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Temporal Cognition in Children with Autistic Spectrum Disorders: Tests of Diachronic Thinking

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Abstract Impaired diachronic thinking—(the propensity and capacity to think about events spreading across time)—was demonstrated in a 2-Phase study in which children with autism were compared with age and ability matched controls. Identical tests of diachronic thinking were administered in both phases of the study, but to different participant groups, with the same results. The marked impairments shown are therefore robust. Various non-temporal explanations of the findings were eliminated by the results of control tasks in Phase 2. Diachronic thinking did not correlate with verbal or non-verbal ability, age, or mentalising ability, consistent with other evidence of the specificity of diachronic thinking ability. Possible causes of impaired diachronic thinking in autism are discussed.

Keywords Autism · Temporal cognition · Episodic memory · Neural binding · Metarepresentation

Introduction

It is widely agreed by those who are in regular contact with people with autistic spectrum disorders (ASDs) that people with ASDs have a poor intuitive sense of time. So, for example, Wing writes of a 'basic inability to make sense of past and present experiences', and continues:

> The problems of time are not related to telling the time by the clock, which some people with autistic disorders are able to do well. The difficulties lie in comprehending the passage of time and linking it with ongoing activities (Wing, 1996, p88).

Research directly investigating these widely reported difficulties is surprisingly sparse (but see Hermelin & O'Connor, 1975; Bennetto, Pennington, & Rogers, 1996; Szelag, Kowalska, Galkowski, & Poppel, 2004). Many well-established research findings are, however, compatible with a defective sense of time (Boucher, 2000, 2001; see also Wimpory, Nicholas, & Nash, 2002). For example, both episodic memory (which involves thinking about the past) and planning (which involves thinking about the future) are well known to be impaired (see e.g. Ozonoff, Pennington, & Rogers, 1991; Bowler Gardiner, & Grice, 2000).

In the studies reported here we investigated children with ASDs' capacity to represent and understand changes that occur across time. This capacity has been described in terms of including a 'diachronic perspective in one's thinking and reasoning' (Montangero, 1996). In this paper, the shorter term 'diachronic thinking' will be used when referring to this capacity.

The development of diachronic thinking in typically developing children has been extensively investigated by Montangero and his colleagues, who have identified three distinct components of this aspect of temporal cognition. These are:

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First, the tendency to evoke the past or future stages of a current situation, rather than thinking of the situation purely in terms of the present moment. If, for example, one wakes up in the morning and sees dripping trees outside the bedroom window, one might infer that it rained during the night (evoking past stages of the current situation); one might also plan to take an umbrella when leaving the house (evoking future events). Following Montangero, this tendency to think 'backwards' and 'forwards' across time will be referred to as the 'diachronic Tendency'. In typically developing children, Tendency develops slowly but steadily between the ages of 7;0 and 12;0 years. Thus, a majority of 7;0 years old describe an object or situation only as it is at the present moment, whereas most 12;0-year-old children make reference to past and/or future states of the object or situation (Montangero & Parrat-Dayan, 1992; Montangero & Pons, 1995; Montangero, Pons, & Cattin, 2000; Pons, Montangero, Quadir, & Bazan, 2002).

Second, understanding that certain entities change qualitatively over the course of time, whilst retaining their identity. So, for example, a caterpillar turns into a butterfly; cake mixture into cake; and babies grow to be children then adults and finally old people. The critical point here is that the changes across time are qualitative, not merely quantitative. Following Montangero, this ability will be referred to as 'diachronic Transformation'. In typically developing children, Transformation develops a little later than Tendency. Up to the age of around 9;0 years, most children conceive changes over time as being mainly quantitative. However, by 11;0–12;0 years, most typically developing children understand that many entities change qualitatively over time (Maurice-Naville & Montangero, 1992; Tryphon & Montangero, 1992; Montangero, Pons & Scheidegger, 1996; Pons & Montangero, 1999).

Third, the ability to conceive of a temporal succession of states or events as compressed into a unitary whole temporally spanning the subordinate events. So, for example, the successive scenes of a play might be synthesised as 'Hamlet'; or packing, driving to the airport, getting on a plane, going through Customs, etc., can be synthesised as 'Going on holiday' or 'A journey'. Following Montangero, this ability will be referred to as 'diachronic Synthesis'. Typically developing children develop the capacity for diachronic Synthesis between the ages of 7;0 and 12;0 years, as is the case for the diachronic Tendency. Synthesis is only rarely seen in 7;0 years old, but is observed in the majority of 12;0-year-old children (Montangero & Parrat-Dayan, 1992; Pons & Montangero, 1999; Montangero et al., 2000).

Diachronic thinking appears to be a relatively specific cognitive ability, in that performances on tests of Tendency, Transformation and Synthesis are correlated with each other, but do not relate strongly to measures of general intelligence in typically developing children (Pons & Montangero, 1999).

The main aim of the research reported here was to test the prediction that individuals with ASDs will show impairment relative to ability matched controls on tests of the three kinds of diachronic thinking identified above, namely Tendency, Transformation and Synthesis. A secondary aim was to assess the specificity of the ability to think diachronically, by examining relationships between performance on each of the three tasks, and also between performance on each task and measures of general ability.

The study reported was carried out in two phases carried out several months apart. In Phase 1, diachronic Tendency, Transformation and Synthesis were assessed in an experimental and a control group, using the same methods as have been used in the numerous studies carried out by Montangero et al. with typically developing children. This was to test the prediction that children with ASDs will have impaired diachronic thinking, relative to controls. The results of these tests were then compared with each other, and with measures of chronological age, verbal and non-verbal ability. This was to assess the specificity of the ability to think diachronically.

In Phase 2, Tendency, Transformation and Synthesis were assessed again in different experimental and control groups but using the exact same methods. This was to test whether the results of Phase 1 could be replicated. In addition, six control tasks were carried out. These were designed to clarify the interpretation of our finding on the three main tasks, should they be replicated. Performance on the three main tasks were again compared with each other, and with age, verbal and non-verbal ability, to assess the specificity of the ability to think diachronically. In addition, a battery of theory of mind tasks was administered, to assess a possible relation between diachronic thinking and mentalising ability.

The two phases of the study are reported consecutively, with discussion of the findings following the report of Phase 2.

Phase 1-method

Participants

Two groups of 23 children and teenagers were assessed: a group with ASDs and a control group

equated with the experimental group for age, verbal ability and non-verbal ability. Verbal ability was assessed using the British Picture Vocabulary Scale (BPVS) Dunn, Dunn, Whetton, and Burley (1997) and non-verbal ability was assessed using the Coloured Progressive Matrices (RM) (Raven, Court, & Raven, 1986). Participant details are shown in Table 1. Independent-samples *t*-tests revealed no significant differences between the groups on any of the measures.

Participants in the experimental group attended one of two special schools. One of the schools catered only for children with ASDs. The other school catered for children with mild to moderate mental retardation with or without autism. All the children in the experimental group had been diagnosed by qualified and experienced medical specialists as having autism or Asperger syndrome, and all had a Statement of Special Educational Needs drawn up by a team of Educational Psychologists, Speech and Language Pathologists and Autism-Specialist Teachers, in which autism-related learning and behaviour difficulties were explicitly identified. Children in the experimental group are referred to as having ASDs, rather than as cases of autistic disorder or Asperger syndrome, because no clear distinction between the two putative subtypes has been established (Ozonoff & Griffith, 2000).

Thirteen children in the control group attended the school catering for children with mild to moderate mental retardation with or without autism, from which some of the children with ASDs were selected. None of the 13 learning disabled controls suffered from an identified syndrome associated with mental retardation, their intellectual disabilities being of unknown aetiology. The remaining ten children in the control group attended a mainstream combined primary and middle school catering for children from a lower to middle class urban area.

None of the children in either group had sensory or physical impairments such as might interfere with their performance on the experimental tasks. Informed consent was obtained from the children's parents or guardians for their child to take part in the research. Following the baseline testing, each child was asked if they wanted to take part in the subsequent tests. If they declined, they were not included in the study. Two potential control participants were excluded for this reason.

General Points of Procedure

Participants were seen individually at school in a quiet room with which they were familiar. Tests were carried out over three (exceptionally four) sessions not less than half a day apart, and were always administered in the order BPVS, Tendency, Transformation, Synthesis and finally RM. Order was always the same because there was some similarity between the materials used to test Tendency and those used to test Synthesis, and the requirements of the Synthesis test could have affected performance on the test of Tendency, but not vice versa. The test of Transformation was placed between the other tests because it offered a contrast of materials and requirements, and to ensure that Tendency and Synthesis were never administered on the same day.

The materials used in the study were identical to those used in previous studies of diachronic thinking in typically developing children (Maurice-Naville & Montangero, 1992; Montangero & Parrat-Dayan, 1992; Tryphon & Montangero, 1992; Montangero & Pons,

Table 1 Participant details: chronological age (*CA*), non-verbal (*RM*) and verbal (*BPVS*) abilities by group in Phases 1 and 2

Group	Sex *M/F*	CA (in months) *M* (SD) range	RM[a] (raw scores) *M* (SD) range	BPVS[b] (raw scores) *M* (SD) range
Phase 1				
Experimental (n = 23)	19/4	152 (28) 90–192	29.0 (5.3) 16–36	89.7 (18.0) 65–133
Control (n = 23)	18/5	148 (27) 87–188	27.0 (5.4) 14–35	88.3 (15.3) 63–125
Phase 2				
Experimental (n = 15)	12/3	172 (22) 144–220	26.4 (4.5) 16–32	83.0 (19.2) 62–117
Control (n = 15)	13/2	176 (18) 151–208	23.7 (6.3) 17–35	89.5 (15.9) 56–109

[a] Raw scores of 29 and 27 convert to age equivalents of 9;9 and 9;3, respectively; scores of 26 and 24 convert to age equivalents of 9;00 and 8;06

[b] Raw scores of 90 and 88 convert to age equivalents of 8;10 and 8;8, respectively, scores of 83 and 90 convert to age equivalents of 8;01 and 8;10

1995; Montangero et al., 1996, 2000; Pons & Montangero, 1999; Pons et al., 2002). The procedures were also closely similar. Where minor changes were made, the goal of the changes was to ensure that children did not fail for non-specific reasons, such as not fully understanding the instruction or giving up too quickly.

Scoring utilised the criteria established in the studies of typically developing children, where they have produced reliable and replicable results from experienced raters. Scoring was carried out by the author with long experience of these tests (FP), and a second, equally experienced rater. Both these individuals were blind to the group to which the individual children belonged. The reliability ratings were as follows: 0.93 for Tendency, 0.91 for Transformation and 0.91 for Synthesis.

Specific Methods: Tendency

Materials

A picture of a seaside scene was drawn in black ink on A4 paper mounted on card (see Fig. 1).

Procedure

The tester placed the picture in front of the child and said: ''Look at this picture. Tell me everything you can about what's *going on* in the picture—about what's *happening*'' (verbs were used to discourage children from listing objects). ''I'm going to write down what you say, and you get a tick for everything you can tell me. See if you can get 10 ticks''. Two types of prompt were used. The first type was used if the child produced fewer than ten responses, in which case the tester said: ''What else can you tell me? What else is going on/happening?'' The second type of prompt was used if the child made a non-diachronic comment about one of the features in the picture which particularly lent itself to an inference about what had happened or what might be about to happen. So, for example, if the child said: ''There's a big wave'', or ''There's some footprints'' the tester said ''Good, tell me more about that'', or ''Go on...''. The test was terminated when the child had said at least something about most or all the main features of the picture, or when prompts failed to elicit any more responses. All responses were recorded verbatim, ticks were given for responding regardless of whether or not the responses demonstrated use of a diachronic thinking, and it was ensured that all children received more than ten ticks, for which they were praised.

Scoring[1]

Responses, which included no mention of past or future events were scored 0. Example: ''There's a person surfing. And someone sunbathing. The sea's making a wave. There are fishes in the sea. There's a sandcastle and a spade and a bucket; some footprints...umbrella, bag, ball...''

Responses which included mention of a single past or future event scored 1. Example: ''There's a man sunbathing. And a man snowboarding. There's a sandcastle. The boy builds it. An umbrella, a bag and a ball. Looks like it's sunny. It's a bit wavy out there.''

Responses which included mention of two or more past or future events scored 2. Example: ''There's a sandcastle, and bucket and spade. The man's lying on a mat—he'll get sunburned if he's not careful. He's asleep and the wave's coming in. A whale might get him...''

Specific Methods: Transformation

Materials

Sheets of A4 paper were prepared with a line ruled towards the bottom of each sheet in landscape orientation. A biro or a pencil was also provided.

Procedure

One of the sheets of paper was placed in front of the child in the landscape orientation, and the biro or pencil placed on the paper. The tester said: ''I want you to draw a tree, on this line here. It doesn't have to be a very good drawing—just a picture of a tree.'' When the child had completed the drawing, the tester placed two additional sheets of paper to the left and right of the first sheet. She then said: ''I want you to draw some more pictures to show me *the whole life of the tree*, how it looked *before* this'' (indicating the child's picture, and indicating the paper to the left of the drawing) ''and how it will look *after* this'' (indicating the paper to the right of the drawing). ''I'll write 'Before' over here, and

[1] (1) A diachronic event is more than the simple evocation of a non-represented part of the object (e.g. ''There are fishes in the sea''), and this type of response did not merit a score. (2) The tense of the verb was not taken into account in the scoring. This was because some participants used the present tense to evoke a past or future event (e.g. ''The boy builds it''). (3) Credit was given for the evocation of past or future events independent of the truth value of the evoked events (e.g. ''A whale might get him'').

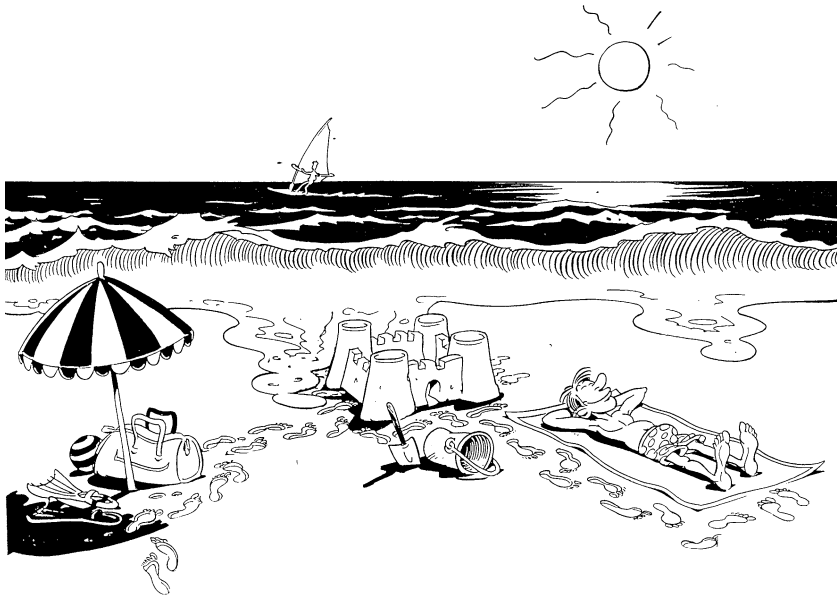

Fig. 1 Picture used in the tests of diachronic Tendency in Phases 1 and 2

'After' over here'' (writing in clear print). ''You can draw as many pictures as you like. Remember to draw the *whole life* of the tree''. Only non-specific prompts and reminders were given, such as ''Now show me how it looked after this'', or ''Do you want to do another picture?—Remember, I want you to draw *the whole life* of the tree''.

Testing was terminated when the child had drawn at least one 'before' and one 'after' picture which differed qualitatively from their original picture; or, in cases where the child had not drawn two pictures differing qualitatively from their original picture, testing was terminated when the child failed to respond to the prompts described above.

Scoring

A set of drawings which only differed from each other in size, with no indication of qualitative change, scored 0. Example: A row of very similar-looking trees, increasing in height from left to right.

A set of drawings which mainly differed from each other in size, but where one showed some qualitative change scored 1. Example: A little tree with leaves; a qualitatively similar but taller tree with leaves; a very tall tree with leaves; and a tree without leaves, or with the leaves falling off, or lying on the ground.

A set of drawings including two or more pictures showing qualitative changes scored 2. Example: Drawings of a seed, then a young shoot, a small tree, a qualitatively similar but taller tree and finally a drawing of a fallen tree.

Specific Methods: Synthesis

Materials

Six pictures 12×8 cm^2 in size were drawn in black ink on white card. The pictures depicted the activities of a man spending a whole day on the beach, from sunrise to sunset then night (see Fig. 2). An envelope just large enough to hold the cards was also used.

Procedure

The tester showed the child that she had a set of picture cards that told a story. She then put each picture down in temporal order in a single line from left to right in front of the child, drawing the child's attention to the position of the sun in the sky before describing what the man was doing: (a) ''Look, it's morning, the sun is just rising. He's off to the beach''; (b) ''It's later in the morning, and the sun is higher. He's building sandcastles''; (c) ''It's the middle of the day and the sun is high in the sky. He's having a rest''; (d) ''It's the afternoon, and the sun has gone down a bit. He's playing with his football''; (e) ''It's the end of the day and the sun is going down. Time to go home''; (f) ''Now it's night, and he's asleep in bed''.

The tester then gathered up the six pictures in order, put them into the envelope and asked the child: ''What do *all the pictures together* show? Can you think of something we could write on the envelope to say what *all the pictures together* show?'' If the child responded, this response was written on the envelope. If the child's

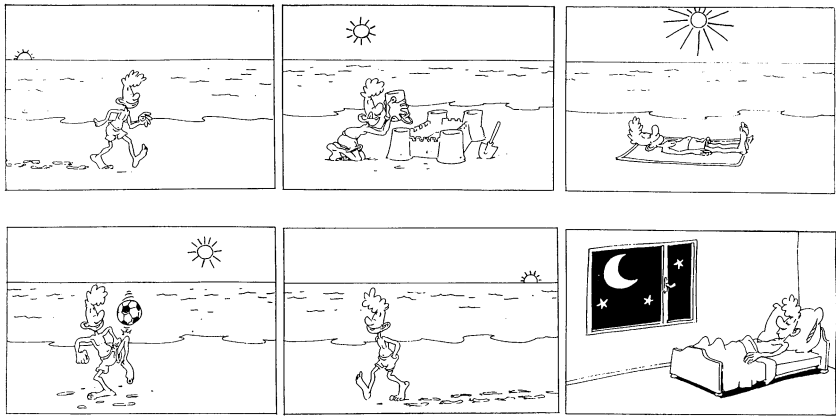

Fig. 2 Set of pictures used in the tests of dynamic Synthesis in Phases 1 and 2

response clearly reflected a capacity for Synthesis the test was terminated. If the child either failed to respond or produced a response which did not clearly indicate a capacity for Synthesis the tester prompted as follows: ''Suppose this story'' (taking the pictures out of the envelope and holding them like a hand of cards to remind the child of the general contents, before replacing them in the envelope) ''was in a book, what could we call the book?—what name could we give it?'' Repeated encouragement was given until the child produced a response (except in one case when a child became distressed and was excluded from this experiment). The response was written on the envelope, the child was praised, and the test terminated.

Scoring

Responses which consisted of a picture by picture description of some or all of the events depicted scored 0. Examples: ''The boy went to the beach, then he built a castle, and he's sunbathing, and playing football, and he went home and gone to bed''./''He went to the seaside to play football and to sunbathe''.

Responses, which included a partial attempt at synthesis scored 1. Examples: ''He went to the beach and he built sandcastles and played with his football—he had a nice day''./''The sunny beach''.

Responses including a complete and accurate synthetic description of all the pictures scored 2. Examples: ''A boy's Summer holiday''./''A day at the seaside''.

Phase 1-results

The results are presented under the headings: (A) Diachronic thinking tasks; (B) Relationships between performances on these three tasks; (C) Relationships between performance on each of the three tasks and participants' chronological age (CA), non-verbal ability (RM) and verbal ability (BPVS).

Diachronic Thinking Tasks

Table 2 shows the two groups' mean scores on each of the three diachronic thinking tasks, and the percentages of children in each group scoring at each of the three levels.

On the test of diachronic Tendency the experimental group had significantly lower mean scores than the controls ($t(43) = 5.29$, $p = 0.000$). The mean number of words used was 55 in the experimental group and 71 in the control group and the means differed significantly ($t(43) = 2.76$, $p = 0.008$). However, the numbers of words used did not correlate with scores in either group.

On the test of qualitative Transformation participants in the experimental group again had significantly lower mean scores than the controls ($t(44) = 3.76$, $p = 0.000$). The mean number of pictures drawn was 4.3 in the experimental group and 5.5 in the control group and the means differed significantly ($t(44) = 2.15$, $p = 0.037$). However, the numbers of pictures drawn did not correlate with scores in either group.

On the test of dynamic Synthesis, participants in the experimental group had significantly lower mean scores than controls ($t(41) = 3.23$, $p = 0.002$).

Relationships Between the Diachronic Thinking Tasks

Correlation tests were carried out to assess relationships between the three diachronic thinking tasks. Across all the participants Tendency correlated significantly with Transformation ($r = 0.52$, $p = 0.000$)

Table 2 Phase 1: results of tendency, transformation and synthesis tasks by group

Group	Tendency		Transformation		Synthesis	
	M (SD) (Max. 2.0)	%-Ss scoring 0-1-2	*M* (SD) (Max. 2.0)	%-Ss scoring 0-1-2	*M* (SD) (Max. 2.0)	%-Ss scoring 0-1-2
Experimental (n = 23)[a]	0.8 (0.9)	50-23-27	0.4 (0.6)	65-31-4	0.8 (0.5)	25-70-5
Control (n = 23)	1.8 (0.4)	0-17-83	1.1 (0.7)	17-57-26	1.4 (0.7)	9-43-48

[a] One child was inadvertently not tested on Tendency, and three children were omitted from Synthesis because of poor intelligibility in two cases and failure to respond in one case

and with Synthesis ($r = 0.32$, $p = 0.039$). Tranformation did not correlate with Synthesis. Within the two groups separately, no correlations reached significance.

Relationships Between Diachronic Thinking, Chronological Age, Verbal and Non-verbal Abilities and Group

Simultaneous linear regression analyses were performed in which Tendency, Transformation and Synthesis were the dependent variable and Group, CA, RM score and BPVS score were the independent variables.

When Tendency was the dependent variable, the association between the five variables was positive (Multiple $R = 0.67$) and significant ($F(4,39) = 8.10$, $p = 0.000$). Almost half (45%) of the variation in the dependent variable was explained by the independent variables ($R^2 = 0.45$). However, neither CA, RM nor BPVS had a significant effect on Tendency, Group alone explaining 42% (partial $r = 0.65$) of the variance ($\beta = 0.66$; $t = 5.40$, $p = 0.000$).

When Transformation was the dependent variable, the association between the five variables was positive (Multiple $R = 0.60$) and significant ($F(4,40) = 5.73$, $p = 0.001$). More than one-third (36%) of the variation in the dependent variable was explained by the independent variables ($R^2 = 0.36$). However, neither CA, RM nor BPVS had a significant effect on Transformation, Group alone explaining 32% (partial $r = 0.57$) of the variance ($\beta = 0.56$; $t = 4.35$, $p = 0.000$).

When Synthesis was the dependent variable, the association between the five variables was positive (Multiple $R = 0.50$) and significant ($F(4,37) = 3.12$, $p = 0.026$). A quarter (25%) of the variation in the dependent variable was explained by the independent variables ($R^2 = 0.25$). Neither CA, RM nor BPVS had a significant effect on Synthesis, Group alone explaining 20% (partial $r = 0.44$) of the variance ($\beta = 0.44$; $t = 3.00$, $p = 0.005$).

Finally, similar simultaneous linear regression analyses were performed separately for the experimental group and the control group. For both groups the results of these analyses were the same as for the whole group: neither CA, RM nor BPVS had a significant effect on any of the three dependent variables.

Additional analyses inserting verbal IQ scores in place of verbal raw scores were carried out to check whether any different findings emerged from the regression analyses, but they did not. The same check could not be made for non-verbal IQ because there is insufficient information provided in the matrices conversion tables. However, there is no reason to suppose that different findings would have emerged.

Phase 2-method

In Phase 2, the three diachronic thinking tasks were repeated with the addition of six control tasks and an assessment of theory of mind. The additional tasks were included to narrow down possible interpretations of the findings in Phase 1.

Participants

Two new participant groups were recruited: a group of children with ASDs and a control group equated with the experimental group for age, non-verbal and verbal ability, as in Phase 1. Participant details are shown in Table 1.

Independent-samples t-tests revealed no significant differences between the groups on chronological age (CA), on verbal ability (BPVS) or on non-verbal ability (RM). The participants taking part in Phase 2 were significantly older (experimental: $t(14) = 3.53$, $p < 0.01$; control: $t(14) = 6.23$, $p < 0.001$) than those participating in Phase 1 and significantly less non-verbally able (experimental: $t(14) = 2.25$, $p < 0.05$; control: $t(14) = 2.46$, $p < 0.05$). Verbal raw scores did not differ between Studies 1 and 2 for either group. However a comparison of verbal standard scores showed that participants in Phase 2 were significantly less verbally able (experimental: $t(14) = 3.40$, $p < 0.005$; control: $t(14) = 3.71$, $p < 0.005$) than those participating in Phase 1.

All but one of the participants in the experimental group attended special schools for children and adolescents with learning disability with or without autism. One boy attended a mainstream school with teaching support. All had been assessed and diagnosed by qualified and experienced specialists as in Phase 1. In addition, all had scores of 30 or above on the Childhood Autism Rating Scale (CARS) (Schopler, Reichler, & Renner, 1988), as assessed by their class teachers.

Participants in the control group were attending one or other of the special schools from which the experimental participants were recruited. As in Phase 1, their intellectual disabilities were of unknown origin. Exclusion criteria and consent procedures were the same as in Phase 1.

General Points of Procedure

Children were tested in their own schools, as in Phase 1. Experimental tests and the Theory of Mind Test (TMT) were carried out over three (exceptionally four) sessions not less than half a day apart, and were always administered in the following order: Session 1: Tendency followed by Control tasks 1 and 2; Session 2: Transformation, followed by Synthesis and Control task 6; Session 3: TMT; followed by Control tasks 3–5.

Scoring was carried out by the two senior authors, JB and FP. Initial reliability rating (Kappa) were 0.88 ($p < 0.001$) for Tendency; 0.72 ($p < 0.001$) for Transformation; and 0.80 ($p < 0.001$) for Synthesis. The large majority of disagreements were resolved in favour of FP's scores, as he was the more experienced rater, and blind to participant group membership.

Specific Methods: Tests of Diachronic Thinking

The three tests of diachronic thinking were carried out using the materials, procedures and scoring methods described in the Method section of Phase 1. The materials and procedures used for the six Control tasks, and for the assessment of theory of mind, are described below.

Specific Methods: Control Task #1—Test of the Ability to Draw Non-temporal Inferences

This control task was included to assess whether impaired ability to draw inferences of any kind might explain impaired performance on the test of diachronic Tendency.

Material

The picture used in the diachronic Tendency task was used, with a set of pre-prepared questions.

Procedure

Immediately following administration of the Tendency task, the participant's attention was drawn to the picture in front of them, and they were asked the following questions, in the order listed. If the participant failed to respond, questions were repeated or asked again in a slightly different form. If any responses were unclear, the tester said: ''Can you tell me again?'' Or ''Can you tell me more about that?'' Responses were written down verbatim.

(1) ''Is it Summer or Winter in this picture?—Which do you think it is, Summer or Winter?'' The order in which the key terms were named was alternated across participants. If and only if the child responded correctly, they were then asked: ''Why do you think it's Summer?—What can you see in the picture that shows it's Summer, not Winter?'' If the response was inappropriate, the tester said ''Is that the best reason for saying it's Summer? Can you think of anything else?'' (if necessary, redirecting the child's attention to the whole picture by gesturing).

(2) ''Do you think this person'' (indicating the surfer) ''is a little boy/girl, much younger than you? Or do you think it's a grown-up person/adult, perhaps a Mum or a Dad?'' The terms used were varied according to the age and ability of the participant, and the order in which key terms were named was alternated across participants. If and only if the participant responded correctly, they were asked: ''Why do you think it's an adult/-/-?'' If the response was inappropriate (e.g. to do with the small size of the image in the picture) the tester asked: ''Is there any other reason why this is probably a grown up person /-/-, not a little boy/girl?''.

(3) ''Why do you think the man's lying on a rug/towel?'' (indicating the sunbather). If the response was inappropriate, or questionably adequate, the tester asked: ''Is that the best reason you can think of? Can you tell me something else about why he's lying on a rug/towel?''

(4) ''Why did the man bring an umbrella, I wonder? Can you tell me why he brought his umbrella and set it up?'' Following an inappropriate or inade-

quate response, the tester asked: ''Is that the best reason you can think of? Can you tell me another reason why he put the umbrella up?''

Scoring

Responses were scored from 0 to 10, as follows: For items (a) and (b): 1 mark each for an appropriate response to the initial question. For all four items: 0 = no justification or inadequate/inappropriate justification; 1 = intermediate justification; 2 = good justification. For example, in response to Question (c) ''Because he's lying on it'' would score 0; ''It's soft'' would score 1; ''So sand doesn't get on his back'' would score 2. Initial reliability rating was 0.87 ($p < 0.001$).

Specific Methods: Control Task #2—Test of the Ability to Generate Responses Which are Spatially, as Opposed to Temporally, Related to the Picture

This control task was included to check whether limited generative ability could explain impaired performance on the Tendency task.

Material

The picture used in the Tendency task was used, plus a clean sheet of unlined A4 paper.

Procedure

Immediately following administration of Control Task 1, the tester placed the clean sheet of paper to the right or left of the picture and said: ''Suppose we had another piece of paper over here, what could we draw?—Something *different* to what's here'' (indicating main picture), ''things further along the beach?'' And/or ''What might there be over here?—What might you see?'' The participant was encouraged to name at least two novel items (i.e. not repetitions or near repetitions of items depicted in the main picture). If no response, or non-novel responses were given (e.g. ''Other people'', or ''More sand'') the tester asked: ''What else might there be?—Something *quite different* to what's in this picture?'' The paper was then moved to the other side of the main picture, and the procedure was repeated. All responses were recorded verbatim.

Scoring

Responses were scored from 0 to 4 for the number of novel responses generated, regardless of the real-life appropriacy of the response (e.g. ''crocodiles'' and ''eagles'' were named by one child, and each scored 1). One participant in the experimental group generated five novel responses, and was scored at the maximum of 4. Scores were then divided by 2 so as to be more readily comparable to scores on the main Tendency task. Initial reliability rating was 0.95 ($p < 0.001$).

Specific Methods: Control Task#3—Test of Knowledge of the Events Depicted, Including Knowledge of Temporal Succession and of the Temporal Order of Cause and Effect

This control task was included to assess whether limited knowledge and experience of the events depicted might explain impaired performance on the test of Tendency.

Material

The picture used in the Tendency task was used again, plus six line drawings on separate cards 8×6 cm^2 depicting the succession of events either shown in, or implicit in, the main picture (Fig. 3). One of the letters T,E,N,D,C,Y was written on the back of each picture, in the order of correct placement. A strip of card with six rectangles 8×6 cm^2 drawn in a horizontal row was also used, as shown in Fig. 3.

Procedure

The six pictures were presented simultaneously in a predetermined predominantly vertical, lay-out and the strip of card was placed immediately in front of the child. The tester said: ''Do you remember the picture we looked at before, showing a man on a beach?'' (showing the main picture to the participant—note: this Control task was not administered until Session 3, see above). ''These little pictures'' (indicating small pictures) ''make a story about the man's day on the beach. The story starts here'' (indicating extreme left hand rectangle on the strip of card) ''and ends here'' (indicating the extreme right hand rectangle). ''Let's make the story. I'll start off'' (picking up the picture of the man walking along the beach carrying his things, and placing it in the extreme left hand rectangle). ''What happened next? Which picture goes here?'' (indicating the left-of-centre rectangle). ''Can you

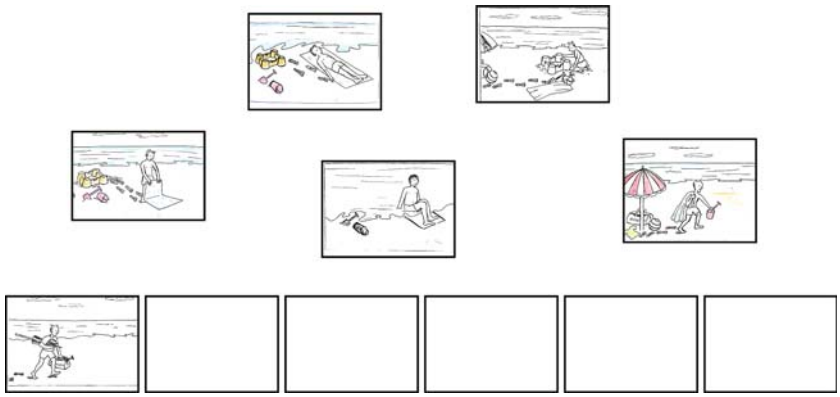

Fig. 3 Materials used in Control task 3 in Phase 2

make the rest of the story, using these pictures?'' (indicating the remaining five pictures). When the participant had placed all the pictures in the rectangles, and indicated s/he had finished, the tester said: ''That looks pretty good to me. Do you want to change it at all? You don't have to change it, but you can if you want to''. When the child indicated that they were satisfied with their placement of the pictures they were praised, and the order of the pictures was noted using the letters on the backs of the pictures.

Scoring

Responses were scored from –1 to +1 using Spearman's Rho correlations. Example, +1 = ENDCY; –1 = YCDNE. Inter-rater reliability was not an issue.

Specific Methods: Control Task #4—Test of the Ability to Generate and Draw Qualitatively Different Forms of Tree, not Involving Time-dependent Changes

This control task was included to assess whether difficulty in generating qualitatively different forms of tree even when these do not involve time-dependent changes might explain impaired performance on the test of qualitative Transformation.

Materials

Sheets of clean, unlined A4 paper and a pencil or biro were used, plus a set of pre-prepared prompts and instructions.

Procedure

The first tree drawn by the participant for the diachronic Transformation task was shown to the child. The tester said: ''This is what lots of trees look like, isn't it? But some trees look quite different. Can you draw a *different sort* of tree?—A tree that looks *quite different* to this one?'' If the Participant drew an unambiguously qualitatively different tree, the response was accepted and praised, and the tester asked the child to draw –''—another, quite different-looking tree—different to this one'' (indicating the child's original drawing) ''and different to this one'' (indicating the child's first Control task response). If the child produced a second acceptable response, the test was terminated.

If no acceptable responses were produced, or only one was produced, the first pre-prepared prompt was given, as follows: ''What about a tree that grows where it's very very hot—in a desert?'' If this prompt failed to produce an acceptable response, a full instruction was given: ''Can you draw a palm tree?'' If two clearly qualitatively distinct drawings of trees had not yet been elicited from the participant, the second pre-prepared prompt was given, as follows: ''What about a tree that grows where its very cold and snowy?'' If this prompt failed to produce an acceptable response a full instruction was given: ''Draw a Christmas tree/a fir tree''. During the test, judgements of qualitative distinctness were made conservatively, so that the majority of the participants were given at least one of the prompts/instructions, and many were given both. Children who failed to produce any acceptable responses were helped to produce a drawing of a Christmas tree (unscored), so as to finish on a positive note.

Scoring

For each drawing, whether Spontaneous, Prompted or Instructed: 0 = same as main task drawing or only quantitative differences; 1 = a bit different compared to main task drawing (i.e. mainly quantitative differences); 2 = clearly different compared to main task drawing (i.e. mainly qualitative differences).

Separate scores for Spontaneous, Prompted and Instructed responses were then calculated. To take into account the fact that a participant who had already produced up to two acceptable Spontaneous drawings would not be asked to produce a full set of Prompted or Instructed drawings, and a participant who had already produced up to two acceptable Spontaneous or Prompted drawings would not be asked to produce both Instructed drawings, the following method of calculating Prompted and Instructed scores was used: (a) Spontaneous scores were calculated first (0–4 for a maximum of two drawings); (b) Prompted responses were then scored (0–4 for a possible two drawings). However, if the participant's Spontaneous score was higher than their Prompted score, then the Spontaneous score was credited as the ''Prompted'' score; (c) Instructed responses were then scored (0–4 for a possible two drawings), and the highest of the three scores, whether Spontaneous, Prompted or Instructed was credited as the ''Instructed'' score.

The initial scores in each category of response were then divided by 2 to make them comparable with the Transformation Main scores.

Initial reliability ratings were 0.85 ($p < 0.001$) for Spontaneous responses, 0.90 ($p < 0.001$) for Prompted responses and 0.87 ($p < 0.001$) for Instructed responses. Pearson's r was computed in place of Kappa, which could not be used because it requires a symmetric 2-way table.

Specific Methods: Control Task #5—Test of General Knowledge of the Natural History of Trees, Including Qualitative Changes Over Time

This control task was included to assess whether limited general knowledge concerning the natural history of trees might explain impaired performance on the test of qualitative Transformation.

Material

Five pictures depicting prototypical stages in the life of a tree were drawn on cards of c. 3×4 cm^2. One of the letters T,R,(X),E,S was written on the back of each picture in the order of correct placement. A strip of card with a horizontal row of five rectangles was also used, similar to that used in Control task 3 as shown in Fig. 3.

Procedure

The five pictures were presented simultaneously in a predetermined predominantly vertical lay-out, and the strip of card was placed immediately in front of the child. The tester said: ''These pictures show the whole life of a tree. Look, here's a tree''—picking up the picture of a stereotypical mature tree (marked (X) on the back) and placing it in the centre box on the card. ''Can you put the other pictures in these boxes'' (indicating the empty boxes on the card) ''to show the *whole life of the tree*?—How it looked *before*'' (indicating boxes to left of central) ''and how it looks *afterwards*?'' (indicating boxes to the right). The instruction was repeated if necessary, until the participant had placed the remaining four pictures into the remaining four rectangles. The tester then said: ''That looks pretty good to me. Do you want to change it at all? You don't have to change it, but you can if you want to''. When the child had confirmed their final response, they were praised, and the order in which they had placed the pictures was noted, using the letters on the backs of the pictures.

Scoring

Responses were scored from –1 to +1 using Spearman's Rho correlations. Example, +1 = TRES; –1 = SERT. Inter-rater reliability was not an issue.

Specific Methods: Control Task #6—Test of the Ability to Synthesise Visually Presented Parts of Objects into Named Wholes

This control task was included to assess whether a generalised difficulty in synthesising parts into wholes and generating an appropriate linguistic term for the perceived whole might explain impaired performance on the test of diachronic Synthesis.

Materials

Four sets of four pictures were individually drawn on cards c. 6×8 cm^2. The pictures in each set depicted key components of an object for which a synthetic description could be requested. The objects were: a house; a face; a pot plant (flower in a pot); and a farm. So, for example, the four pictures selected as key components of a face were two eyes, a nose, a mouth and two ears; the farm was represented by pictures of a tractor, a man with a crook and a sheepdog, a field of cabbages, and a cow.

Procedure

The four pictures of a set were placed in a random group (not a single line) in front of the child. The

tester said ''Have a look at these''. The tester then gathered the four pictures up into a single pile and asked: ''What do these *all together* make?'' If the participants failed to respond, or produced an inappropriate or inadequate response (e.g. listing the component pictures individually), the tester repeated the procedure. Responses were written down verbatim and praised.

Scoring

Each of the four items (house, face, plant, farm) was scored from 0 to 2 as follows: 0 = description of some or all of the individual pictures (e.g. ''eyes, nose, mouth, ears''); 1 = incomplete or inaccurate synthetic description (e.g. ''a person''); 2 = synthetic description of all the pictures (''a face''). Combined scores ranged from 0 to 8. Initial reliability (Pearson's r) rating was 0.85 ($p < 0.001$).

Specific Methods: Theory of Mind Test

This test was included to assess whether impaired performance on tests of diachronic thinking might relate to defective metarepresentational ability and impaired theory of mind.

Material and Procedure

The Theory of Mind Test (TMT) (Pons & Harris, 2002) was used. This test consists of an A4 picture book with a simple cartoon scenario (or picture) on each page. The test is divided into ten blocks of three items each (i.e. 30 items in total) presented in a fixed order. Each block assesses a particular component of theory of mind (e.g. Flavell, 2004): (a) Level 1 perspective taking; (b) Level 2 perspective taking; (c) Comprehension of intentionality; (d) Comprehension of ignorance; (e) Comprehension of false belief; (f) Comprehension of the distinction between appearance and reality; (g) Comprehension of lies; (h) Comprehension of jokes; (i) Comprehension of second order false belief; (j) Comprehension of double-bluff. The general procedure is divided into two steps: (a) While showing a cartoon scenario (or picture), the experimenter reads the accompanying story about the depicted character(s) (or the content of the picture); (b) the participant is then asked to choose between two possible answers to a question, e.g. ''What do I see, a *fish?*—or a *pig?*''; ''What will the girl think is in the box, *strawberries?*— or *peanuts?*''

Scores

The overall level of theory of mind was calculated by summing the items correctly answered, giving a maximum score of 30 points. Inter-rater reliability was not an issue.

Phase 2-results

The results are presented under the headings: (a) Diachronic thinking tasks; (b) Control tasks; (c) TMT; (d) Relationships between performances on the three diachronic thinking tasks; (e) Relationships between performance on each of the diachronic thinking tasks and participants' chronological age (CA), non-verbal ability (RM), verbal ability (BPVS) and theory of mind (TMT).

Diachronic Thinking Tasks

Table 3 shows the two groups' mean scores on each of the three diachronic thinking tasks, and the percentages of participants in each group scoring at each of the three levels.

On all three tests of diachronic thinking the experimental group had significantly lower mean scores than the controls: on Tendency $t(28) = 2.31$, $p < 0.05$; on Transformation $t(28) = 4.54$, $p < 0.001$; and on Synthesis $t(28) = 4.43$, $p < 0.001$.

The significant group differences replicate the findings of Phase 1.

Control Tasks

Table 4 shows the two groups' mean scores on each of the six Control tasks. No significant differences were found between the experimental and the control groups on any of the tasks.

Theory of Mind Test

Mean scores out of 30 on the TMT were 22.4 (SD = 4.82) in the experimental group, and 25.2 (SD = 4.96) in the control group. These scores were not significantly different ($t(28) = 1.57$, $p > 0.10$).

Relationships Between the Three Diachronic Thinking Tasks

Across all the participants Tendency scores correlated significantly with Transformation scores ($r = 0.31$,

Table 3 Phase 2: results of tendency, transformation and synthesis tasks by group

Group	Tendency		Transformation		Synthesis	
	M (SD) (Max. 2.0)	%-Ss scoring 0-1-2	*M* (SD) (Max. 2.0)	%-Ss scoring 0-1-2	*M* (SD) (Max. 2.0)	%-Ss scoring 0-1-2
Experimental (n = 15)	0.9 (0.8)	40-23-27	0.3 (0.6)	73-20-7	0.6 (0.6)	47-47-7
Control (n = 15)	1.5 (0.7)	13-20-67	1.5 (0.7)	13-27-60	1.5 (0.5)	0-47-53

Table 4 Phase 2: results of control tasks by group

Group	n	Tendency			Transformation				Synthesis
		Control 1	Control 2	Control 3	Control 4			Control 5	Control 6
		M (SD)	*M* (SD)	*M* (SD)	Spontaneous *M* (SD)	Prompted *M* (SD)	Instructed *M* (SD)	*M* (SD)	*M* (SD)
Experimental	15[a,c]	8.7 (1.2)	1.7 (0.6)	0.71 (0.51)	0.8 (0.9)	1.4 (0.7)	1.7 (0.5)	0.93 (0.26)	1.9 (0.2)
Control	15[b,d]	7.9 (1.5)	1.6 (0.8)	0.58 (0.40)	0.6 (0.3)	1.2 (0.8)	1.4 (0.7)	0.87 (0.33)	1.9 (0.2)

[a] One participant was not tested on Control 3

[b] One participant was not tested on Control 2

[c] One participant was not tested on Control 4

[d] One participant was not tested on Control 5

$p < 0.05$) and with Synthesis scores ($r = 0.42$, $p < 0.01$). In addition, Transformation correlated with Synthesis ($r = 0.38$, $p < 0.05$), which was not the case in Phase 1. As in Phase 1, no correlations reached significance within the two groups separately.

Relationships Between Diachronic Thinking, Chronological Age, Verbal and Non-verbal Abilities, Theory of Mind and Group

Simultaneous linear regression analyses were performed in which Tendency, Transformation and Synthesis were the dependent variables and CA, BPVS, RM, TMT and Group were the independent variables.

When Tendency was the dependent variable, the association between the six variables was positive (Multiple $R = 0.51$) and approached significance ($F(5,24) = 1.65$, $p = 0.09$). More than a quarter (26%) of the variation in the dependent variable was explained by the independent variables ($R^2 = 0.26$). However, neither CA, RM, BPVS nor TMT had a significant effect on Tendency, Group alone explaining 14% (partial $r = 0.37$) of the variance ($\beta = 0.38$; $t = 1.92$, $p < 0.05$).

When Transformation was the dependent variable, the association between the six variables was positive (Multiple $R = 0.80$) and significant ($F(5,24) = 8.79$, $p < 0.001$). Almost two-thirds (65%) of the variation in the dependent variable was explained by the independent variables ($R^2 = 0.65$). However, neither CA, RM, BPVS, nor TMT had a significant effect on Transformation, Group alone explaining 38% (partial $r = 0.62$) of the variance ($\beta = 0.53$; $t = 3.86$, $p < 0.001$).

When Synthesis was the dependent variable, the association between the six variables was positive (Multiple $R = 0.68$) and significant ($F(5,24) = 4.12$, $p < 0.01$). Almost half (46%) of the variation in the dependent variable was explained by the independent variables ($R^2 = 0.46$). Neither CA, RM, BPVS nor TMT had a significant effect on Synthesis, Group alone explaining 31% (partial $r = 0.56$) of the variance ($\beta = 0.56$; $t = 3.31$, $p < 0.005$).

Finally, similar simultaneous linear regression analyses were performed separately for the experimental group and the control group. For both groups the results of these analyses were the same as for the whole group: neither CA, RM, BPVS nor TMT had a significant effect on these three variables.

Phases 1 and 2-Discussion

The main aim of the study reported here was to test the prediction that individuals with ASDs would show impairment relative to ability matched controls on tests of diachronic thinking as defined by Montangero (1996). Three types of diachronic thinking were assessed: (a) the propensity to evoke the past or future stages of a current situation, rather than thinking of the situation purely in terms of the present moment (''Tendency''); (b) understanding that certain entities

and situations change qualitatively over time (''Transformation''); and (c) the ability to conceive of a temporal succession of states or events as compressed into a single superordinate event (''Synthesis'').

The study was carried out in two phases. In Phase 1, a group of children and adolescents with ASDs was compared with a group of age and ability matched controls on tests of Tendency, Transformation and Synthesis using methods developed by Montangero, Pons et al. in their assessments of diachronic thinking in typically developing children (e.g. Montangero & Pons, 1995; Montangero et al., 1996, 2000). As predicted, the children with ASDs were significantly impaired on all three tasks.

However, we could not safely conclude that our findings demonstrated an impairment of diachronic thinking, because the findings were open to alternative interpretations. In particular, poor performances on the test of Tendency could have resulted from a generalised difficulty in drawing inferences, or from limited generative ability, or from a lack of general knowledge of the subject matter represented in the picture. Impaired performance on the Transformation task might also have resulted from impaired generativity, or from limited general knowledge. Poor performance on the test of Synthesis could have resulted from an impairment of a generalised ability to synthesise parts into wholes, whether parts of an event or parts of an object. A further objection to the methodology used in Phase 1 was that we had not made any independent check of the experimental participants' diagnoses.

In Phase 2, therefore, we repeated the tests of Tendency, Transformation and Synthesis using the same methods as in Phase 1, but with different participant groups. We added six Control tasks designed to test each of the possible alternative explanations of the original findings, as listed above. In addition, the ASD participants' diagnoses were confirmed using the CARS. The results of Phase 2 replicated those of Phase 1 in that the children with ASDs were markedly impaired on all three tests of diachronic thinking (see Tables 2, 3). By contrast, there were no differences between the groups on any of the Control tasks, the participants with ASDs performing at least as well as the comparison group on these tasks (see Table 4).

We conclude, therefore, that children with ASDs do, as predicted, have a marked impairment in their propensity to think diachronically. We further conclude that this cannot be explained in terms of non-temporal cognitive impairments of inferencing or generativity, or lack of the relevant general knowledge. Nor can the impairment of diachronic thinking be explained in terms of non-specific motivational or attentional impairments, because the children with ASDs performed at least as well as the comparison group on all the Control tasks in Phase 2. These findings are striking and clear cut. Moreover, the fact that we replicated the main findings using different participant groups suggests that the findings are robust. They are also consistent with the clinical and anecdotal evidence concerning the difficulties people with ASDs have in experiencing and comprehending the passage of time (except in terms of clocks and calendars).

The secondary aim of the study was to assess the extent to which the ability to think and reason diachronically is a specific ability independent of other more general cognitive capacities, as has been shown to be the case in typically developing children (Pons & Montangero, 1999).

To assess the specificity of the diachronic thinking impairments we examined relations between performances on the three main tasks in Phase 1, and again in Phase 2. Scores were significantly correlated in 5 of 6 comparisons, suggesting that the cognitive processes required for the three tasks are to a large extent shared. We also assessed relations between each of the main tasks and verbal and non-verbal ability (in Phase 1) and verbal ability, non-verbal ability and theory of mind ability (Phase 2). In neither Phase 1 nor Phase 2 did performance on any of the three main tasks correlate with either verbal or non-verbal ability. The consistency of these findings provides strong evidence that the ability to think diachronically is not strongly related to either language level or to non-verbal reasoning ability. Nor did performance on any of the main tasks correlate with scores on the theory of mind test battery in Phase 2.

Further evidence suggesting that the propensity and capacity to think diachronically is a quite specific cognitive ability comes from a comparison of the control groups' scores with data from typically developing children tested using the same materials and procedures (see e.g. Montangero & Pons, 1995; Montangero et al., 1996, 2000). Specifically, the performance of the control groups in both phases of the present study was comparable to that of typically developing children aged between 10;0 and 12;0 years: very few of the controls performed at the zero score level on any of the tests as might have been predicted on the basis of their verbal and non-verbal ability age-equivalents (see Table 1). In other words, in children and adolescents with mild to moderate mental retardation the ability to think diachronically is more nearly age-appropriate than other core cognitive abilities. This observation is underscored by the fact that the

control participants tested in Phase 2 performed at least as well as the controls tested in Phase 1, despite being significantly less able; again suggesting that performance of the three main tasks is not closely related to either linguistic or non-verbal reasoning ability.

Given the independence of diachronic thinking from general ability, a positive relation with age might perhaps have been expected. This was not found, probably because our groups included some older adolescents with moderate to severe mental retardation and some younger children who were mentally unimpaired, or only mildly impaired. The non-significant effects of ability on the diachronic thinking tasks (see the regression analyses) could have prevented a relation between age and scores on the diachronic thinking tasks from showing through.

In sum, in addition to showing that children with autism are markedly impaired in the propensity and capacity to think diachronically, the results of this study confirm and extend Pons and Montangero's (1999) suggestion that diachronic thinking is in critical respects a specific ability, relatively independent of other core cognitive abilities.

How might these findings be explained? The immediate answer to this question is to say that they are not easy to explain, and that any explanation at this stage is necessarily speculative. With this caveat in mind, we will outline our own hypothetical explanation first, followed by a short-section drawing on theories of the development of time-based thinking in the broader philosophical and psychological literature.

Wendy Lawson, a highly able woman with autism has written: ''Whatever it is that neuro-typical individuals possess that gives them a sense of 'timing', we, as individuals with ASD certainly lack it''. (Lawson, 2001, p43). This comment is consistent with the suggestion put forward by Boucher (2000, 2001) that the biopsychological mechanisms for analysing and representing the temporal components of event structure may be impaired in autism. Recent evidence from another research group provides support for that part of Boucher's hypothesis which suggests that basic timing mechanisms are defective (paper in preparation). This part of the hypothesis is also compatible with the suggestion of defective temporal binding in autism (Fost, 1999; Brock, Brown, Boucher, & Rippon, 2002). Moreover it is compatible with the phenomenon of weak central coherence combined with spared processing of perceptual detail in autism (Brock et al., 2002; Brown, Gruber, Boucher, Rippon, & Brock, 2005). It is also compatible with the distinctive pattern of memory troughs and peaks characteristic of autism (DeLong, in press): specifically, contextualised, richly associative episodic memories are impaired, whereas memory for single items, including decontextualised facts, is spared.

The suggested links from defective timing/neural binding mechanisms to impaired diachronic thinking are speculative, but have been argued for in detail in a recent paper (J. Boucher, submitted). In summary, an argument can be made from defective oscillatory mechanisms with roles in timing and neural binding, to impaired episodic/event memory, to impoverished representation of the temporal structure of events; and thereon to impaired ability to imagine or to plan or indeed to think about events or situations involving temporal structure (unless in terms of clock or calendar time). Figuratively speaking, trying to imagine or plan a future event, or to reconstruct an episode, with no implicit knowledge of temporal frameworks would be like trying to build a house without scaffolding.

Impaired ability to imagine, or think about, temporally structured events or episodes could explain why the children with ASDs in Phase 2 of the present study had sufficient factual knowledge to succeed on Control tasks 3 and 5, but were unable to imaginatively generate the ''before'' and ''after'' story of the man lying on the beach in the test of Tendency, or the successive stages of the life history of a tree in the test of Transformation. It can also explain why the children with ASDs were able to generate ideas with no temporal dimension in Control tasks 2 and 4, whilst unable to generate thoughts about past and future (Tendency) or the stages of change in the life of a tree (Transformation).

In the broader literature in which the origins of the uniquely human ability to form temporal concepts and to think and reason about time is discussed, low-level biopsychological processes have been proposed as fundamental by certain authors, notably Tulving (1983, 2002; see also Povinelli, Landry, Theall, Clark, & Castille, 1999). However, most contributors to such discussions focus on other cognitive capacities unique to our species, which are argued to be necessary prerequisites for an understanding of time. These other capacities include episodic memory, conscious awareness of self and higher-order representational abilities such as are utilised in false belief tasks and other tests of theory of mind (see Hoerl & McCormack, 2001; Moore & Lemmon, 2001, for representative sets of essays on these topics).

It is striking that all these uniquely human capacities are generally thought to be impaired in autism, and it seems probable that they are all causally related in some way, at least in part. Findings from the present study argue against an explanation of impaired

diachronic thinking in terms of impaired metarepresentation and theory of mind. Moreover, if—as argued by Perner and Ruffman (1995)—metarepresentation is necessary for episodic memory and conscious awareness of self as well as for theory of mind, then the lack of correlation between performance on the TMT and tests of diachronic thinking in the present study might also argue against an explanation of impaired diachronic thinking in terms of a prior deficit of either episodic memory or conscious awareness of self. However, the lack of group difference on the TMT in Phase 2 was somewhat surprising, and this issue warrants further investigation.

Meanwhile, the discrepancy between the abundant clinical and anecdotal evidence of an impaired sense of time in people with ASDs, and the lack of empirical evidence relating to the experience of time and to temporal cognition in autism remains striking. The immediate priority would therefore appear to be to continue to try to confirm or disconfirm the existence of particular time-related problems in autism, and to characterise any difficulties more precisely.

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