Towards an interactive system eliciting narrative comprehension in children with autism: A longitudinal study

Megan Davis, Kerstin Dautenhahn, Chrystopher Nehaniv, and Stuart Powell

x.1 Background

Research has shown a deficit in the comprehension and creation of narrative in children with autism which impacts on their social skills. Children with autism form a very diverse group; our research agenda is to develop an interactive software system that elicits children's narrative comprehension while addressing the needs of *individual* children. This article documents progress towards an adaptive interactive software system (in the context of a game) for children with autism, specifically in the context of narrative and social understanding, and presents results from a longitudinal study involving 12 children. The work falls under the umbrella of the Aurora project (Aurora 2000) which, through focussed studies, investigates the potential enhancement of the everyday lives of children with autism through the use of robots and other interactive systems as therapeutic or educational 'toys'. A playful context and enjoyment are central to our approach.

x.2 Autism, narrative and social comprehension

Autism is a lifelong pervasive developmental disorder affecting social ability. Although people with autism form a very diverse group, they all exhibit impaired social interaction and communication, and have a limited range of imaginative activities, collectively referred to as the *triad of impairments* (Frith 1989; Wing 1996; Powell 1999). Additionally it is common to find particular sensitivities (Bogdashina 2003), repetitive behaviour patterns and resistance to change in routine (NAS 2004). People with autism have great difficulty making sense of the world, in particular the social world. We do not imply that there is no meaning to the lives of people with autism, but that socially constructed meaning is difficult. The more socially constructed the meaning, the greater the difficulty. Autobiographical accounts such as Grandin (Grandin 1995) show that people with autism who do live successfully in the, to them bizarre, world of so-called 'normal people' do so at least in part by learning explicit rules: for example, remember to look interested when someone is talking to you; or, if someone smiles at you, you should smile back (note that even this apparently simple rule does not always apply).

It is postulated that narrative is central to the construction of social meaning. By fitting events into a narrative pattern we construct and inhabit a meaningful, consistent and predictable world (Bruner 1986; Bruner 1990; Schank 1990; Linde 1993; Bruner 2002). We develop our sense of self and are able to understand the behaviours of others (people or other agents which we imbue with intent), and to respond in ways seen as meaningful and consistent. Narrative gives a framework for interpreting new events, in particular surprising events or behaviours which do not accord with our expectations, and for fitting them into a temporal framework (Schank 1990; Bruner 2002; Porter Abbott 2002).

It has been shown that children with autism do have some specific difficulties with narrative. Studies using narrative pictures showed references to causality and affect may be missing or inappropriate (Tager-Flushberg *et al.* 1995; Capps *et al.* 2000). Abell *et al.* showed, using animated triangles, that children with autism were more likely to attribute inappropriate mental states than typically developing children or those with general intellectual impairment (Abell *et al.* 2000). This impairment in mentalising is often attributed to a deficit in a theory of mind (Baron-Cohen 1999). However, narrative comprehension may be viewed as causal rather than symptomatic; as being fundamental to the perception, creation and communication of meaning in social interaction (Bruner *et al.* 1993; Dautenhahn 2002; Hutto 2003). Thus we may view difficulties with narrative as underlying the social and temporal difficulties we see in autism.

There are a number of theories of narrative comprehension, but it is clear that each narratee actively constructs an internal representation of the narrative, sometimes called a *situation model*. The constructionist theory (Graesser 1999) predicts that the narratee will make inferences which establish both local and global *coherence*, and *explain* events and motivations. Picture narratives are of particular interest to us; in the domain of comics McCloud refers to our ability to construct a continuous situation model, *'mentally construct a continuous, unified reality'*, from discrete panels (McCloud 1993). He refers to the space between the panels as central, *'the very heart of comics'*.

What then is narrative? Views vary widely: we are concerned here with simple narratives in which the chronology of the exposition follows the chronology of events in the story; and in which the story follows, or is a simple variation on, a format proposed by Bruner for a “story worth telling” (Bruner 1986; Dautenhahn 2002). This format supposes a sequence of events involving purposeful characters. The basic pattern of events comprises: a *steady state* which establishes a world view; a *precipitating event* which is some break in the steady state, unexpected by the protagonists, not necessarily by the audience; a *restoration* in which the precipitating event is resolved and some steady state restored; and a *coda* which signals that the narrative is at an end. Variations may occur on this skeleton; one narrative may nest inside another or a stage may be repeated, vestigial or merely assumed.

Relevant work exists in the area of software systems which elicit narrative from children such as Cassell’s story listening systems (Cassell 2002), the PETS storyteller (Montemayor *et al.* 2000), and the emergent narrative systems described by Aylett (Aylett *et al.* 2003). Work with children with autism, in addition to the Aurora project previously mentioned, includes work in the area of educational games for children with autism (Sehaba 2005), and studies investigating the use of virtual reality systems with children with autism (Heerera 2005; Moore 2005). Grynszpan is working towards guidelines for developing software for children with autism (Grynszpan 2005). Our work differs from these in that we are following individual children through a longitudinal study, focussing on 'primitive' elements of narrative, presented as proto-narratives, in an interactive adaptive software game.

x.3 The preliminary study

Our goal is to identify aspects of narrative where therapeutic intervention with interactive computer systems could be applied for individual children with autism. As we are concerned with narrative comprehension rather than ability to read we initially propose a software system which allows exploration of the abilities of children with autism to build coherent narratives from discrete stimuli such as events in pictures or photographs. Many children with autism have difficulties in understanding remote object references, such as pointing with a finger, and in generalization from one context to another. They may not understand how a mouse works, or may take a long time to learn, and so the software system was presented using a touch sensitive screen.

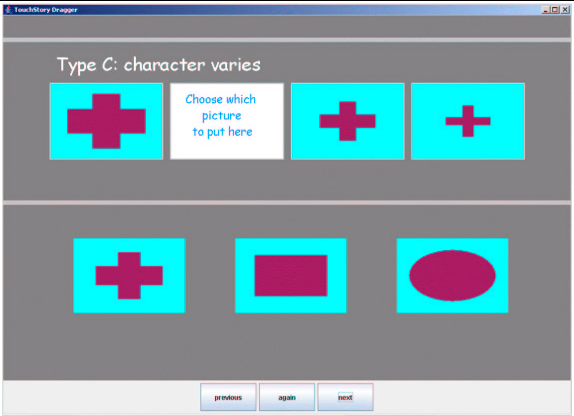
Figure 1. TouchStory in use during the prototype trials

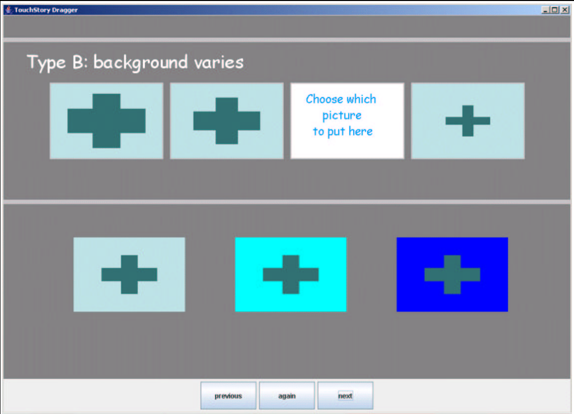
Children with autism form a heterogeneous group, a program or set of stories appropriate for one child will not necessarily be appropriate for another. As autistic subjects have difficulties with social interaction and communication, and may have limited productive language, usual methods of requirement elicitation and software evaluation, such as interviews, focus groups and collaborative design, are not possible. Therefore a pilot study was carried out using a simple fill-the-gap picture story activity concerned with narrative recognition and construction. In order to create a playful context the activity was presented as a 'game'; a playful task involving the experimenter and child. The study compared a physical game using laminated cards with a computer based version of the same game which we called TouchStory (see figure 1.). A correct answer was rewarded with verbal praise, and in the case of TouchStory the on screen reward was that the remaining possible answers were removed, leaving just the complete story. In the case of a wrong answer the child was invited to try again. 18 children were involved and our intention was to investigate whether they were as engaged and successful with a touch sensitive screen as they were with physical cards. Results were encouraging (Davis *et al.* 2004) and led to the preparation of a longitudinal study focussing in more depth on the particular aspects of narrative which individual children found difficult. The longitudinal study also uses an *adaptive phase* where the stories presented by the system varied depending on the *interaction history* with a particular child, i.e. the scores that child had achieved previously. The goal of this adaptation was to tailor the system towards the children's individual needs, aiming to provide more opportunities for learning in areas the children had difficulties, while still providing sufficient, rewarding experience in a play (game) context.

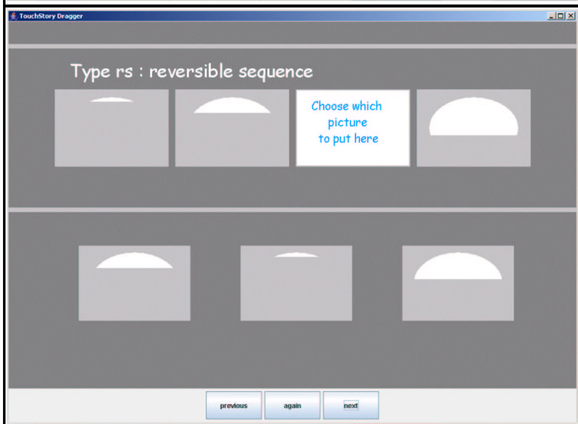
x.4 The Longitudinal Study

We introduce the term *t-story* to mean picture narratives and proto-narratives collectively, in contrast to the fully developed complex 'stories' of daily life. Our intention was to investigate 'primitive' elements of narrative (proto-narratives) as a precursor of narrative comprehension, using t-stories. Primitive elements of narrative were identified and t-stories prepared for each primitive type. The classification and an example from each type can be seen in Figure 2.

The longitudinal study used a set of 56 t-stories moderated for correctness and lack of ambiguity by a panel of 10 adults. The panel consisted of 7 men and 3 women, with a range of technical experience in using computers. The panel had no previous involvement with the project or knowledge of the children involved. The order of presentation was randomized for each adult, and they were asked to select the best picture to fit in the given slot and to verbalise any observations, such as if they thought 2 or more answers, or none, could be correct. In most cases (551/560) the picture the panel members selected was the one expected by the experimenter according to the originally defined answer scheme.

<table>
<tr><th colspan="2">t-story examples and classification</th></tr>
<tr><td>
</td><td>Type c
The t-story opposite is of type c.

Type c addresses character variability and continuity, by presenting a choice among 3 different characters (in this case different shapes).</td></tr>
<tr><td>
</td><td>Type b
The t-story opposite is of type b.

Type b addresses background variability and continuity, by presenting choice among 3 different backgrounds (in this case backgrounds of differing colour).</td></tr>
<tr><td>
</td><td>Type rs
The t-story opposite is of type rs.

Type rs addresses the sequencing aspect of narrative in a simple form (there is no temporal dimension), by presenting a choice among stages of the sequence.</td></tr>
<tr><td colspan="2">This figure continues on the next page</td></tr>
</table>

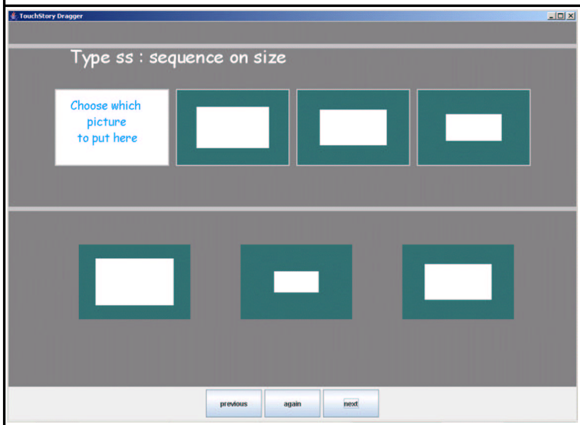
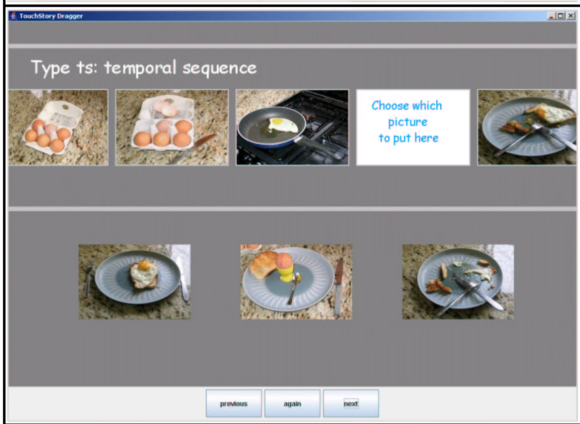
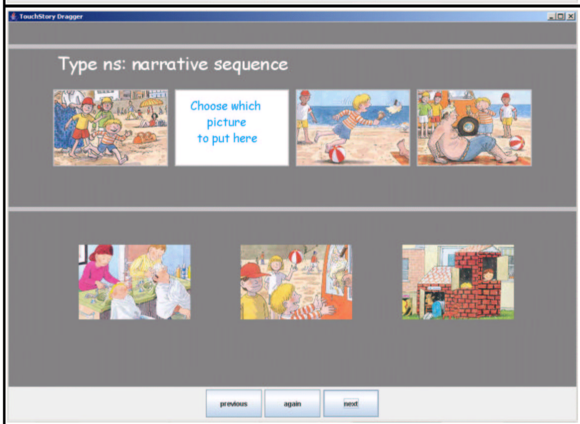
t-story examples and classification	
	**Type ss** The t-story opposite is of type ss. Type ss is a special form of reversible sequence in which the choice is limited to the size of the character.
	**Type ts** The t-story opposite is of type ts. Type ts addresses temporal aspects sequences of events by presenting a choice among stages of a temporal sequence.
	**Type ns** The t-story opposite is of type ns. t-stories of type ns are complete mini-narratives extracted from published sources.

Figure 2. t-story examples and classification

The study took place in a day school unit for children with impaired communication. All 12 children of the unit were involved, 10 of whom, all boys, were diagnosed either with autism, or behaviours suggestive of autism. We do not claim that these children are representative of all children with autism, but consider them as *individual* cases, from which some generalisations may be made. The remaining 2 children were girls. The children were aged between 5 and 11 years. Twelve visits were made to the unit between February and June 2005.

In order to ground the study in activities relevant to everyday school life, and understand the children's use of TouchStory in the context of their normal behaviours, the children were profiled, involving the children's communication therapist, using a narrative comprehension task based on the work of Paris and Paris (Paris 2003.). This involves prompted comprehension questions about a picture story. As children with autism have specific difficulty with 'why', 'what' etc. questions the questioning strategy was extended to allow the children's therapist to elicit the child's understanding using her usual prompting techniques and the scoring rubric adapted by the experimenter to record both unprompted and prompted answers. The narrative comprehension task was scored by the therapist and the experimenter independently.

The trial using TouchStory consisted of two phases. No adaptation to the individual child took place in the first phase to allow time for TouchStory to become part of the children' sestablished routine, to respond to any initial difficulties, and to create an initial profile of each child. During this phase all children saw the same t-stories at any one visit; new types of t-story were gradually introduced and the actual t-stories shown gradually varied.

The second phase was *adaptive*; the number of t-stories within each category was tailored to each individual child. The purpose of the adaptive phase was that the children would be offered challenging t-stories while retaining the aspect of an enjoyable game. It is central to our approach that we evaluate a simple adaptive formula and increase complexity as necessary. The formula used was, for each t-story type and each child:

1) If the child has seen one or zero examples of this type of t-story, or on two or fewer occasions then show two t-stories of this type;
2) If the child has had 100% correct answers for this type of t-story on at least two occasions, using a sliding window of 4 occasions, then decrease number of instances of this particular t-story type by 1;
3) Otherwise increase the number of instances of this t-story type by 1.

The profile is then adjusted to fall within the range 12-14 t-stories by generating random numbers to increase or decrease in proportion to the target. Correctness was determined by visual inspection of logs written from the TouchStory programs, (see figure 3) which show the child' s interaction with TouchStory, in conjunction with notes taken by the experimenter at the time.

Log	Interpretation and comments
next story eggmeal	t-story ‘eggmeal’ (shown in figure 2, type ts)
time 11:36:09	is shown at time 11:36:09
option 1 (wrong) selected	the child selects the middle (wrong) option,
option 1 at 433 371	and drags it across the screen,
option 1 at 472 225	through these coordinates
option 1 fitting---------	and docks this, wrong, option in the t-story gap.
option 1 at 482 102	
time 11:36:10	The child realises this is a wrong answer,
option 1 (wrong) selected	and, by choice, drags the option out of the way,
option 1 at 391 172	through these co-ordinates.
option 1 at 329 354	
time 11:36:11	
option 0 (correct) selected	The child now selects option 0, the leftmost one,
option 0 at 356 192	drags it though this coordinate,
option 0 fitting*********	and docks this, correct, option in the t-story gap.

Figure 3. TouchStory log for one child attempting one t-story

The first picture to be docked in the gap was taken as the child' s intended answer, this allows the child to touch or move pictures on the workspace as part of the thought process prior to moving one picture into the gap. The adaptive formula was applied by hand between sessions (but will be automated in future work). The order of presentation of t-stories was randomised in the adaptive phase to ameliorate possible effects of fatigue, boredom, early termination of the session, or interference from the mental model engendered by t-stories seen previously in the session.

x.5 First Observations

The results showed similarities and differences among the categories and between children, which we illustrate with summary results in Table 1. As the adaptive phase means that the number of t-stories shown in each category differs from child to child, the results show the total number of t-stories correct at first attempt as a percentage of the number seen by that child. Consider child ch4, there is a clear distinction between the t-story types he has no difficulty with, and those he does. He finds the narrative sequences difficult, but even more so the temporal sequences; ch1 shows a similar pattern, though gaining higher scores. The profile of ch6 differs, he is relatively successful with narrative sequences, but not with reversible sequences. Children ch2 and ch3 do not have dignoses of autism. Figure 4 shows the effect of the adaptation for each child by showing the percentage of t-stories correct considering all stories up to the numbered visit; thus column **to7** shows the percentage of correct answers up to and including visit 7 etc.

Table 1. Similarities and differences among the categories and between children: showing for each category, over the whole study, the total number of t-stories correct as a percentage of the number seen by that child

Child	c	b	ss	rs	ts	ns
ch1	100	100	67	72	25	62
ch2	77	67	67	41	36	35
ch3	64	70	75	47	31	30
ch4	100	100	83	54	8	29
ch5	100	100	87	100	100	88
ch6	100	91	100	57	55	71
ch7	No results shown as this child left after visit 5					
ch8	100	78	43	27	67	62
ch9	100	92	78	70	32	48
ch10	100	100	100	73	50	60
ch11	45	50	78	48	60	none seen
ch12	80	64	50	38	0	67

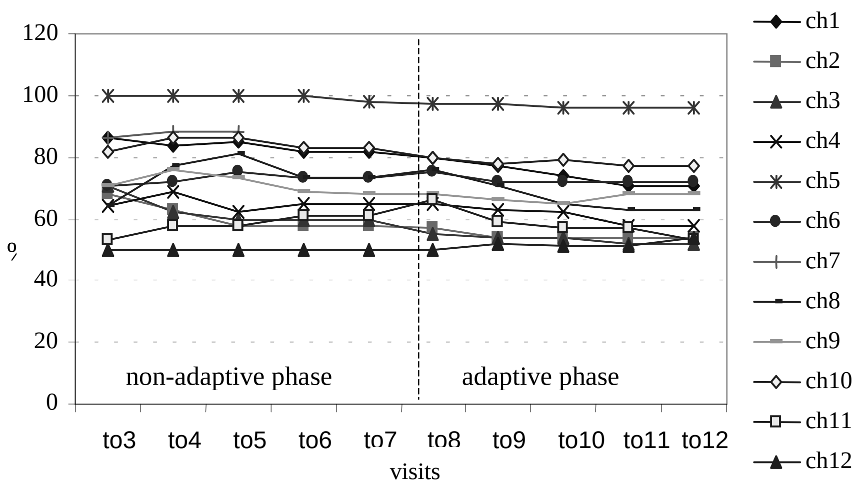


Figure 4. Percentage of TouchStory answers correct over all categories for each child as the study progresses

Our expectation was that in the non-adaptive phase we would see a variety of effects, due to the competing effects of increasing familiarity and confidence with TouchStory, and the introduction of new story types. In the adaptive phase we expected an initial decline as the children were exposed to a higher proportion of t-stories they found difficult. In a longer study we would expect to see an eventual upturn if learning took place. The graph shows the expected downturn during the adaptive phase for several children, especially those with a clear and focussed deficit such as children ch1,4,5,8,10. We attibute the upturn for child ch9 to an increased interest in getting the right answer.

Results relating experiences with TouchStory to real world aspects of narrative comprehension as shown by the adapted Paris & Paris narrative comprehension task (NCT) are as follows. We firstly observe the scores of the two raters of the NCT correlate highly using Spearman rank order correlation r (12) = 0.96, $p<0.05$. The average score given by the two raters was taken as the child's NCT score. The average number of t-stories correctly answered at first attempt, per visit, was taken as a measure of the child's overall success with TouchStory (the TS score). The NCT scores and TS scores were found to correlate significantly at r (12) = 0.82, $p<0.05$. Although this correlation might relate to more general issues of competence and compliance, our results encourage us to think that TouchStory has the potential to illuminate autistic children's understanding of narrative.

x.6 Discussion

For TouchStory to be effective the adaptive formula must be robust. By requiring the child to gain 100% on 2 out of the 4 most recent occasions, we consider that it deals adequately with correct guesses. The results show that it is robust against a child having an 'off-day' and making occasional mistakes. Atypical wrong answers can be seen in the profiles of several children, but because the adaptive formula requires 100% correct answers in 2 of the most recent 4 sessions, they have no effect. It is not robust against a story which the child consistently and atypically gets wrong. This would reduce the outcome to less than 100% every visit it was offered. In future work we will address this. Secondly, the adaptive formula must find a tradeoff between providing rich learning experience for story types that children need to practise, while still presenting sufficient numbers of story types that the children are able to master well, in order to maintain an enjoyable and rewarding context. Last but not least, the learning rate, i.e. rate of adaptation during a longitudinal study, could be modified in future work.

x.7 Conclusions and Further Work

The focus of this work is to find ways of enhancing the ability of individual children with autism to deal with narrative. In particular to further understand how to construct computer software that adapts to get the best out of a child in order to directly effect improvement in narrative comprehension or identify aspects of narrative where therapeutic intervention could be applied.

TouchStory is a prototype and we have already touched on a need to further develop e.g. the adaptive formula; but it does seems that TouchStory already goes some way towards identifying aspects of narrative where therapeutic intervention could be applied. However to *directly* effect improvement in narrative comprehension it seems likely that there must be more directed reflection than TouchStory currently provides. Thinking aloud protocols (where users are asked to vocalize their thoughts, feelings, and opinions while interacting with the system), or even informally asking the children questions in the middle of their TouchStory game, is not an option, so more indirect methods of inquiry and pedagogy, possibly including observational analysis will be investigated. Narrative is fundamental to understanding ourselves and the social environment. Interactive computer systems will not be able to provide a quick cure for the narrative deficit found in children in autism. Improvements of children's narrative skills, if any, will only be illuminated in longitudinal studies that also need to show generalisation to other contexts. Thus, the goal is ambitious, but any, even very small steps towards helping children with autism to join in the narrative construction of our (social) world will be an achievement worthwhile, and highlight the challenges of developing computer based interactive learning environments for children with autism.

x.8 Acknowledgements

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