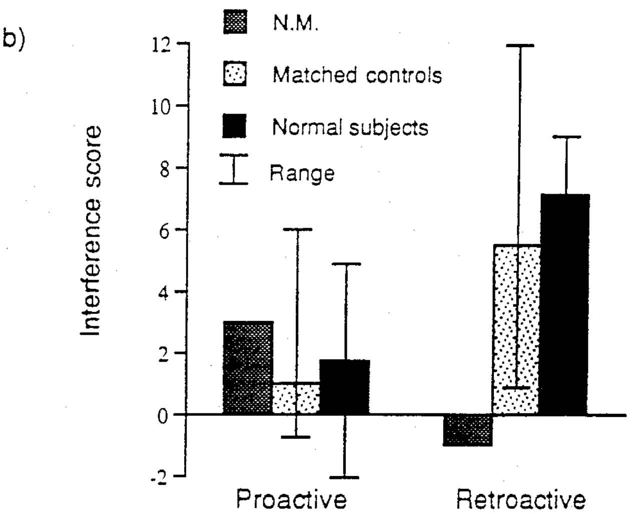


FIG. 1. Performance levels with proper names for NM, matched controls, and normal subjects. (a) Number of items recalled from A, B, and A′. (b) Proactive and retroactive and retroactive interference scores (0 indicates no interference). Performance range of matched controls and normal subjects indicated by bars.

Method

Materials. Two sets (1 and 2) of two lists (A and B) of 15 common nouns were used. The items were frequent (Baudot, 1992), imageable substantives. Lists A and B were matched for frequency [$\times$=77.5 for A1 and 74 for B1, $t(14)=0.323$, n.s.; $\times$=79.4 for A2 and 62.4 for B2, $t(14)=1.197$, n.s.), length, frequency of letter in the initial position of a word, and membership category. The procedure was the same as in Experiment 1.

Results

Figure 2a indicates the presence of both proactive and retroactive interference in normal subjects. An ANOVA yielded a significant list effect [$F(2,14)=56.123$, $P<.0001$] attributable to a better recall of A than of both B and A′ (t-test, 2-tailed; $P<.01$ in both cases). Matched controls also showed the effects of proactive and retroactive interference. Here, too, a significant list effect was found [$F(2,14)=43.202$, $P<.0001$], explained by the better recall of A over A′ and B (t-test, 2-tailed; $P<.01$ in both cases). NM's performance suggests both proactive and retroactive interference, as performance was diminished with both B and A′ compared with A. Moreover, NM's recall scores for common names was just above the range for matched controls.

Proactive and retroactive interference scores were computed for each subject using the same procedure as in Experiment 1 (Fig. 2b). Retroactive interference was larger than proactive interference for both matched controls [$t(7)=-5.227$, $P<.01$] and normal subjects [$t(7)=-2.824$, $P<.05$]. NM, instead, showed a somewhat larger proactive than retroactive interference effect. While his proactive score fell within the range obtained by matched controls, his retroactive score fell below the range for matched controls but within that for normal subjects.

EXPERIMENT 3 MATRIX LEARNING

This experiment was devised to compare the effectiveness of different encoding strategies. It consisted of an encoding stage where subjects were asked to memorise matrices of nine proper names in various encoding contexts, and a recall stage where different types of recall cues indicated a name to be recalled. If a particular context was used at encoding, its suppression at recall was expected to produce a decline in performance. Three different contexts were considered: spatial, verbal, and spatial–verbal. The spatial context referred to the position of the item in the matrix. The verbal context referred to associations between names regardless of their relative position in the matrix. The spatial–verbal context referred to combined spatial and verbal relations, such as the name "Stip" being encoded as "right of Mottron" or "left of Belleville".

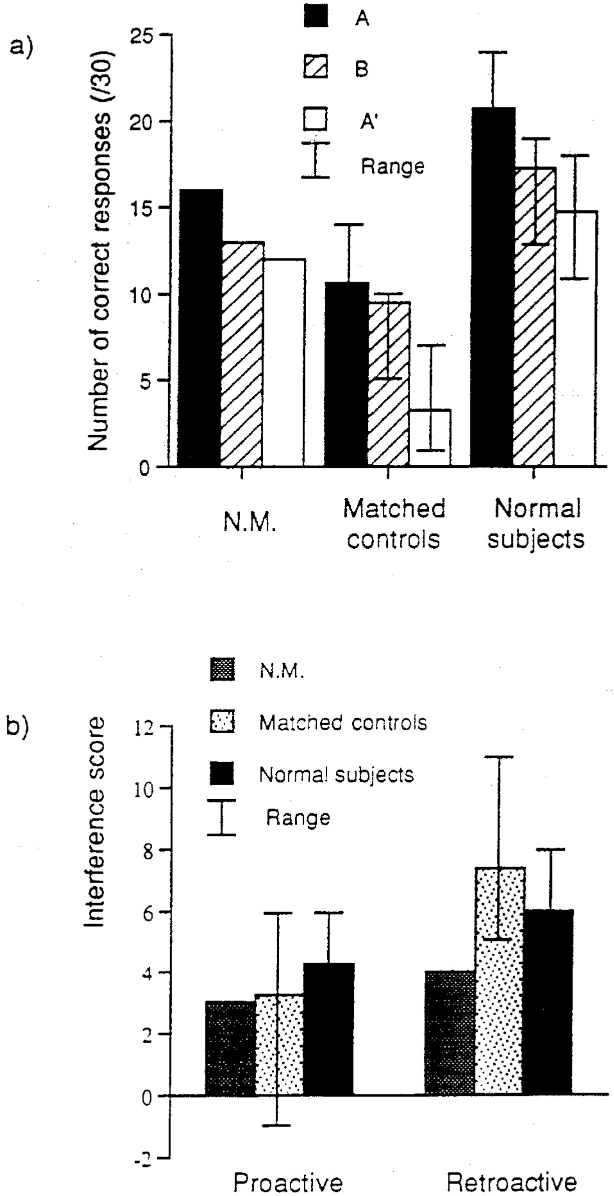


FIG. 2. Performance levels with common names for NM, matched controls, and normal subjects. (a) Number of items recalled from A, B, and A′. (b) Proactive and retroactive interference scores (0 indicates no interference), Performance range of matched controls and normal subjects indicated by bars.

Method

Materials. A total of 27 lists (nine per condition) were constructed, each containing nine proper names of intermediate frequency (from 50 to 1000 occurrences in the telephone directory). At encoding, each list was organised as a 3×3 matrix formed by a grid in which the nine names were randomly arranged. Three different types of stimuli were constructed for the recall stage. In the "spatial cue" condition, the stimulus consisted of an empty grid similar to that used at encoding. Extra thick borders were added to the matrix cell of the name to be recalled. It was assumed that this condition would eliminate both the verbal and the combined spatial–verbal cues while maintaining the spatial ones. In the "verbal cue" condition, the names were presented in a single column with the name to be recalled omitted. The order of the names in the column was such that items adjacent in the matrix at encoding were not neighbours at recall. This condition was intended to suppress the spatial and combined contexts while maintaining the verbal one. Finally, in the "spatial–verbal cue" condition, the matrix was presented again with the original cell of the word to be recalled left empty. The positions of the remaining items were scrambled. This condition was designed to prevent subjects from using spatial and verbal cues in combination, while allowing them to rely on purely spatial or verbal cues.

We hypothesised that if subjects rely on spatial cues for recall, then suppressing these cues would result in poor recall performance (verbal cue condition) and vice versa (other two conditions). Similarly, if subjects rely primarily on verbal cues for recall, then they would perform better in the verbal and spatial–verbal cue conditions than in the spatial cue condition. Finally, if subjects rely on the combined spatial–verbal context for recall, then their performance would be especially poor when the relation between spatial cues and contextual names is scrambled (i.e. in the spatial-verbal cue condition).

Procedure Matrices were presented visually. At the encoding stage, subjects were asked to read aloud the nine names composing the matrix and to memorise them. Then, subjects were immediately shown one of the three cue conditions and asked to recall the item in question. Recall conditions were randomised after a pretest showed that NM was not disturbed by their alternation. This ensured that subjects would not favour a particular encoding strategy by anticipating the recall condition. The lists were presented in three blocks of nine random matrices. Each block was separated by an unrelated task.

Results

Matched controls found the task extremely difficult and frustrating. It became obvious that matched controls would not sustain the necessary attention and motivation for the task if the same number of lists was used as with NM. For this reason, the number of lists was reduced to 18 (six trials per condition) for

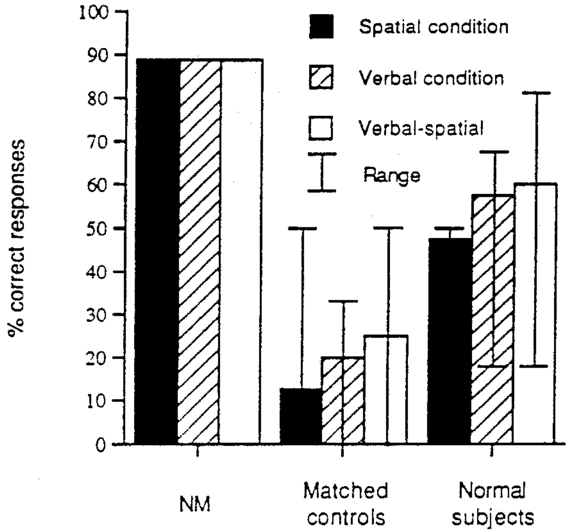


FIG. 3. Correct response percentage on proper-name matrices for NM, matched controls, and normal subjects in three recall conditions. Performance range of matched controls and normal subjects indicated by bars.

matched controls and normal subjects. Consequently, the correct-response percentage was used as a dependent variable in the analysis.

Normal subjects showed no significant differences across the three recall conditions, although the spatial–verbal cue condition appeared to yield slightly higher recall levels (see Fig. 3). A one-way ANOVA carried out with ''condition'' (verbal, spatial, spatial–verbal) as the within-subject factor revealed no condition effect [$F(2, 14)=0.786$, n.s]. Matched controls showed a similar pattern of results with no condition effect [$F(2, 14)=2.510$, n.s.]. In performing this task, NM read out the names in alphabetical order despite the fact they were not so arranged. He answered quickly and demonstrated excellent recall in the three conditions. Not only was NM's performance level far above the range for matched controls, it surpassed that of all normal subjects.

DISCUSSION

The three experiments described here that explored the possible mechanisms underlying the hypermnesia of an autistic person produced some interesting findings. First, unlike normal subjects and matched controls, NM demonstrated an absence of retroactive interference in learning lists of proper names. Furthermore, he was somewhat less susceptible to proactive interference than matched controls. Given that interference is an important contributing factor in forgetting, NM's resistance to proactive and particularly retroactive interference could explain his exceptional list recall performances. This is supported by the fact that the absence of interference is restricted to learning proper names. Interference had much the same effect on NM as on matched controls when common names were used. Indeed, NM's memory for common names is nowhere as impressive as for proper names.

Memory research with normal subjects has shown that interference depends on two major variables: the mnemic strength of the interfering material (Slamecka, 1960) and the similarity between the interfering and the learned material (McGeoch & McDonald, 1931). It does not depend on the strength of the initial material (Slamecka, 1960). NM's absence of interference cannot be imputed to insufficiently strong interfering material, as NM showed an excellent recall of List B. Moreover, it cannot stem from the level of similarity between the lists. Categorical similarity has been shown to be particularly interfering for normal subjects when they are asked to memorise lists of verbal items. For example, normal subjects demonstrate proactive interference when two lists of items belong to the same taxonomic category (e.g. animals), because semantic information is used at encoding (Craik & Birtwistle, 1971; Wickens, 1970). Here, NM showed no interference even though the two lists of words belonged to the same category of proper names. It is possible, however, that proper names possess distinctive features that are more relevant to NM than to normal controls. This would make the two lists of names more dissimilar and thus less susceptible to interference for NM. Although possible, we do not think that this explanation is sufficient to explain NM's absence of interference, given that even lists of unrelated words create interference in normal subjects.

Another factor influencing the amount of interference is the ability to select relevant answers and inhibit irrelevant ones (Dempster & Brainerd, 1995). This aptitude is selectively impaired in frontal-injured subjects, which would explain their increased susceptibility to interference (for example, Shimamura et al., 1995; Van der Linden, Bruyer, Rolland, & Schils, 1993). The present findings suggest that NM, a person with autism with a special ability, presents normal inhibition capacities. His ability to inhibit irrelevant information appears even better than average in his domain of special ability. This exceptional performance could be explained in terms of impairments in executive functions that are only partial. In a recent review of the literature, Pennington and Ozonoff (1996) concluded that cognitive flexibility was impaired in autism but not inhibition. Recently, Ozonoff and Strayer (1997) have shown normal negative priming, a task suggested to measure inhibition in autism. This is congruent with the present data which suggest that the inhibition mechanisms involved in the selection of information from long-term memory are spared in NM. However, our results are not consistent with the hypothesis suggesting the presence of medial temporal lesions in autistic persons, as these lesions usually lead to severe amnesic symptoms. NM's recall performance was clearly unlike that of an amnesic subject, be it with proper or common names. Other studies have come to the same conclusion, i.e. normal episodic memory in autism (Morrasse, Belleville & Mottron, 1998).

In Experiment 3, NM demonstrated a very high level of performance in recalling a proper name missing from a list, regardless of the cue given at the recall stage. The experiment thus failed to identify the type of cues NM uses in memorisation. NM's performance was compatible with the use of all three proposed cues, as he was not affected by their respective removal. Of course there is also the possibility that he relied on a completely different type of cue not manipulated in the experiment. Nevertheless, the results from this experiment may shed some light on why NM obtains such brilliant performances. NM perhaps memorises a list as a whole or a single unit. NM's processing of these list-units may correspond to that of word-units or object-units by normal subjects. Consequently, it would be as easy for NM to retrieve parts (names) of this whole (list) as it is for normal subjects to identify the missing part of an incomplete object. This could also explain why he shows so little interference. Indeed, interference effects are usually not observed within units, but across them. For example, subjects would not interchange the letters of two words in a list, only entire words across lists. Thus, if each list is processed as a single unit, one is much less likely to run interference on the other.

One point should be made here about the possible impact of lack of interference in NM. Although absence of interference is probably very helpful for NM to memorise lists of items, it is likely to have detrimental effects, or reflect anomalies having such effects, on other aspects of cognition. First, as mentioned earlier, interference probably reflects the fact that the cognitive systems are organised along dimensions shared by numerous items which would result in a categorical structure. On the other hand, forgetting, to which interference is a contributor, is probably essential to the creation of categories and prototypes. Even though the causal direction remains to be clarified, lack of interference in NM may be connected to anomalous concept formation.

The results reported here may also be relevant to developmental neuropsychology. Pathologies occurring early in development, as is the case with autism, may result in substantial neuronal reorganisation. This reorganisation is likely to impact on the architecture of cognitive functioning. Yet, it is possible that the special abilities exhibited by autistic persons result from such reorganisation. The performance pattern exhibited by NM may be an example of such a phenomenon. We have shown here that his exceptional performance is obtained through abnormal processes. His memory is not only more efficient quantitatively than that of normal subjects, it is also different qualitatively, as evidenced by the absence of interference. It remains to be demonstrated, however, whether and how all this may be generalised to apply to the autistic population as a whole, with or without special abilities. It would also be important to understand how the memory phenomena described here relate to the symptoms that characterise the autistic disorder.

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