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ABSTRACT

This paper presents four studies which illustrate the variety of deficits in executive function displayed by individuals with autism. The concept of executive function is used to encompass all the mental operations which are involved in self-reflective and goal-directed behavior. Four forms of executive control are addressed: mental disengagement, coordination of two separate acts into a goal-directed temporal sequence, cognitive flexibility, and planning. The results of the first two studies indicate that subjects with autism are impaired in the processes required for learning behavioral strategies which involve a counter-intuitive or arbitrary association between response and target. The dysfunction may result from "stuck in set" perseveration, recurrent perseveration, or failure to sustain a plan of action in the absence of environmental cues. Results from the third study indicated a deficit in the processes required to shift attention from a salient dimension or category and engage attention upon a previously irrelevant stimulus. Results of the fourth study showed that subjects with autism are unable to find efficient solutions to planning problems which require a depth-first search to anticipate obstacles and the cognitive flexibility to change plans so as to avoid these obstacles. (Contains 21 references.) (JDD)

VARIETIES OF EXECUTIVE DYSFUNCTION IN AUTISM

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In this paper we shall present four studies which, taken together, illustrate the variety of deficits in executive function which are displayed by individuals with autism. The phrase 'executive functions' is used to encompass all the mental operations which are involved in self-reflective and goal directed behaviour.

We have at least two reasons for making such an investigation. Firstly, the neural substrate for executive control is generally considered to be the prefrontal cortex. However impairments of executive control have recently been shown in a number of diverse developmental disorders [e.g. childhood schizophrenia (Schneider & Asarnow, 1987), Tourette's syndrome (Incagnoli & Kane, 1981), conduct disorder (Lueger & Gill, 1990) ADHD (Chelune, Ferguson, Koon & Dickey, 1987) and PKU (Welsh, Pennington, Ozonoff, Rouse & McCabe, 1990). Such finding emphasise the need for more precise accounts of the impairments typical of each group. Secondly, there may be potential for developing our understanding of the dysfunctions underlying each disorder through comparing these profiles of performance across a range of frontal tests. For instance, we know already that there is no blanket impairment of executive function in autism - - many individuals with autism perform very well on certain tests that are considered to be sensitive to frontal dysfunction, tests such as the Raven's matrices and the Block Design test (Shah & Frith, 1983).

The 4 forms of executive control which we shall focus on during this paper comprise of:

1) Mental Disengagement- inhibition of prepotent incorrect responses towards a salient element in the environment (e.g., reaching to grasp a sweet)

2) Co-ordination of 2 separate acts into a goal-directed temporal sequence - involving both (i) learning to co-ordinate actions which carry only an arbitrary relation to each other and to the goal, and (ii), inhibiting other more direct actions so as to execute this newly learned sequence

3) Cognitive Flexibility - learning to suppress behaviour governed by a previously correct rule that is no longer adaptive

4) Planning, creating a hypothetical model of a situation which anticipates obstacles along a goal-path

-- The subjects participating in our studies ranged in age from 6- to 18-years, and in mental age from 4- to >14 years [assessed by the Test for Reception of Grammar, (1982) and the Matrices task from the British Abilities Scale (Elliot, Murray & Pearson, 1983)] , so in presenting our results we shall be asking not only "What are the differences in performance between subjects with autism and non-autistic subjects (matched for age and mental age)?", but also "What are the differences within the autistic group?" Are there, for instances any developments in executive control (or any changes in the kinds of errors made), and are these related to increases in mental ability?

The starting point for the studies to be presented in this paper was the observation that many TOM tasks place significant demands on a subject's capacity for executive control over his or her thoughts and actions (Hughes & Russell, 1993). In fact, even ordinary interactions can depend not only on mind-reading, but also on executive control, in that often a number of cues need to be integrated in order to detect a speaker's actual meaning. For example, if someone said "it's getting hot in here", the intended meaning could be entirely metaphorical...

More formally, success on standard false belief tests depends on reference not to an actual state of affairs, but to another agent's mistaken representation of the real situation. As a result, it may be misleading to account for the difficulty that individuals with autism experience on these tasks solely in terms of a problem with 'mind-reading'. The impairment might simply be one of learning behavioural strategies which depend upon executive control. That is, there exist important points of contact between an agent's ability to deceive and his or her level of goal-directed self-control.

This possibility was confirmed by the results of a study known as the 'Windows task', conducted by Russell, Mauthner, Sharpe, and Tidswell (1991), working with normal 3- and 4-year olds, children with Down's Syndrome and children with autism (both clinical groups having a verbal mental age of at least 4-years).

One of the features of this study was that it included a training period to familiarise subjects with the reward contingencies common to deception tasks, contingencies which may seem rather counter-intuitive to an individual with autism. During this training phase the subject and an opponent (an adult experimenter) were shown 2 opaque boxes (one red, one blue) and asked to hide their eyes as the controlling experimenter placed a sweet (a Smartie or M&M) in one of the boxes. The subject was then asked to choose a box for the opponent to open. If the opponent found the sweet in the chosen box he ate it, but if the box was empty, then the controlling experimenter gave the sweet in the unopened box to the subject. In this way the subjects could learn to win sweets by leading the opponent to the empty box, even though in the training phase they did not actually know which box this was. The training phase consisted of 15 trials. From the 11th trial the subject was asked a question at each trial to check that he or she understood the contingencies for winning and losing the sweet (e.g., "Oh, look- the box is empty, so who wins the sweet?"). Only those subjects able to give 3 consecutive correct responses proceeded on to the test phase.

At this point we can explain why the task has been dubbed the 'Windows' test, since at the start of the test phase the two opaque boxes were replaced by a second pair, this time with windows, positioned so that the contents of each box were visible to the subject but not to the competitor.

SLIDE

The questions we were interested in at this stage were:

1) Would the subjects mislead their opponents on the first trial of the test phase?

2) Would subjects who did not deceive their opponents on this first trial succeed in learning the appropriate (reward-winning) response after a number of trials? To consider this possibility the test phase continued for a total of 20 trials.

The results from the test phase were very striking. Not only did subjects with autism (and 3-year olds) fail to deceive their opponents on the first trial, but they also failed to learn this strategy when given the opportunity. Indeed, the majority of subjects with autism in this study perseverated in pointing to the baited box for all 20 trials. Performance on this strategic deception task was strongly correlated with performance on a standard false belief task given to the subjects in the same testing session.

In the first of the studies we'd like to present here, we repeated the design of the Windows task, but using 4 conditions. Our subject population was made up of 60 subjects with autism (MA...) and 60 non-autistic subjects with mental handicap (matched for NVMA, VMA but slightly younger in CA).

1) Half the group were asked to make their choice verbally, and half to indicate their choice with a pointing gesture. This was to exclude the possibility that the perseverative pointing to the baited box observed in the first study was simply a consequence of poor motoric inhibition, that is, to ensure that the subjects weren't simply displaying a kind of 'utilisation behaviour'. (L'hermitte, 1983)

SLIDE- Lhermitte's model patient

2) Half the subjects were presented with the task with an opponent as before, and half were given the task without an opponent. For this condition, the experimenter sat beside the subject, so she too could see the sweets, and if the subject failed to point to the empty box the sweet was simply returned to a pile in front of them both. Without an opponent, the problem at hand is no longer one of deception. From the TOM hypothesis one would

therefore predict that the performance of subjects with autism should be improved, since the situation no longer depends upon taking another agent's mental states into account. By contrast, if the principal difficulty for subjects with autism is one of executive control then their performance in this non-competitive situation should be as poor as before.

Our results replicated those of the previous study in that on the first test trial significantly more subjects with autism than non-autistic subjects with mental handicap pointed to the baited box: 70% versus 37%. Moreover, perseveration was a striking feature of the responses shown by subjects with autism: 21/60 subjects with autism continued to point (incorrectly) to the baited box for the subsequent 20 trials, whereas none of the control subjects did so. This study adopted the same criteria for success as the original Russell et al study: a 'liberal' criterion that successful subjects should make no more than 3 references to the baited box; and a 'conservative' criterion which included the additional stipulation that a subject could only be categorised as successful if he/she had correctly indicated the empty box on the first trial.

No. of subjects (/15) choosing the incorrect (baited) box on the first trial of the test-phase under the 4 conditions.

Group: Condition.	**Autistic**	**Mentally-Handicapped**
No opponent, verbal	10 (6)	7 (0)
No opponent, non-verbal	13 (8)	7 (0)
Opponent, verbal	9 (3)	4 (0)
Opponent, non-verbal	10 (4)	4 (0)
TOTAL	**42 (21)**	**22 (0)**

(Numbers of these who perseverated for all 20 trials in parentheses.)

Percentage of Subjects Passing the Windows Test on the 2 Criteria in Each Condition.

On the 'Conservative' Criterion.		
	Autistic	Mentally Handicapped
No opponent, verbal	13.3 (2)	46.7 (7)
No opponent, non-verbal	6.7 (1)	40.0 (6)
Opponent, verbal	13.3 (2)	73.3 (11)
Opponent, non-verbal	20.0 (3)	73.3 (11)

On the 'Liberal' Criterion.		
	Autistic	Mentally Handicapped
No opponent, verbal	13.3 (2)	66.7 (10)
No opponent, non-verbal	6.7 (1)	53.8 (8)
Opponent, verbal	13.3 (2)	93.3 (14)
Opponent, non-verbal	20.0 (3)	93.3 (14)

Our results also indicated no difference at all between the performance of subjects with autism in the 4 conditions. All of the subjects with autism who succeeded did so from the very first experimental trial, although the majority of the autistic group were not successful on the first trial and did not manage to learn the appropriate strategy. By contrast, in the non-autistic group, subjects frequently began in error and improved as the session continued. However, even under the conservative criterion (under which fewer non-autistic subjects could be categorised as successful) there was a clear group difference in the proportion of successful subjects. This is strong support for the view that the poor performance of individuals with autism on the original deception task stemmed at least in part from their problems of executive control.

The effect of mental age: The distribution of mental ages for the autistic group could be divided quite evenly into 3 NVMA bands, whereas the mentally handicapped group showed NVMAs which corresponded with only the lower 2 of these 3 bands. Chi-squared analysis for the mentally handicapped group revealed no significant effect of either NVMA, VMA or CA. This may be a ceiling effect, since the majority of subjects with mental handicap in the low NVMA or VMA bands achieved both criteria for success.

There was no significant effect of CA for the autistic group, but a significant effect of both NVMA and VMA with the significant point of change being at a mental age of about 8-years, (corresponding to a CA of about 14-years for this group). Only 2/40 individuals with autism succeeded with a mental age lower than 8-years, whereas 6/14 of those with a NVMA > 8-years (6/13 for the VMA banding) achieved criterion. This result suggests that a developmental progression in strategic control of behaviour can be observed, despite the overall poor performance of the autistic group.

Before we take these findings too far, it is important to notice two points concerning the performance of the control group. Firstly, the control group in this study did not do quite as well as the control group for the first study. This may be explained at least in part by the fact that the original study involved a control group of children with Down's syndrome: children who are well known for their social acumen. By contrast, only one of the 60 control subjects in the current study had Down's syndrome. Secondly, closer examination of the effect of condition on the performance of the control group showed that for these subjects, the presence of a competitor was actually helpful. A sceptic might therefore argue that the poor performance of the autistic group may simply have been a consequence of their lack of competitive attitude. In particular, the presence of the experimenter may have been construed as competitive, despite efforts to appear as a collaborator in the task.

BOX TASK

The second study to be presented here addressed the problem of competition directly. For this study, an apparatus was designed such that presentation of the reward was mechanically controlled and contained no elements of competition

The task itself involved retrieving a large marble from its platform inside a box, and was inspired by Adèle Diamond's object retrieval studies with infants (e.g., Diamond & Gilbert, 1989)

The most obvious means of retrieving the marble would be by a direct line of sight reach through the hole in the front face. However, reaching through this hole interrupted a photoelectric circuit (rather like the motion detectors used to deter burglars). This circuit controlled a trap-door just beneath the marble, causing the marble to drop out of view.

At the start of the experiment subjects were encouraged to play with the box and attempt to retrieve the marble. After 4 or 5 unsuccessful attempts the experimenter demonstrated that no matter how carefully or how quickly one moved one's hand, it was impossible to retrieve the marble by this route.

The experimenter then showed the subject that the green light was on, and told the subject that this light indicated that it was possible to obtain the marble by turning a knob on the right-hand-side of the box. This knob was connected to a lever paddle which knocked the marble down a chute to a catch tray (rather like a pin-ball machine). A pilot study with preschool children had shown that this route was trivially simple, even for 2-year olds, and so this route was always presented first as a familiarisation / screening task. In fact all of the subjects with autism tested were able to recover the marble in this way, further confirming that their problems of self-control are not simply a matter of motoric inhibition of a visually guided reach.

Once the subject had made 3 consecutively correct retrievals by this route, the experimenter threw a latch across the lever paddle. This action caused the green light to be extinguished and a yellow light to be illuminated. The experimenter showed the subject that turning the knob was no longer effective, and showed them that the required route was now to flick a switch on the left-hand-side of box before reaching in for the marble. Having modelled this action sequence the experimenter then asked the subject if they also could retrieve the marble. Subjects were given 15 trials in which to attain a criterion of 3 consecutively correct responses.

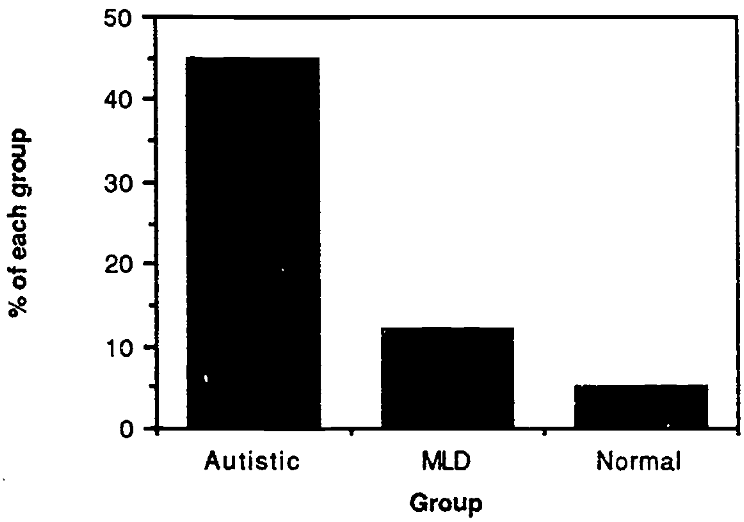
As an incentive for achieving criterion, subjects were shown a plastic trumpet made up of 16 coloured segments and allowed to blow it a couple of times, after which the trumpet was dismantled. Each time the marble was retrieved by the switch route, one segment of the trumpet was reassembled. Thus, by the end of the experiment subjects had assembled trumpets whose sizes varied according to how many trials they had taken to attain a criterial run.

An autism-specific deficit in executive control would result in the subjects with autism in this study having substantially greater difficulty with the switch-route than either young nonnal or non-autistic subjects with mental handicap. This outcome could not of itself explain why deception is difficult for children with autism, but it would reinforce the executive dysfunction account of their performance on the Windows task.

Results

The number of subjects failing to achieve criterion is shown in the following graph...

Failures on the switch-route



Subjects with autism were significantly more likely to fail to attain the criterion on the switch route than were the other two groups: 45% of children and adolescents with autism did not achieve criterion, as compared with 5% of normal preschoolers, and 8% of children with mental handicap.

We also examined the effect of within group variables such as age or mental age on performance... Here the subjects with autism were divided into 4 groups of 10 subjects in terms of CA, VMA and NVMA. The ordinate shows the average performance for each subgroup. This could range from +1 (if every subject reached criterion) to -1 (every subject failing criterion). Thus, if the histogram is < 0, more subjects in that particular subgroup failed than succeeded to attain criterion. This reveals a disjunction between the lowest quartile of subjects and the other quartiles: on all 3 measures (CA, VMA, NVMA) more subjects in the lowest quartile failed to reach criterion than attained it. Indeed, none of the subjects in the lowest quartile for NVMA reached criterion, while failure to attain criterion is not uncommon in subjects with autism and a mean MA of around 7-years.

We then considered whether there were any qualitative differences in performance between the two clinical groups?. Looking at the detailed records for each subject group enabled us to distinguish 3 separate patterns of failure.

i) Direct-route perseveration (immediate repetitions of a direct reach)... strongly analogous to the perseverative reaches observed during the 'Windows' experiment. Sixty-five percent of subjects with autism made at least two such consecutive reaches, as against 32% of the subjects with mental handicap. Moreover, 3 of the subjects with autism produced nothing but direct reaches throughout the 15 trials, whilst a number of other subjects with autism produced responses which were almost all direct reaches. So, although perseveration on a direct route to the goal was not as prevalent as in the Windows study (perhaps as a result of using a less desirable target), it was still significantly more common in subjects with autism than in the clinical control group.

ii) Response perseveration. Only co-ordinated switch-then-reach sequences were coded as correct. A fraction of the subjects with autism (about 20%) developed elaborate sequences of touching the knob and then flicking the switch several times, without ensuring that it was in the correct position before reaching. This is in comparison with only one case of a non-autistic handicapped subject touching the knob on the first trial and in this case the action was not repeated.

iii) Failure to Capitalise. Some of the more able subjects with autism did manage to produce an effective 'switch-then-reach' sequence, only to follow with a direct reach resulting in failure. These subjects seemed almost unable to sustain a plan-of-action without a strong external reminder, such as a the noise of the marble dropping through the trapdoor. This 'failure to capitalise' did not occur in the group of normal preschoolers, and occurred only twice (8%) in the mentally handicapped group; however it occurred in 42.5% of the subjects with autism.

The most common type of error displayed by subjects with autism differed at each mental level: direct reaches and knob-touching responses were almost entirely confined to the lowest quartile. [Note that this is the band that corresponds most closely to the subject populations typically recruited for standard TOM tasks.] Failure to capitalise was the most common type of error amongst second and third quartiles. No failures were encountered in the most able quartile of subjects. By contrast, no mental age effect was observed within the mentally handicapped control group. A possible explanation for this lies in the group's heterogeneity, differences in the severity of attentional and behavioural disorders would be expected to over-ride factors such as mental age, since all of the group had a significantly higher mental age than the young normal children.

Overall, the results of the Box study indicate that in addition to the problems of 'visual seduction' first suggested by the results of the Windows studies, subjects with autism have difficulty in changing response strategies, and in a executing planful goal-directed sequence of acts.

The next two studies consider each of these problems in turn, and involve tasks carried out on a touch-screen computer. These tasks are taken from the CANTAB battery of neuropsychological tests and have been used with adult patients with frontal damage (Own et al, 1990; 1991), PD (Downes et al, 1989) and DAT (Sahakian et al, 1990). They had not previously been used with children, so in these studies a second control group of young normal children was also included

Table 1: Subject characteristics banded by NVMA

Group Mental Age	Autistic	MLD	Normal	Student's t-test
LOW (4-				
6yrs)	**4.93**	**4.96**		A = MLD < N
mean	(0.17)	(0.27)		A = MLD < N
nvma	**4.91**	**5.15**	**5.65**	A = MLD > N
mean vma	(0.37)	(0.22)	(0.06)	
mean age	**13.42**	**11.25**	8	
n=	(0.98)	(1.16)		
	13	7		

MED (6-				
9yrs)	**7.90**	**7.81**		A = MLD > N
mean nvma	(0.18)	(0.13)		A = MLD = N
mean vma	**7.03**	**6.78**	**7.21**	A = MLD > N
mean age	(0.72)	(0.39)	(0.13)	
n=	**12.04**	**12.76**	20	
	(0.96)	(0.62)		
	11	20		
HIGH (>				
9yrs)	**12.24**	**10.02**		A > MLD = N
mean nvma	(0.53)	(0.29)		A = MLD = N
mean vma	**10.45**	**9.38**	**9.93**	MLD > A > N
mean	(0.46)	(0.55)	(0.10)	
age	**12.98**	**15.30**	19	
	(0.76)	(0.19)		
n=	11	11		

(std errors given in brackets)

n.b. Student's t-test made assuming that for normal gp, MA=CA. All differences significant at the $p < 0.01$ level.

ID/ED TEST

The first of these tasks goes by the rather daunting name of 'intradimensional - extradimensional shift test'. This task which we'll call the ID/ED for short taps esssentially the same kinds of abillities as the WCST, a classic test of frontal function which has already been shown in previous studies to be sensitive to the impairments of executive control found in high functioning subjects with autism (e.g., Prior and Hoffmann,1990; Ozonoff, Pennington and Rogers1991)

The aims of the present study are two fold: (1) to exploit the stage-wise design of the ID/ED study so as to clarify the focus of difficulty for subjects with autism; and (2), to establish whether significant group differences in 'set shifting' can still be observed when less able autistic and non-autistic groups are compared.

Before beginning the ID/ED test subjects are given a motor-screening task to familiarise them with pointing to various stimuli on the touch-screen and to test their ability to discriminate between these stimuli. The ID/ED shift task itself is presented to subjects in separate stages of difficulty, up to a maximum of 9 stages.

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1) Simple discrimination (3 mountains, say)

2) Simple reversal (rhino-from behind)

3) Introduction of distractor compound elements, positioned to the side of the main exemplars to inhibit configurational thinking (still rhino)

4) Distractor elements now superposed on main forms (still rhino)

5) Second reversal of rule (3 mountains again)

6) Intra-dimensional shift- total change of exemplars, but still large shapes relevant (say fox shape)

7) Rule reversal (now elephant from behind)

8) Extra-dimensional shift- total change of exemplars, but now it is the previously irrelevant white lines which are reinforced (say cube-corner)

9) Extra-dimensional reversal (t form)

At each stage of the task subjects are given up to 50 trials in which to obtain 8 consecutive correct responses. When this criterion is reached the programme moves automatically onto the following stage.

What are the advantages of this design (compared with the WCST)?

• we know that subjects who reach the first transfer stage are capable of reversing a learned rule, so deficit is not a global problem of shifting responses.

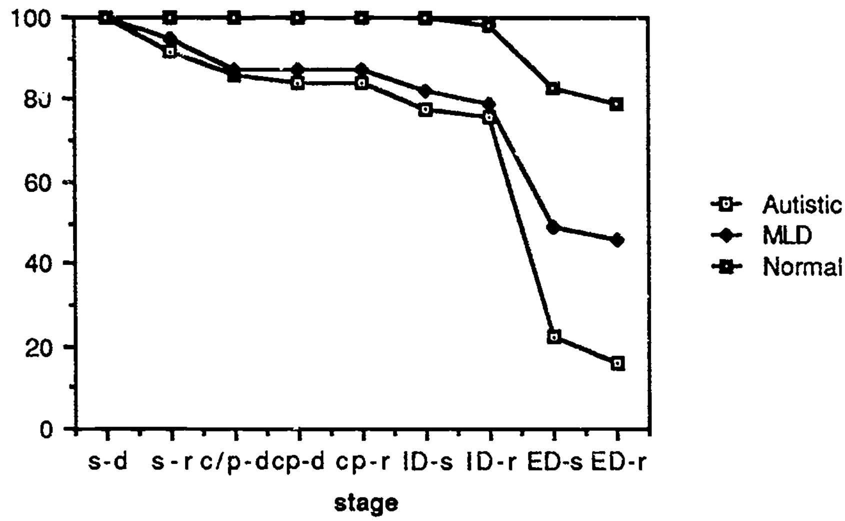
• similarly, we know that subjects who reach the ED stage are capable of ID-s, so that it is not the total change of exemplars which is a problem, or the need to transfer a rule.

• the total change design is more conservative, since the new exemplars alert subjects to the change and so weaken the tendency for perseveration.

• the total change design also clearer than the WCST, since in the latter the specific exemplars remain the same, although the rule may change (so difficult to discern whether perseveration is directed at the exemplar or the dimensional level).

One of the simplest means of representing the results from the IDED test is in terms of 'survival rates', that is, the number of subjects attaining criterion at each stage.

Figure 6.2: Percent survival at each stage of task



From these results we can see that although both clinical groups (autistic and non-autistic subjects with mental handicap) were impaired relative to the normal group at almost every stage of the task, the only autism specific deficit emerged at the ED-s stage. That is, subjects with autism were no more impaired than non-autistic subjects with mental handicap at reversing a rule they had learned, at sustaining this rule despite the introduction of distractors, at reversing the rule once more, at making a shift within a governing dimension.

Looking at the first shift stage we found that measures of performance in terms of TTC and ETC showed that although the performance of the two clinical groups on the ID-s was equivalent, the types of errors made by each group differed. In particular, the errors made by subjects with autism were typically in response to the novelty of the exemplars, whereas those made by subjects in the control clinical group were predominantly failures to maintain set.

We then considered the 2nd shift stage, and found that failure at this stage was very common amongst subjects with autism of all mental ages...

Although these subjects had successfully passed all the preceding stages of the IDED test, so that we can exclude factors such as rule-reversal and transfer of learning as underlying the autistic impairment, there remains an element of ambiguity in these results. This is because applying an extra-dimensional (or extra-categorical, if you prefer) shift involves two processes. First the subject must cease responding to a previously salient dimension (note that for some subjects the large forms may have been reinforced for as many as 300-400 trials). Secondly, the subject learn to attend to a dimension (or category) which has previously only been randomly reinforced. Subjects have had to learn that the white lines were irrelevant in order to succeed on the prior stages. They may therefore now be rather difficult to recognise as relevant.

Thus, failure at the ED-s stage may result from what Sandson and Albert (1984) have called 'stuck-in-set' perseveration, or from an effect of enhanced learned irrelevance, analogous to the latent inhibition seen in animal learning studies. Indeed, recent clinical work by Owen et al in London, using a modified version of the ID/ED test to distinguish between these two possibilities has shown that whereas frontal patients show stuck in set perseveration, the problems of patients with PD on the IDED task result from enhanced learned-irrelevance. Michelle Turner at the University of Cambridge is currently applying the new IDED task to a sample of high functioning children and adolescents with autism, so this ambiguity should very soon be similarly resolved for the case of autism.

SOC study

The final study to be described here is known as the 'Stockings of Cambridge' or SOC test and is a computerised version of Tim Shallice's TOL (1982). As such it is very closely related to the TOH, a classic test of planning involving moving a pyramid of discs from one of 3 pegs to another. This test has already been given to subjects with autism (e.g., Ozonoff, Pennnington and Rogers, 1991). Apart from its computerised format, the principal differences between the SOC and the TOH are:

1) Coloured balls are used rather than differently sized discs - obviating the problems of rule-violations posed by the rather complex rule in the TOH that no disc may be placed above a disc smaller than itself.

2) However, this modification increases the size of the problem space, and so the pegs are reduced in size such that only one peg can take 3 balls, one can take 2, and one can take a single ball only

3) Rather than presenting subjects with the full tower-to-tower transfer, and recording how many attempts are needed to find the perfect solution, subjects are presented with a graded series of partial problems, requiring between 2 and 5 moves. To simplify the representation of our results we have grouped together the 2- and 3-move problems as an 'easy set', and the 4- and 5-move problems as a 'difficult set'

In this way subjects can be tested on novel problems, thus removing the possibility that differences in procedural learning skills contribute to differences in performance. Thus the SOC test provides a purer measure of planning ability.

The measures of performance used were:

i) Solns. within allowed number of moves, providing a base-line check that sub; cts were actually attempting to make a copy as instructed.

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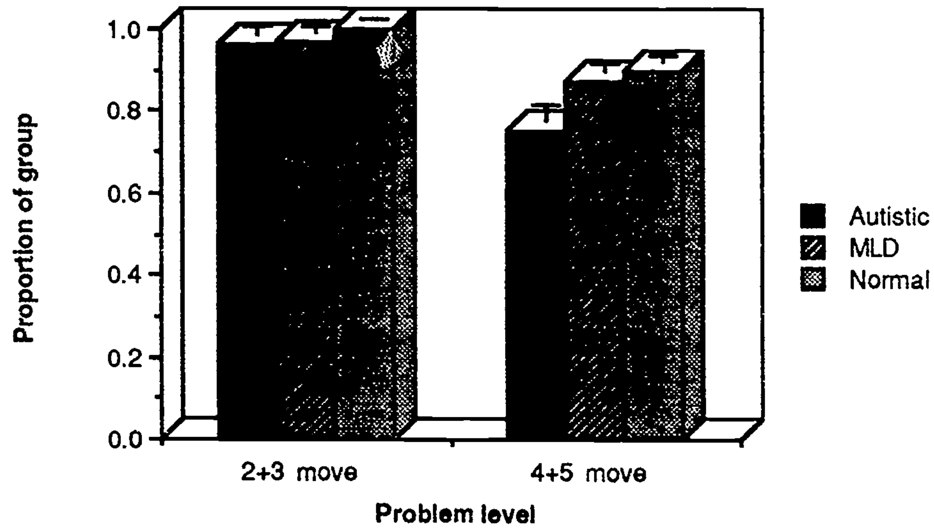
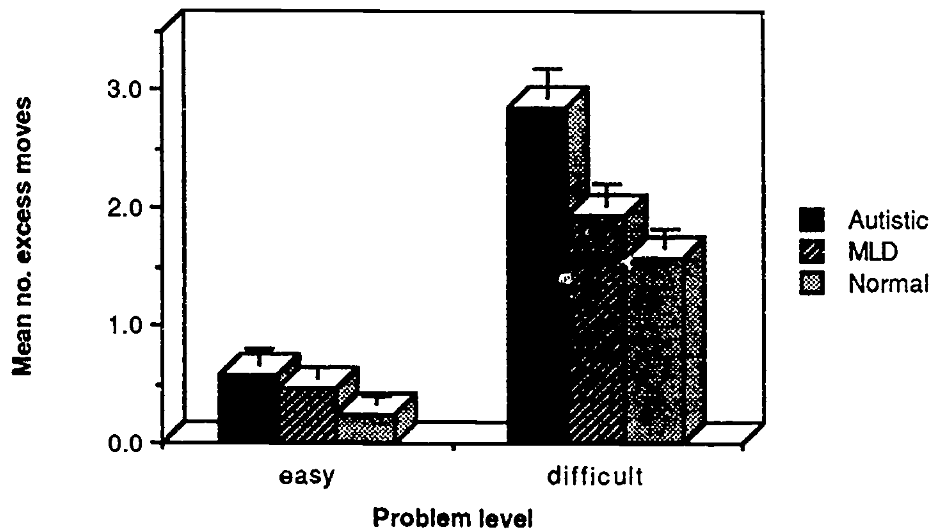
Figure 1a: Solutions within limited no. moves



ii) Number of moves in excess of minimum -

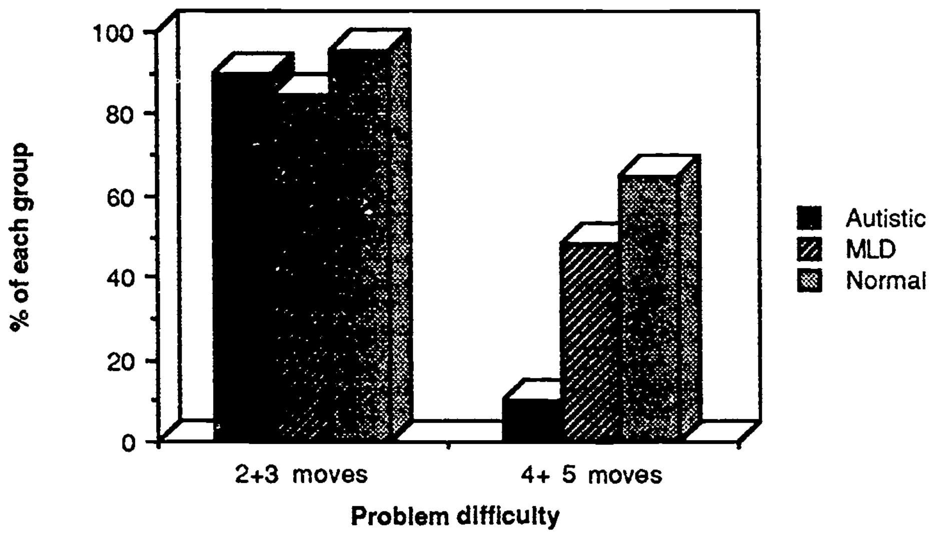
SLIDE- shows that subjects with autism were significantly less efficient in the solutions that they produced to the difficult set of 4 and 5 move problems.

No. extra moves required



iii) Perfect solutions on at least half Although the number of extra moves taken does show a difference in solution efficiency for the 3 groups, it remains rather difficult to interpret. It would be possible for example for a group of subjects to appear to be doing very well if they consistently exceeded the minimum by a small number of moves. A more sensitive measure is therefore to consider how many perfect solutions subjects in each group obtained, and in particular, how many subjects solved more than a criterial proportion (say, half) of the problems perfectly.

Fig 2b: Subjects reaching criterion for planning



- by NVMA and group for difficult- the impairment in planning in autism appears independent of mental age...

Closer scrutiny of the problems in the difficult set revealed that 6/8 of these had unique solutions, such that the first move of the solution path was critical. This probably contributed significantly to the poor performance of the autistic group, since this group produced significantly fewer correct first moves, and so were precluded from performing well on the planning criterion right from the start. Furthermore, while all 3 groups displayed a significant tendency to make the same first move (placing the red ball in the top pocket); the 2 control groups quickly learned that this move was maladaptive, whereas subjects in the autistic group were more likely to persist in this maladaptive strategy, despite the problems that resulted from this.

iv) Timing

The computerised format of the SOC task also permits more detailed information about the time taken to solve problems than does the TOH task. This is especially true since the SOC test presents each subject with a set of yoked 'follow' problems, in which the pattern at the top of the screen changes by one ball at a time and the subject is required to follow on the bottom arrangement. So if a given subject took 7 moves on a 4-move problem, in the corresponding follow problem that subject would be required to execute exactly the same sequence of 7 moves. By a method of subtraction it is thus possible to provide an estimate of thinking time (both prior to the first move and per subsequent move) that is independent of a subject's actual movement times. In this way factors such as impulsivity could be excluded from accounts of performance differences.

Summary of SOC: The results obtained in this study indicate that subjects with autism display a planning deficit that is independent of impulsivity, rule compliance, procedural learning and mental age, but related to the required depth of search, and thus appears as a relatively pure deficit in the construction of plans. Alternatively, it is possible that subjects with autism were able to construct a plan which enabled them to anticipate obstacles, but were unable to change this plan once formulated. Such persistence would create difficulties both within a problem (where often the appropriate response to a detected error was to retrace one's steps) and across problems, since the set required different strategies for each problem.

Discussion

In these 4 studies we have outlined a number of specific dysfunctions of executive control that are found in children and adolescents with autism across a broad range of mental abilities....

STUDY	AREA OF DEFICIT	UNDERLYING DYSFUNCTION?
		-'stuck-in-set' perseveration
Windows, Box	Behavioural strategies with no immediate contingency between response and reward	-recurrent perseveration
		-failure to sustain action plan
		-'stuck-in-set' perseveration
ID/ED	Shifting attention from salient to previously unreinforced dimension or category	-enhanced learned irrelevance
		-poor response to novelty

SOC	Depth-first search to anticipate and avoid obstacles on solution path	-problems in constructing hypothetical models - Failure to suppress a plan -Failure to change a maladaptive strategy

The results of the first two studies indicate that subjects with autism are impaired in the processes required for learning behavioural strategies which involves a counter-intuitive or arbitrary association between response and target. The dysfunction in question may result from 'stuck in set' perseveration, recurrent perseveration or failure to sustain a plan of action in the absense of environmental cues.

The results from the ID/ED study indicated a striking and autism specific deficit in the processes required in order shift attention from a salient dimension or category and engage attention upon a previously irrelevant stimulus. At this point it is not possible to determine whether this is another example of stuck in se. perseveration, or rather an effect of 'enhanced learned irrelevance', such as has been found among patients with PD.

The results of the SOC study showed that subjects with autism are unable to find efficient solutions to planning problems which require a depth-first search to anticipate obstacles and the cognitive flexibility to change plans so as to avoid these obstacles. The deficit may be at the first stage of planning construction, but may also be affected by failures to suppress a plan that has been formulated, or to change a strategy that proves unsuccessful.

Alongside these deficits, the results of these studies show a number of skills and processes which are intact in autism. These include inhibitory control at the level of simple motor acts, simple discrimination learning and reversal learning, sustaining a rule in the face of distracting elements, transferring a learned rule, and executing a sequence of up to 12 moves so as to achieve a goal.

There are two axes along which these clusters of impaired and intact abilities can be compared. The first of these is the level of inhibitory control, the deficit in autism appearing to be predominantly one of high-level inhibitory control, resulting in stuck-in-set perseveration. The second factor (which may be related to the first) is the need for temporal integration of an action sequence or plan. It may be possible to express the second domain in terms of the first: by Gestalt, temporal contiguity is a strong external cue for association. Therefore when two events are temporally contiguous only a low level of organisation is needed, and demands on the agent's central system of executive control are correspondingly reduced. All this is very speculative-- but we are beginning investigations of working memory function in individuals with autism to establish some empirical foundations for such hypotheses.

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