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'If pigs could fly': A test of counterfactual reasoning and pretence in children with autism

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The authors report an experiment with children with autism, using the Dias & Harris (1990) method, to test the predictions that: (i) children with autism will show intact counterfactual reasoning, and (ii) since such children are impaired in pretence, they would not then show the normal facilitation effect of pretence on counterfactual reasoning ability. Children with autism and matched verbal mental age (VMA) controls were presented with a series of counterfactual syllogisms, in two conditions. One condition (Counterfactual plus Pretence) involved prompting the child's imagination during the reasoning task, whereas the other condition (Counterfactual Only) included no such prompting. Results showed that both normal 4–5-year-old children, and children with moderate learning difficulties improved in their reasoning performance when prompted to use imagination. This replicates and extends findings from Dias & Harris (1990). In children with autism, however, performance was good in the Counterfactual Only condition, but became worse when imagination was prompted. These results show that although abstract counterfactual reasoning appears intact in children with autism, their counterfactual reasoning is not facilitated by pretence in the normal way.

Traditionally, children were not used as participants for logical reasoning tasks involving syllogisms, possibly because of the claim by Piaget (Inhelder & Piaget, 1958) that children cannot comprehend formal logic until their early teens. However, research in recent years has questioned this assumption, with evidence that under certain conditions children as young as 4 years old demonstrate syllogistic reasoning capacity (Dias & Harris, 1988, 1990; English, 1993; Hawkins, Pea, Glick & Scribner, 1984). Dias & Harris (1990), for example, showed that normal 4-year-olds are by and large rather poor at counterfactual syllogistic reasoning—until these problems are set in a pretend context.

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Once the child is engaged in pretending, such reasoning becomes easier. Thus, given the premise 'all pigs can fly' and 'John is a pig', 4-year-olds have difficulty drawing the conclusion 'John can fly'. But, if they are first told 'let's pretend that [all pigs can fly] . . .', then performance is facilitated.

It is not clear exactly why this facilitation occurs. It may be because counterfactual propositions initially appear nonsensical and confusing, because by definition they contradict the child's real-world knowledge. When prefixed with 'let's pretend that (x)', this may clarify for the child that these propositions are intended to refer to an imaginary world. The 'let's pretend' prefix may have the effect of cueing the child to 'change gear' in cognitive terms: switching to pretend mode, where anything is possible, may allow them to reveal their reasoning abilities at an abstract level—that is, removed from the constraints of reality.

While there have been several studies exploring syllogistic reasoning in young, normally developing children, there has been little research conducted with young clinical populations. Recent evidence has shown that children with autism may not have a deficit in abstract reasoning (analogies and transitive inferences) compared to matched controls (Scott & Baron-Cohen, 1996*a*); children with moderate learning difficulties also seem capable of such reasoning (Robertson, 1993; Scott & Baron-Cohen, 1996*a* (but see Leevers & Harris, 1996), who found that children with autism appear unlikely to adopt a logical strategy).

Intact reasoning performance in autism may not be as surprising as it sounds. Recent research has suggested that people with autism may be intact in their ability for 'folk physics', even though their 'folk psychology' is deficient (Baron-Cohen, 1997). Folk physics presumably depends on reasoning skills (e.g. 'Unsupported objects fall; this ball will be unsupported; therefore this ball will fall'). This cognitive profile of intact folk physics and impaired folk psychology may also be true of their parents, one of whom may carry the genes for autism (Baron-Cohen, Wheelwright, Stott, Bolton & Goodyer, 1997). That is, there may be two distinct cognitive domains concerned with reasoning about the world: one which relates to social causality (folk psychology), and one which relates to physical causality (folk physics) (Sperber, Premack & Premack, 1995). People with autism appear intact in folk physics skills. However, the evidence to date is limited. Certainly, one might expect to find problems with counterfactual reasoning among the autistic population if they have an inability to disengage from reality (Russell, 1996). Given their apparent success with other forms of reasoning, this warrants further exploration.

Markovits (1995) suggests that the initial difficulty that faces a normal individual when presented with counterfactual premises involves representing the premises without interference from real-world knowledge. This requires the individual to construct an internal model that does not incorporate information from long-term memory (LTM), because this information would contradict the counterfactual, and empirically false, premises. This does not come naturally to the normal person, as the drive to relate new information to already acquired knowledge is strong. Frith (1989) calls this normal phenomenon 'strong central coherence'. The inclusion of a pretend context helps to prevent real-world information from LTM interfering with the representation of the counterfactual premises.

It could be argued that children with autism would not experience this initial difficulty because they show deficits in the ability to integrate information in relation to context and

previous knowledge (Frith, 1989; Happe, 1997); they are said to have 'weak central coherence' (Frith, 1989). Children with autism may therefore address counterfactual premises as totally isolated information, without the normal drive to try and relate them to LTM and their existing empirical knowledge. If this is the case then, paradoxically, performance with counterfactual syllogisms *per se* would be expected to be good. However, whereas normal children benefit from the introduction of a pretend context, children with autism may be unlikely to show the same facilitation effect following pretence. Given the evidence that children with autism have a profound impairment in the spontaneous production of pretence and imagination (Baron-Cohen, 1987; Gould, 1986; Jarrold, Boucher & Smith, 1993; Scott & Baron-Cohen, 1996*b*; Ungerer & Sigman, 1981), the authors expected that children with autism would show no benefit from setting a counterfactual reasoning task in a pretend context; indeed, their performance may even suffer under those conditions. Use of context may be problematic for individuals who may neither understand the nature of that (pretend) context, nor spontaneously utilize context for meaning. At the same time, in contrast to the group with autism, the authors expected that the children with moderate learning disabilities, who have no recorded difficulties with either coherence or pretence, would show the normal pattern of improving performance when counterfactual syllogisms are set in a pretend context.

To summarize, the authors employed the Dias & Harris (1990) method with children with autism with two aims. The first was to establish if counterfactual reasoning *per se* was intact in autism. As has been mentioned, non-counterfactual reasoning appears intact in autism (Scott & Baron-Cohen, 1996*a*), but is the same true for counterfactual reasoning? A strong version of the executive dysfunction theory (Russell, 1996) would predict an inability to 'disengage from reality', and therefore poor counterfactual ability in autism. In complete contrast, central coherence (Frith, 1989) would predict an inability to utilize context for meaning, suggesting the possibility that interference from real-world knowledge will not occur and counterfactual reasoning may thus be intact. Equally, the 'folk physics' argument may suggest that children with autism will be intact on all logical reasoning tasks that do not involve a 'mental' or 'folk psychology' element.

The second aim was to test if autistic difficulties with pretence had predictable consequences for their pattern of logical reasoning. Specifically, it was predicted they would not show the normal facilitation effect of pretence on counterfactual reasoning.

Method

Participants

Three groups of participants were tested. The first was a group of 15 children with autism, all of whom were attending special schools for autism in London and met established criteria for autism (DSM IV, 1993; Rutter, 1978). The second group contained 14 children with moderate learning disabilities[1] (MLD) attending special schools for learning disability in Norfolk. The final group comprised 15 normal children, all attending a primary school in Norfolk.

[1] The term 'learning disabilities' is used synonymously with the older, but now less-used, terms 'mental handicap' or 'retardation'.

Table 1. Chronological and verbal mental ages, by participant group

	Chronological age			Verbal mental age		
Group	Range	*M*	SD	Range	*M*	SD
Normal	4.9–4.11	4.10	0.743	—	—	—
MLD*	8.6–18.2	12.3	36.28	4.0–5.0	4.6	5.13
Autism	7.9–18.0	12.11	35.70	4.0–6.0	4.7	7.57

Notes. SD in months. VMA was assessed using the Test of Reception of Grammar (TROG; Bishop, 1983) as this was felt to give a more conservative estimation of verbal ability than traditional vocabulary measures.
* Moderate Learning Difficulties

Design and procedure

Participants were seen individually by the experimenter, in a quiet room. The experimenter told the participant that he or she was going to hear some little stories about things that were very different, but that they should play a game that these things were true. Each participant was then asked a series of 10 Reality control questions in order to check for relevant general knowledge about the themes of the later stories (e.g. 'Can you tell me what noise cats make?'). These questions are listed in Appendix 1.

The task had two conditions, Counterfactual Only (CO) or Counterfactual plus Pretence (CP)[2], and each participant received both of the conditions, in different sessions and with at least a one-month interval between each. Some participants received the CO condition first, while others received the CP condition first. Owing to an administration error these two orders were unequally weighted. Six children from each of the three groups received the CO condition first, leaving nine children in the autistic and normal groups and eight children in the MLD group who received the CP condition first.

Counterfactual Only (CO). In this condition, after answering the Reality control questions and being reminded of the instructions, the participant was then presented with five counterfactual syllogisms, one at a time, spoken by the experimenter in a neutral tone of voice (see Appendix 2). After hearing the premises (e.g. 'All cats bark'; 'Rex is a cat') the participant was asked to repeat them to ensure that they had been heard correctly. (If they were not repeated correctly, the experimenter repeated the premises.) The experimenter then went on to ask the Conclusion question (e.g. 'Does Rex bark?'). After the participant had responded, he or she was prompted for a justification by the experimenter asking, for example, 'Why does Rex bark?' until a justification of some kind had been given. These were later coded into (a) Theoretical (i.e. based on the content of the syllogism), (b) Empirical (i.e. based on the participant's knowledge of the real-world), or (c) Arbitrary (i.e. random, irrelevant or obscure).[3]

Counterfactual plus Pretence (CP). In this condition, after answering the Reality control

[2] This study concentrated on one aspect of pretence as explored by Dias & Harris (1990): 'imagining'. These two conditions differed in terms of direct encouragement of the imagination process.
[3] An example of a Theoretical justification would be 'Because you said all cats bark'. An example of an Empirical justification would be 'Because cats don't bark, they go miaow!'

questions, the participant was led through a set of seven Pretence Training and Control questions:

1. Can you make a picture in your head of a pig?
2. Can you make the pig do something different/funny?
3. Can you make the pig in your head fly?
4. Is the pig in the air, or on the ground? (The order of choices was counterbalanced.)
5. What is the pig doing?
6. Is the pig real, or in your head? (Again, the order of choices was counterbalanced.)
7. Can *I* see the pig in your head?

These questions were intended to prompt the child's imagination, and at the same time test what the child understood about the nature of imagination. The experimenter was careful not to use the word 'pretend' in the Pretence Training, so as not to disadvantage the children with autism, who may not understand the specific term (Tager-Flusberg, 1993). When the participant had answered all of these questions, and their responses had been recorded, the experimenter then repeated the original instructions, but this time adding that the participant should try and make a picture in his or her head about each of the stories. The participant was then told five syllogisms (see Appendix 3), which were again spoken by the experimenter in a neutral tone of voice. As in the CO condition, the experimenter first tested if the participant could remember the premises and also checked that the child was attempting to visualize each 'story'. The experimenter then asked the Conclusion question, and again asked the participant to justify his or her answer. As before, justifications were recorded and later coded into the same three categories.

Results

Reality control questions

All participants in each of the three groups passed the 10 Reality control questions without any difficulties.

Experimental conditions

Table 2 shows the mean number of correct syllogisms for each group according to condition and order of presentation. A three-way ANOVA comparing Group (Autism, MLD, Normal) by Order (CO 1st, CP 1st) by Condition (CO, CP) was conducted. Results demonstrated a significant interaction for Group × Condition ($F(2,38) = 7.38$, $p = .002$), but no main effects for either Group ($F(2,38) = .89$, $p = .419$) or Condition ($F(1,38) = .02$, $p = .888$). Simple effects tests were used to explore the interaction of Group × Condition further. These showed a significant effect of Group for CO ($F(2,38) = 9.03$, $p = .0006$), but not for CP ($F(2,38) = 1.86$, $p = .169$); they also showed a significant effect of condition for the Autistic Group ($F(1,38) = 8.00$, $p = .007$), but not the MLD Group ($F(1,38) = 3.55$, $p = .067$) nor the Normal Group ($F(1,38) = 4.01$, $p = .052$), although both of these latter results almost reached the .05 significance level.

Table 2. Mean number of correct syllogisms (out of five) shown by condition and order of presentation, for each group

	Counterfactual Only (CO)			Counterfactual + Pretence (CP)		
Group	1st	2nd	Overall	1st	2nd	Overall
Autism	4.0 (2.0)	3.67 (1.87)	3.84 (1.86)	2.78 (2.22)	1.33 (2.16)	2.06 (2.24)
MLD	2.0 (1.89)	1.25 (2.11)	1.32 (2.14)	3.13 (2.03)	2.17 (2.4)	2.65 (2.1)
Normal	3.17 (2.14)	1.44 (1.88)	2.31 (2.1)	3.56 (1.67)	2.83 (1.84)	3.25 (1.71)
Overall	3.06	2.12	2.49	3.16	2.11	2.65

Note. Standard deviations in parentheses.

Post hoc paired *t*-tests were conducted to confirm whether the children with autism performed better than both control groups in the CO condition (Autism × Normal, $t(28) = 2.32$ (two-tailed), $p = .028$; Autism × MLD, $t(27) = 3.05$ (two-tailed), $p = .005$; Normal × MLD, $t(27) = .72$ (two-tailed), $p = .48$). Thus, while the two control groups were not significantly different in their performance in the CO condition, the children with autism were significantly better than both the MLD group and the Normal group. Fig. 1 shows the mean number of correct syllogisms as a function of group and condition.

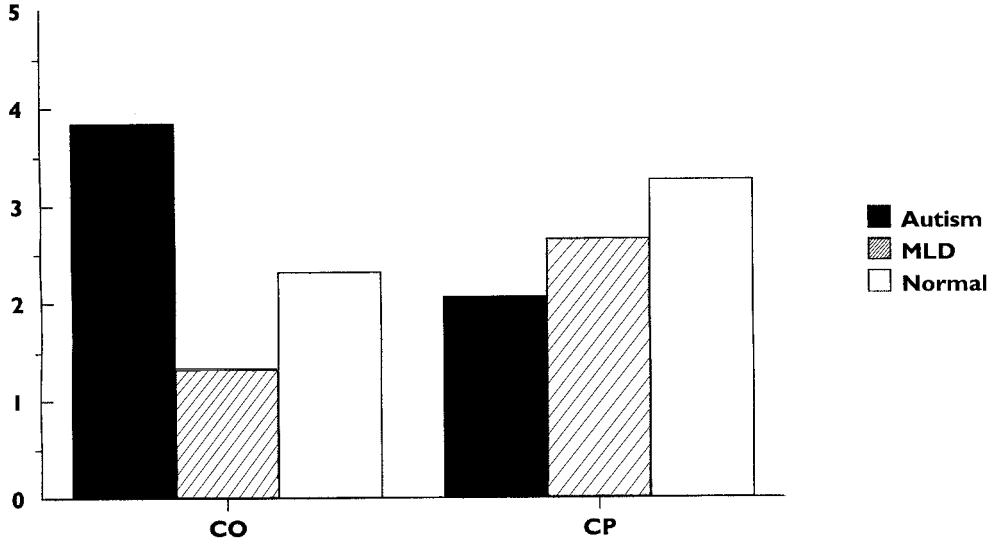

Figure 1. Mean number of correct syllogisms for each condition by group

The ANOVA also showed a significant interaction for Order × Condition ($F(1,38) = 8.67$, $p = .005$), but no main effects for either Order ($F(1,38) = .01$, $p = .921$) or, as noted above, for Condition ($F(1,38) = .02, p = .888$). Simple effects tests showed no significant effect of Order for CO ($F(1,38) = 1.81$, $p = .186$) or CP ($F(1,38) = 2.87, p = .098$); there was also no significant effect of Condition for CO 1st ($F(1,38) = 2.01$, $p = .164$) or for CP 1st ($F(1,38) = 3.26$, $p = .079$). The absence of

significant effects is unusual given a significant interaction for Order × Condition. However, it is likely that the interaction is owing to the fact that the simple effects, while non-significant in their own right, are in opposite directions.

The interaction of Group × Order × Condition was non-significant ($F(2,38) = .12$, $p = .887$), nor was there any significant interaction of Group × Order ($F(2,38) = .35$, $p = .707$).

Table 3. Responses to Pretence Training and control questions, shown by number of participants

	1. Picture of Pig?		2. Do Funny?		3. Pig Fly?		4. Pig in Air/ Ground?		5. What is the Pig Doing?*		6. Pig Real/in Head?		7. Can I see?	
Group	Yes	No	Yes	No	Yes	No	Air	Gd	Fly	NA	Rl	Hd	Yes	No
Autism	15	0	10	5	15	0	15	0	15	0	7	8	8	7
MLD	14	0	13	1	14	0	14	0	14	0	1	13	2	12
Normal	15	0	15	0	15	0	15	0	15	0	0	15	0	15

* This was scored 'Fly' if something relating to flying/air was mentioned, and 'NA' if something inappropriate was mentioned.

Pretence Training and control questions

Questions 1, 3, 4 and 5 were answered at ceiling by all children. However, the children with autism performed poorly compared to the two control groups on questions 2, 6 and 7. This pattern of results is shown in Table 3. Chi-square analyses confirmed the significant differences in group performances for Questions 2, 6 and 7 ($N = 44$):

Q2 'Can you make the pig do something different/funny?'—successful attempts $\chi^2(2) = 7.79, p = .02$.

Q6 'Is the pig real or in your head?' (counterbalanced)—head responses $\chi^2(2) = 12.66$, $p = .002$.

Q7 'Can *I* see the pig in your head?'—positive responses $\chi^2(2) = 12.98, p = .002$.

It is worth noting that of the eight children with autism who correctly answered 'head' for Q6, only three also then answered Q7 correctly. In other words, it was not the same seven or eight children with autism passing questions 2, 6 and 7. Performance by the autistic group was not consistent.

Comparison of integrated vs. less-integrated syllogisms

Five of the ten syllogisms used may not have required as great an integration of the first and second premises in order for the participant to provide a correct response (syllogisms 2, 4 and 5 in CO condition (see Appendix 2), and syllogisms 2 and 3 in the CP condition (see Appendix 3)). A χ^2 analysis was therefore conducted to check whether children were more successful at the less-integrated syllogisms than the arguably more logical integrated syllogisms. Results demonstrated no significant differences in performance for the

two kinds of syllogisms (CO, integrated vs. less-integrated, $\chi^2(1)$ (N = 44) = .18, p = .67; CP, integrated vs. less-integrated, $\chi^2(1)$ (N = 44) = .04, p = .84).

Finally, an examination of the justifications provided by participants demonstrated that a theoretical response was given when the syllogism was answered correctly, and an empirical response was given when the syllogism was answered incorrectly. Every response given fell into one of these two categories, and all of the children in all three groups provided justifications for each syllogism presented. Inter-rater agreement was 95%. The exception to this was one child with Down's Syndrome whose response could only be classified as arbitrary. However, many of the responses involved repeating Premise 1. Examples of justifications are shown in Appendix 4.

Discussion

This study set out to test a set of predictions. First, given earlier studies (Dias & Harris, 1990), it was predicted that young normal children would show poor performance on a basic counterfactual syllogistic reasoning task, but improved performance if such a task was set in a pretend context. Second, it was predicted that a learning disabled group of older children would likewise show poor performance on the task, but improved performance with the introduction of pretence. Both these predictions were supported. Third, it was predicted that the children with autism might show good performance on counterfactual reasoning, while failing to show a facilitation effect of pretence. This prediction was also supported. Participants with autism showed evidence of good logical reasoning ability in the Counterfactual Only (CO) condition—they were nearly at ceiling and performed significantly better than the two control groups, supporting earlier findings of intact reasoning (Scott & Baron-Cohen, 1996*a*). This is consistent with the suggestion that the lack of a drive to integrate new information with information in LTM (i.e. weak central coherence) may actually lead to good performance on counterfactual tasks, but is inconsistent with a strong executive dysfunction argument.

The two control groups improved in their performance in the Counterfactual plus Pretence (CP) condition, replicating and extending the results of Dias & Harris (1990), although in the pesent study this did not quite reach significance, perhaps owing to small sample sizes (MLD (N = 14) p = .067, normal (N = 15) p = .052). However, the children with autism showed *worse* performance in the CP condition. This pattern is consistent with the suggestion that counterfactual reasoning is intact in autism, while pretence is impaired. This might also be interpreted as demonstrating a discrepancy between folk physics and folk psychology, if a broad definition of folk physics is used to include all non-social logical reasoning.

The finding of intact counterfactual reasoning in autism appears to be genuine, since the children with autism gave theoretical justifications to their answers (e.g. 'Yes, Rex barks, because you said that all cats bark'). However, some caution may be required in that justifications often involved inclusion of the first premise in the response, as in the example above. Some authors argue that true understanding is not always being shown just because children successfully pass syllogisms (Markovits, Schleifer & Fortier, 1989), whereas others suggest that requiring children to give detailed explanations of their reasoning process is too strict a criterion, and that young children *are* capable of logical reasoning even though they are not always clear in their justifications (English, 1993). The present authors tend to

agree with the latter opinion: the children used in the present tasks were only of a verbal mental age of between 4 and 5 years, so to expect very detailed justifications could be argued to be over-restrictive. Additionally, there were no differences in performance between the syllogisms with less-integrated premises and those which required full integration. If participants were passing only those syllogisms which arguably allowed success by consideration only of the first premise, and were justifying by repeating the first premise, then this argument might be warranted. This was not the case.[4]

A second argument that could be raised against the finding of intact counterfactual reasoning in autism is that the syllogisms presented only required a 'Yes' response. While this was a design strategy aimed to prevent underestimation of children's abilities (since children find negative response syllogisms harder to understand, e.g. English, 1993), it may be argued that the children with autism demonstrated superior performance in the CO condition because they had a 'Yes' bias. However, if this were the case then these children would have presumably also demonstrated a 'Yes' bias in the CP condition. This clearly did not happen. In addition, they justified their responses theoretically when they answered correctly, but gave empirical responses when they answered incorrectly. This does not suggest either echolalia or response bias.

A further question arises from these findings. Why were the children with autism *worse* in their performance at the CP condition? It was predicted that there would be no facilitation effect of pretence for children with autism owing to their recorded problems with pretend play and imagination, but it is not clear what it is about the pretence which detrimentally affected their performance. The capacity for pretence emerges in normal development towards the end of the second year (Leslie, 1987) and frequently (but not always) involves counterfactuals. When normally developing children or children with MLD are presented with counterfactuals in syllogisms, spoken in a neutral tone of voice, they may assume the statement is to be taken literally, even though they were told to play a game in which the stories were true. As a result, they may attempt to integrate the information with empirical information from LTM, and reject the premises as untrue (Markovits, 1995). In the CP condition, although still presented in a neutral voice, the training period and subsequent instructions to mentally picture the premises seems to clarify for these children that the premises should be interpreted in a pretend context, allowing an internal model to be constructed which does not attempt to incorporate empirical LTM information, and thus demonstrating their capabilities in logical reasoning of this kind.

For the children with autism, however, the training period and subsequent instructions appear to have led to 'reality intrusion' errors. It is unlikely this can be explained simply as owing to the extra task load of the training questions in the CP condition, as the children with autism only performed differently to controls in three of the seven questions and did not show perseverative responses. However, while the control children had no difficulties in understanding that the imagined pig in the training questions was 'in their head', only about half of the children with autism answered in this way. Furthermore, the children with autism were significantly worse than both control groups at correctly stating that the

[4] Contrary to some other studies of syllogistic reasoning in young children, the authors received justifications for every syllogism, from every child, and no failures to respond. This may have been simply owing to the fact that the experimenter would prompt the child until he or she had attempted a justification.

experimenter could *not* see the imaginary pig, with only about half answering correctly.[5] This last result is all the more striking in view of previous findings showing that children with autism have no trouble determining when someone can and cannot see a *physical* object (Baron-Cohen, 1989, 1991; Hobson, 1984; Leslie & Frith, 1988). These results suggest that the children with autism were confused about the ontological status of the mental states that were being talked about during the pretence training.

The answers to the question 'Can you make the pig do something different/funny?' also suggest that children with autism may only imagine non-empirical images (such as flying pigs) when specifically instructed to do so, and that their *spontaneous* images were of empirically normal situations, since here also children with autism were significantly worse in their performance than controls. This pattern amplifies findings from other studies that (a) children with autism do not spontaneously produce pretend play (Baron-Cohen, 1987) but may 'pretend' when instructed (Charman & Baron-Cohen, 1996; Lewis & Boucher, 1988) and (b) children with autism will spontaneously produce drawings of empirical objects (e.g. a man) but not of 'impossible' objects (e.g. a man with two heads) (Scott & Baron-Cohen, 1996*b*).[6] The worsening of performance by children with autism seen in the CP condition may therefore be owing to an intrinsic deficit in the process of imagination (Craig, Baron-Cohen & Scott, 1998).

An alternative explanation may relate to understanding of intentions. Normally developing children and MLD children may be confused about what the experimenter intends in the CO condition: she says '. . . play a game . . .', then talks in a 'serious' voice about cats that bark. This uncertainty about what is expected may lead the children to disregard the counterfactual premises as untrue. In the CP condition the experimenter's intentions are clarified when she encourages them to pretend. For the children with autism, who have difficulty understanding intentions (Phillips, 1993; Phillips, Baron-Cohen & Rutter, 1998; Roth & Leslie, 1991), the CO condition would not be problematic, as they would not spontaneously be concerned with experimenter intentions. However, the pretence training questions and instructions in the CP condition may have forced them to try and consider the experimenter's intentions, leading to a worsening of performance owing to their deficit in this area. These two alternative explanations need not be mutually exclusive, since both understanding intentions and the ability to imagine and pretend involve mental states, and thus both are arguably related to 'folk psychology'.

In conclusion, the present results suggest that children with autism, and children with MLD, are capable of reasoning by syllogism, even when the syllogisms run counter to reality. This supports and extends the findings of intact reasoning ability in these clinical populations by Scott & Baron-Cohen (1996*a*). It appears that the suggestion that children with autism may perform quite well on the CO condition owing to a lack of the normal drive to cohere the new information with LTM information, and may perform badly on

[5] It is worth noting here that it was not the same children with autism who passed both of these questions. One child might say 'It is in my head' but then answer 'Yes, you can see it'. The distribution of responses was uneven, and the children were apparently operating at chance level with these two questions.

[6] Leevers & Harris (1998) found no differences in performance between children with autism and controls with a picture-completion task, even when the picture to be completed was 'impossible'. Craig *et al.* (1998) also found that older and more able children with autism could produce some impossible manipulations with the Scott & Baron-Cohen (1996*b*) task, but when presented with more demanding material again showed significantly worse performance than matched controls. There are also differences in the task presentation and ratings of 'impossibility' between the Scott & Baron-Cohen (1996*b*) and Craig *et al.* (1998) studies, and the Leevers & Harris study (1998).

the CP condition when they are required to consider the context, has been borne out. The context of 'pretence' is clearly problematic for children with autism—either because of constraints on the flexibility of their imagination (Scott & Baron-Cohen, 1996*b*), or because of more general deficits in folk psychology (Baron-Cohen, 1997; Phillips *et al.*, 1998). Distinguishing between these possible explanations is an area for future research.

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Appendix 1

Reality Control Questions

What noise do cows make?
What colour are bananas?
Where do fish live?
What temperature is ice/How does it feel?
What colour is milk?
What noise do cats make?
What are books made of?
What colour is snow?
How do birds move?
What colour is blood?

Appendix 2

Counterfactual Only condition, counterfactual syllogisms

Method of presentation

I have a story where . . .
All cows go 'Quack' (Premise 1)
Freda is a cow (Premise 2)
In my story . . .
Does Freda say 'Quack'? (Conclusion Question)

(p1) All bananas are pink
(p2) John is eating a banana
(c) Is the banana pink?

(p1) All fish live in trees
(p2) Tot is a fish
(c) Does Tot live up a tree?

(p1) All ice is hot
(p2) Anne has some ice
(c) Is the ice hot?

(p1) All milk is green
(p2) James is drinking some milk
(c) Is the milk green?

Appendix 3

Counterfactual plus Pretence condition, counterfactual syllogisms

Method of presentation

I have a story where . . .
All cats bark (Premise 1)
Rex is a cat (Premise 2)
In my story . . .
Does Rex bark? (Conclusion Question)

(p1) All books are made of grass
(p2) Andrew is looking at a book
(c) Is the book made of grass?

(p1) All snow is black
(p2) Tom touches some snow
(c) Is the snow black?

(p1) All birds swim
(p2) Pepi is a bird
(c) Does Pepi swim?

(p1) All blood is blue
(p2) Mary has cut her finger
(c) Is the blood blue?

Appendix 4

Examples of justifications provided by subjects in each group (all children passed the Reality Control Questions)

Normal

'Cos you said books are grass' (C.K., 4, 10. Theoretical).
'All cats bark' (C.C., 4, 9. Theoretical).
'Yep,' cos Pepi is a bird and birds swim' (E.L., 4, 11. Theoretical).
'Cows go "Quack" in your story' (S.H., 4, 11. Theoretical).
'Fish don't live up trees silly!' (J.C-H, 4, 10. Empirical).
'Bananas yellow' (D.R., 4, 9. Empirical).
'I cut my finger and it bleeded and its red blood' (J.M., 4, 9. Empirical).
'I like milk. Milk is white' (C.C., 4, 10. Empirical).

MLD

'You said so' (Exptr: 'What did I say?') 'All cats bark' (L.M., VMA 4, 3. Theoretical).
'Black snow, black, black, snow is black' (J.M., VMA 4, 9. Theoretical).
'Yeah, fish live in trees' (P.M., VMA 4, 9. Theoretical).
'You saided birds swim' (N.B., VMA 5, 0. Theoretical).
'Cows go Moo, Moo-cow' (P.B., VMA 4, 0. Empirical).
'Books aren't grass. Books are paper' (E.S., VMA 4, 3. Empirical).
'Blood is red' (D.B., VMA 5, 0. Empirical).
'Ice is cold' (A.M., VMA 4, 0. Empirical).

Autism

'All cows go "Quack"' (N.L., VMA 4, 0. Theoretical).
'Bananas are pink' (M.F., VMA 4, 0. Theoretical).
'Ice is hot' (M.S., VMA 4, 9. Theoretical).
'All fish live in trees' (C.C., VMA 4, 6. Theoretical).
'Snow white. Snow is white' (P. D-P., VMA 4, 0. Empirical).
'Cats don't bark. Miaow' (A.T., VMA 5, 0. Empirical).
'Birds in air flying' (Y.A., VMA 4, 6. Empirical).
'Banana yellow' (A.B., VMA 5, 0. Empirical).